Organisation: Hebron University

Course title: Beekeeping (51411)

Course type: Developed course

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BENEFIT

A Smart Sensor-Based Measurement System for Advanced Bee Hive Monitoring

Dr. Abdul-Jalil Hamdan
Hebron University
Palestine
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E.mail: ajhamdan@hotmail.com; ajhamdan@hebron.edu

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Organisation: Hebron University
Course title: Beekeeping (51461)
Degree: B.Sc
EQF level: 4th Year
Language of the course: English
Names of the lectures: Dr. Abdul-Jalil Hamdan
Supervisor: Dr. Abdul-Jalil Hamdan

Course content: The course include: historical background of beekeeping, basic facts about bees, starting beekeeping, working the colony, the bee year, honey plants, bee diseases & predators, bee poisoning, extraction of honey, feeding & taking care of honey bee. Application of smart beekeeping.

Introduction:

Beekeepers have been facing various challenges due to the environmental conditions surrounding the beehives and within the beehives, such as:

- un-controlled temperature, humidity, and
- traditional management of beekeeping

These challenges result in:

- low production of honey and colony losses and
- colony collapse disorder (CCD).

In order to improve the above situation, there is a need to develop a platform through which we can:

- monitor, collect, and analyze the conditions within the bee colonies.

Cecchi, et al., 2020., reported that a smart sensor systems are being developed for real-time and long-term measurement of relevant parameters related to beehive conditions, such as:

the hive weight,
sounds emitted by the bees,
temperature, humidity, and CO2 inside the beehive,
as well as weather conditions outside.

Colony collapse disorder (CCD) is a recent, pervasive syndrome affecting honey bee colonies in Europe and the rest of the world, which is characterized by a sudden disappearance of honey bees from the hive.

Causes of CCD are not perfectly clarified yet, but mites and viruses, malnutrition, pesticides, beekeeping practices, electromagnetic radiation, and genetically modified crops may be mentioned among the possible ones.

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CCD has emphasized the importance of enabling a continuous, multiparametric, and extensive monitoring of the beehives, to investigate factors that may negatively affect the life cycle of bees.

In this context, a continuous monitoring and an automatic analysis of the beehives' status can help to safeguard and to protect their life, by early detection of potential threats.

Focusing on a general monitoring system for beehives, some contributions can be found in the literature, the results of the "Electronic Bee Hive" project are reported.

In particular, the analysis of numerous sensors located at specific points inside the beehive, and capable of recording various parameters such as temperature, humidity level, carbon dioxide concentration, and also the weight of the beehive, has been considered.

A web monitoring system based on internal sensors and a cloud architecture to monitor and follow bees' behavior is described.

In particular, temperature, humidity, air quality sensors, and an accelerometer compass are installed within the hive to collect the data that are managed through the proposed cloud architecture, realized with a lambda architecture and a scientific data sharing platform.

Focusing on the adoption of wireless technologies, several projects can be mentioned:

- **Murphy, et al., 2015.,** reported a smart beehive for agriculture, environmental, and honey bee health monitoring system composed of heterogeneous Wireless Sensor Networks (WSNs) technologies to gather data unobtrusively from a beehive has been described. In this case, a wide range of sensors were used such as oxygen, carbon dioxide, pollutant levels, temperature, and humidity measurement devices.

- **Chazette, et al., 2016.,** reported a beehive monitoring system to monitor essential parameters of a beehive (such as temperature, sound, and weight) and additionally including an image recognition algorithm to observe the degree of infestation with Varroa mites has been reported.

- **Gil-Lebrero et al., 2017** reported a remote monitoring system (called WBee) based on a hierarchical three-level model formed by the wireless node, a local data server, and a cloud data server, capable of measuring temperature, humidity inside a beehive, and its weight has been presented.

State of the Art of Measurement Systems for Beehives:

In this Section we will describe the use of the sensors considered in our platform (such as sound, weight, humidity, temperature, and CO2) as referenced in the literature:

1. Weight Measurement: The analysis of the literature shows that among the different quantities of interest in beehive monitoring, the time variation of their weight can accurately reflect the productivity of the colony, as well as its health and well-being conditions.
A low-cost platform to monitor the bees' health and the amount of honey produced by them was developed in 2018 by **Seritan et al**. The measured parameters include inner and outer temperatures, humidity and weight, and the CO2 concentration inside the hive, which is representative of the bees' health.

Anand, et al., 2018. reported a swarm Detection and Beehive Monitoring System using Auditory and Microclimatic Analysis. Focusing on the detection of the swarming events, it is observed that prior to the take-off of the bees, there seems to be a rapid rise in temperature and humidity moments before the observed drop in weight.

Ochoa et al. 2019., address the design of a multisensory measurement platform for precision beekeeping, aimed at gathering humidity, temperature, and weight measurements data to enable an optimized management of the hives, minimizing resources consumption and maximizing the productivity of the colony

2. Sound Measurement: The sound analysis of the beehives is a useful technique applied to determine the bees' state in a noninvasive manner. The bees communicate each other using vibration and sound signals generated in several ways, such as gross body movements, wing movements, high-frequency muscle contractions without wing movements, and pressing the thorax against the substrates or another bee.

These signals are also strictly related to particular events, such as swarming and queen behavior during swarming as we will see in what follows. The sound can be recorded by means of microphones placed in specific position inside or outside the hives. As an alternative to the use of microphones, accelerometers sensors could also be used to sample the hive vibrations to sample the hive vibrations.

During the swarming event, it is also possible to retrieve from the audio analysis the presence of the queen bee. As a matter of fact, young queens emit piping sounds during the swarming process. These signals are directly transmitted to the substrate through close contact between the vibrating thorax and the comb.

Moreover, during the year, also the worker bees produce different piping sounds with relation to the presence or the absence of the queen in the colony.

Recently, the use of Deep Learning and Machine Learning has been introduced to classify the recorded audio samples and to define an objective status of the analyzed beehives

3. Humidity and Temperature Measurement:

The analysis of the temperature and humidity inside and outside the hive can be helpful to understand some aspects of the colony.

They are important parameters that can influence the bees’ health, the brood, and the productivity of the beehive.

It has been found that the temperature influences the bees and brood health and also that the productivity of the beehive is strongly affected by external ambient and internal hive conditions.

Various system architectures implemented with different methods and approaches to monitor the beehive temperature.

Relative Humidity (RH) is another important physical parameter that affects colony development and bees’ behavior. Several studies capable of identifying and measuring the optimum range of humidity within the hive have been reported.

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4. CO_2 Measurement:

The measurement of carbon dioxide (CO_2) plays an important role for the analysis of the beehive behavior. In particular, it is linked to the bees' metabolism, as a change in the respiratory emission of CO_2 is associated to metabolic heating of a bee in its normal activity.

Furthermore, when the carbon dioxide within the hive reaches much higher levels than the normal atmospheric ones, honey bees start using fanning and gas exchange events to expel the CO_2-rich air, and to keep the CO_2 at an acceptable level (i.e., between 0.1% and 4.3%).

This means that this parameter is also related to the internal humidity and temperature and the quantity of sound generated by the bees, which can vary with fanning and gas exchange events.

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Applications of Smart Beehive Monitoring and Control System

Ntawuzumunsi et al., 2021. suggested the following smart bees farming technology:

1. A smart beehive multi-sensing circuit board that integrating various sensors, such as: temperature sensor, electric fan and thermo-electronic heater, digital camera, and the security of the bees in the hive will also be monitored remotely.

2. A mobile application interfacing with the smart beehive, allowing beekeepers to keep track of their bee colony and honey even when they are far from the hives through an application in their mobile phones

3. Different parameters, such as temperature, humidity, weight, gas and flame, will be monitored and regulated remotely through a mobile phone or through an automated system connected on the Cloud.

4. Generation of energy based on different energy harvesting technologies, such as piezoelectric energy harvesting from the force of the hive applied to a piezoelectric transducer, from bees' vibration, and electromagnetic wave and energy harvesting from the surrounding environment where the hive is located.

The proposed new system will achieve the following five objectives:

- To design and develop an IoT-based SBMaCS using multi-sensors.
- To provide beekeepers real-time updates on their mobile phones about the real life of bees inside the hive and about the environment surrounding the hive.
- To provide an automatic control of temperature and humidity of the hive for the purpose of enhancing the honey production.
- To design a self-powered model for SBMaCS based on different energy harvesting technologies.

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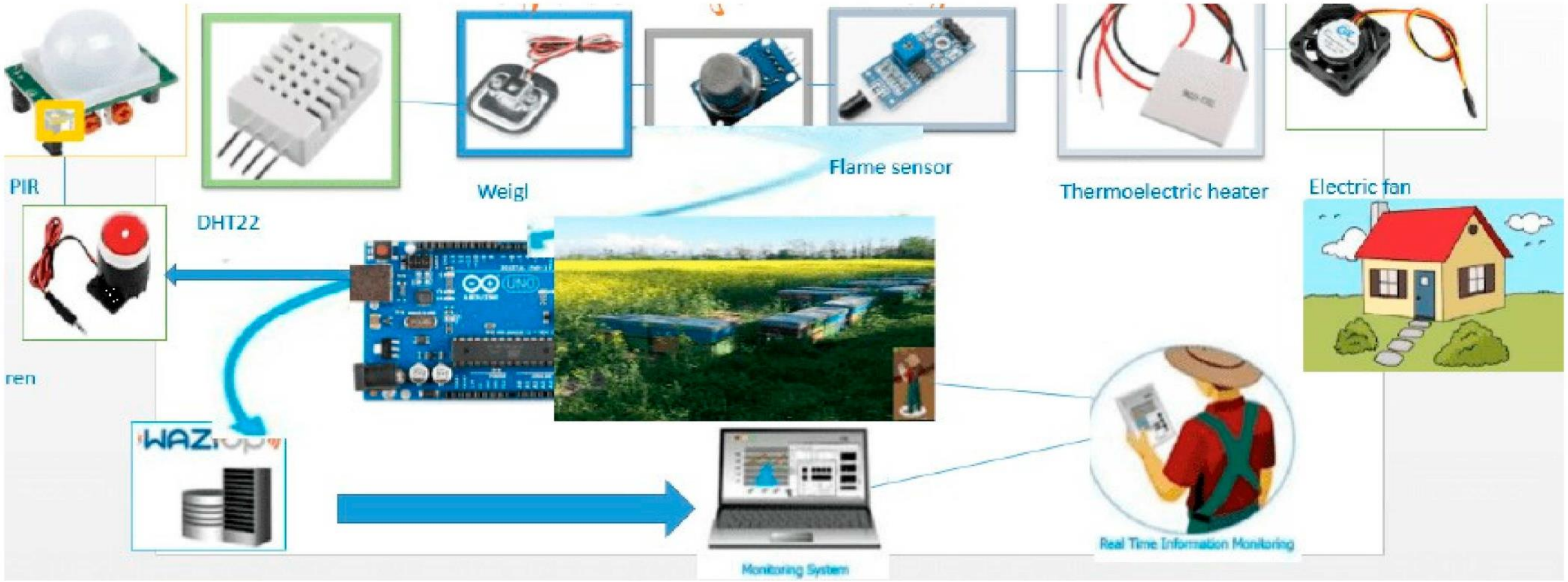
Architecture of Smart Beehive Monitoring and Control System (SBMaCS)

These components include a microcontroller, GSM module, LoRa gateway, and different sensors, such as a humidity sensor, weight sensor, flame sensor, PIR sensor, temperature sensor, and an electronic fan, electromagnetic heat, and a digital camera.

The control and communication mechanisms are aided by a software component developed by programming the microcontroller. The integrated SBMaCS for remote monitoring and control is shown in Figure 1:



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SBMaCS has a liquid crystal display on the hive displaying all information of the hives, which helps beekeepers to maintain remote control of the beehives.

- The temperature of the hive is an important factor to be maintained.
- An automatic controlled thermostat that works in the optimum range (32–36 ◦C) is installed so that bees work well , and bees always need this temperature when they have larvae.
- The weight of the hive increases gradually when the queen is working properly.
- If the weight is decreasing, We set a threshold minimum weight and a threshold maximum which give an SMS alert to the farmers when the weight reaches these thresholds.
- The flame sensor gives an alert to the beekeeper when a forest fire or any kind of smoke is detected.
- For protecting the bees from the varoa mites, we need to control the humidity inside the hive based on a minimum threshold of humidity.
- Furthermore, an electric fan is used to help ventilate the hive and control the humidity.
- Image sensors were installed to detect birds or moths entering the hive during propolis production.

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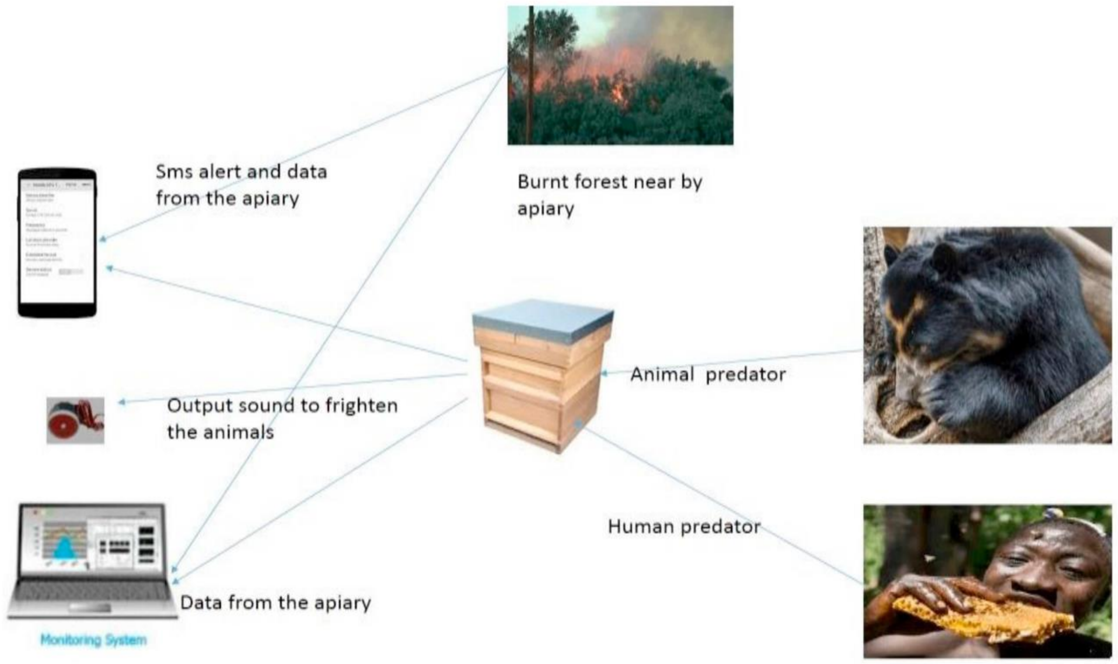
- An alarm will be received on the phone of the beekeeper if there is problem such as displacement of the hive or other problems related to the security of the apiary. The weight sensor will indicate if the hive is blown away from the stand.

- These sensors help beekeepers to gather information about the hive and automatically send information to the owner of the apiary.

- In addition, there are also digital cameras for ensuring security of the apiary.

- The digital siren is used to threaten the animals which come to harvest honey, and at the same time, the apiary's owner receives an alert message that there is insecurity in the apiary.



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Conclusions and Future Works:

A multisensor platform capable of realizing a real-time and long-term measurement of relevant parameters related to beehives' conditions, such as the hive weight, sounds emitted by the bees, temperature, humidity and CO2 inside the beehive, as well as weather conditions outside, has been presented.

The system is composed of two modules, one installed on each hives of the colony (i.e., the Bee Board Module) and the other one handling all the data acquisitions, including also the weather parameters (i.e., the Queen Board module).

Several analyses have been performed considering the measured parameters and some events that can occur within the colony. In particular, the normal activity of the bees during a day, the honey gathering over one week, comparing the spring and the summer season, and the swarming event registered in two different hives have been considered.

From the results, it is evident that long term measurement of these parameters in real time plays a fundamental role in enabling advanced beehives monitoring, and the collected data can be used as a strong indicator of honey bees' health.

Future works will be oriented on the introduction of a server-side automatic tool for the determination of honey bees' status taking advantage of advanced algorithms of digital signal processing.

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Thanks a lot for listening

Organisation: Hebron University

Course title: Smart technology application in food industry (54314)

Course type: New course

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Smart Application in Food Industry

Ch1. Post Harvesting Technology

Mr. Wesam Sammar

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University College of Applied Sciences

- Being living organs, fruits and vegetables continue to respire even after harvesting when they have a limited source of food reserves.

- In addition to degradation of respiratory substrates, a number of changes in taste, colour, flavour, texture and appearance take place in the harvested commodities which make them unacceptable for consumption by the consumers if these are not handled properly.

- Post harvest technology starts immediately after the harvest of fruits and vegetables.

Ripening

- Final stage of fruit development

- Ripening is a process in fruits that causes them to become edible. The fruit becomes sweeter, less green and softer

- Fruit ripening is a highly coordinated, genetically programmed, and an irreversible phenomenon involving a series of physiological, biochemical, and organoleptic changes, that finally leads to the development of a soft edible ripe fruit with desirable quality attributes.
- However, all fruits do not ripen in the same manner. On the basis of their ripening behavior, fruits are classified as:

Climacteric Fruits Non-Climacteric Fruits

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- In **climacteric**, the respiration slows down as the fruit ripens and develops good eating quality

- In climacteric fruits, ripening refers to fruits that can be harvested when physiologically matured

- The start of ripening is accompanied by a rapid rise in respiration rate, called the respiratory climacteric

Examples: Mango, Banana, Papaya, Guava, Sapota, Kiwi, Fig, Apple, Passion fruit, Apricot, Plum, Pear.

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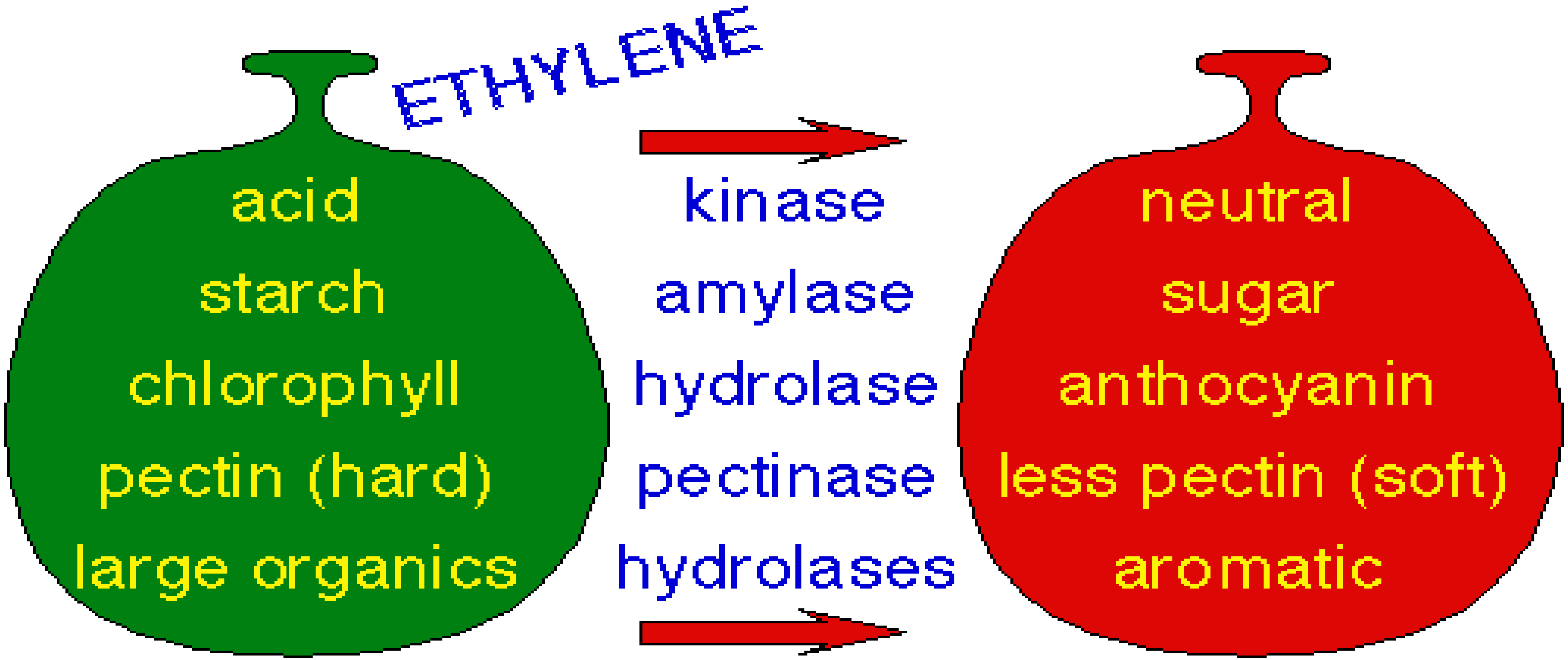
- In **non climacteric** ripening refers to those fruits which ripe on the tree as observed in cherry, grape, lemon etc

- Respiration rate decreases gradually during growth and after harvest

Examples:

Orange, Mousambi, Kinnow, Grapefruit, Grapes, Pomegranate, Litchi, Watermelon, Cherry, Raspberry, Blackberry, Strawberry.

Changes during ripening



Action of Different enzymes

Pigment changes

- **Chlorophyll** (Green color) - a loss of chlorophyll in tomatoes is good but a loss in chlorophyll in broccoli is bad
- **Carotenoids** (Yellow, Orange and Red colors) - Carotenoids are desirable in fruits such as apricots, peaches and citrus giving them their yellow and orange color. In tomatoes and pink grapefruit a specific carotenoid called lycopene gives them their red color
- **Anthocyanins** (Red and Blue colors) - Anthocyanins give red and blue color to apples, berries, cherries etc.
- **Phenolic compounds** - Are responsible for tissue browning.

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- **Changes in the firmness**

➢ Middle lamella of cell wall is made up of calcium pectate

➢ Hydrolases synthesised during ripening process leads to the destruction of cells wall and tissue

Propectin (unripe)

↓

Pectin

↓

Pectinic acid

↓

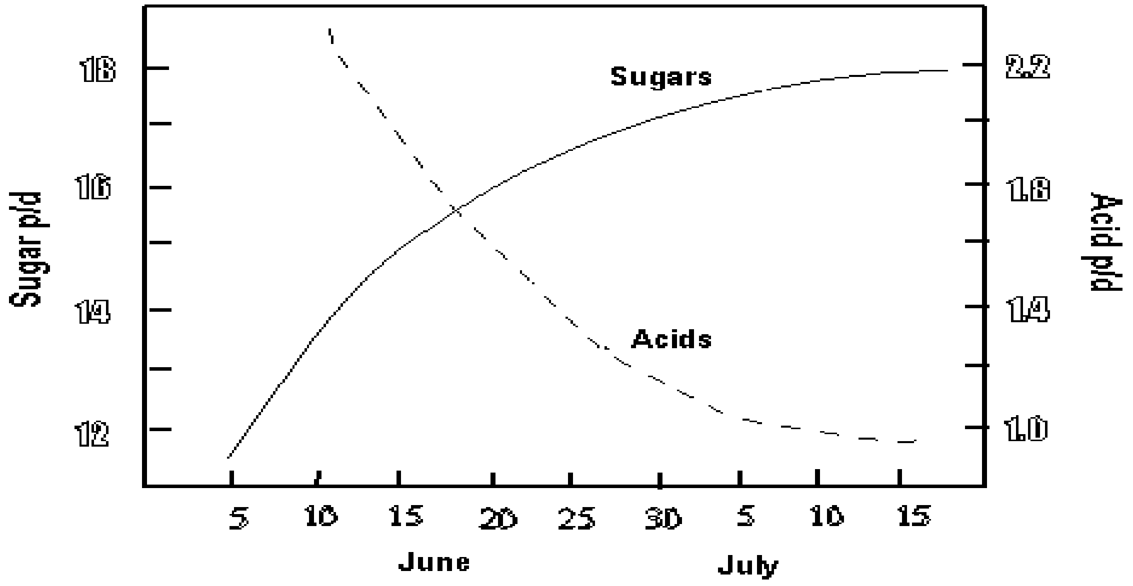
Glactouronic acid (ripe)

Carbohydrate changes

- Conversion of starch to sugar - Not desirable in potato but very desirable in apples, bananas
- Conversion of sugar to starch - Not desirable in sweet corn but very desirable in potato
- Conversion of starch and sugars to CO_2 and water during respiration - Not desirable because it leads to a reduction in quality

Other Changes

- Organic acids (affects sweetness)
- Proteins (affects texture and Flavor)
- Lipids (affects flavor)
- Development of wax
- Change in tissue permeability



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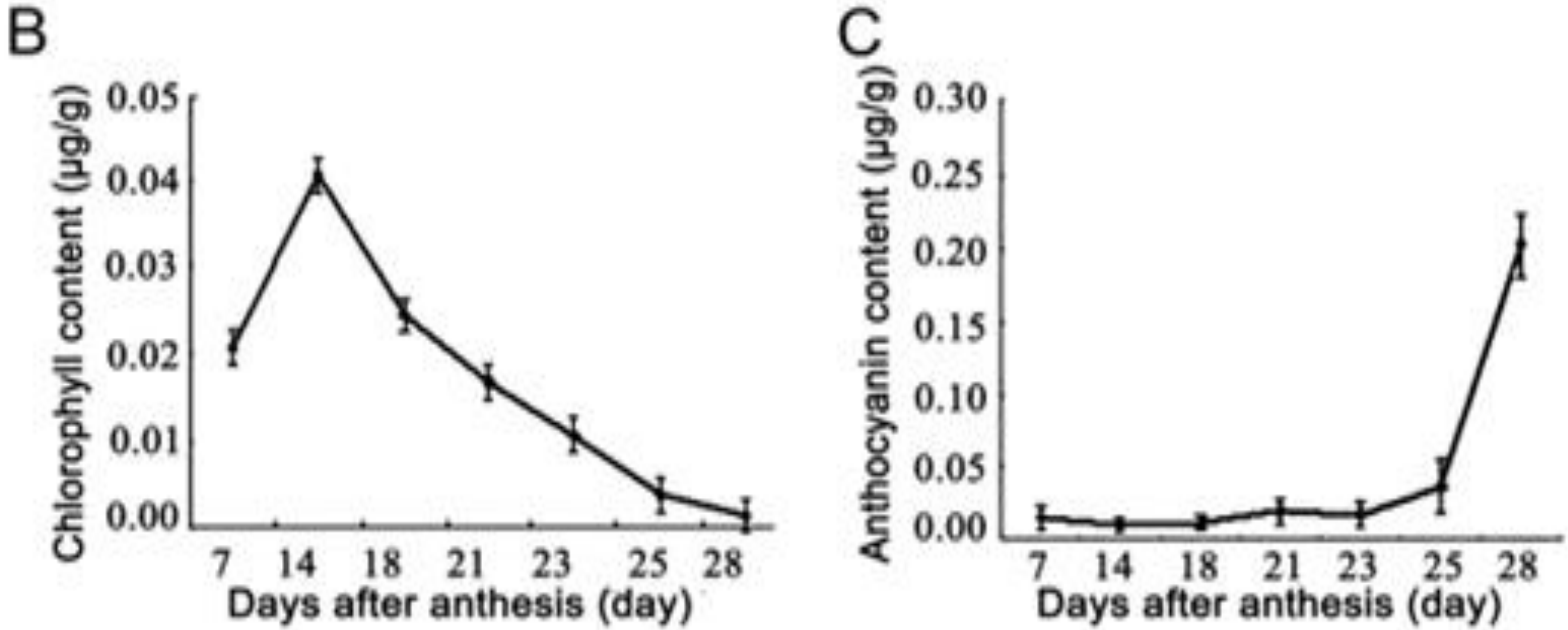

Fig: Changes in Chlorophyll and Anthocyanin content in strawberry fruit during ripening

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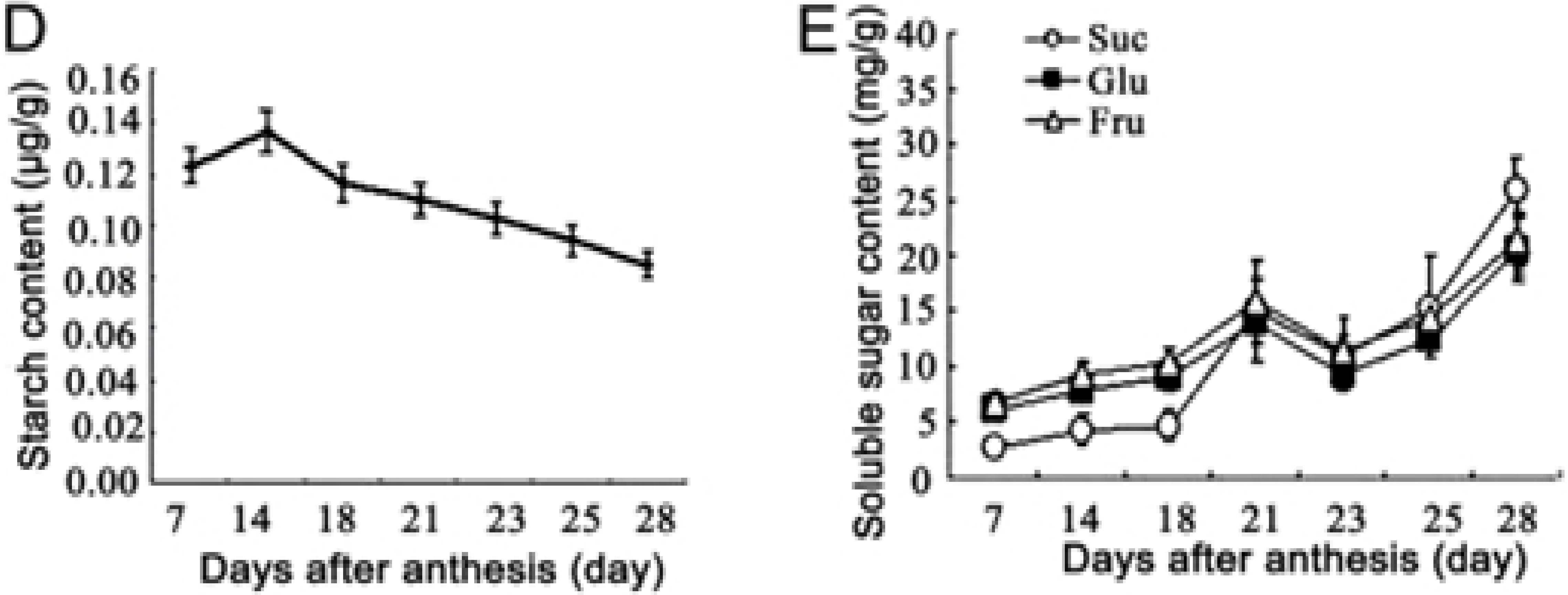

Fig: Changes in Starch and Soluble sugar content in strawberry fruit during ripening

Mechanism of ripening

- **RNA metabolism-** In many fruits the maturation process is accompanied by an increased RNA synthesis
- **Enzymes-** increase in the activity of many hydrolytic enzymes. Softening of the fruit and Alteration in taste
- **Pigment formation-** The most striking change that a ripening fruit undergoes concerns with its color by the synthesis of carotenoid and anthocyanins.
- **Change in permeability-** Solubilisation of pectic substances

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Ripening of Climacteric Fruits

Conventional Ripening Method

- Calcium Carbide reacts with moisture in the air to produce acetylene gas which acts as a ripening agent but is believed to affect the nervous system by reducing supply of oxygen to the brain.
- Despite its well known health hazard, it is still in use as a potent ripening regulator in the tropical fruits like mango and banana.
- For banana ripening, the general dose is around 5g/10 bunch in closed or air tight condition to 10-60 g per 230 liter drum (Pantastico and Mendozoa, 1970; Bautista, 1990).
- In mangoes, it was found that at 25°C and a 24 hour exposure time then at least 1 ml per liter of acetylene was required to initiate ripening (Medlicott *et al.*,1987).

Ripening with Ethylene

- The only scientific and safe ripening method accepted worldwide is the use of **Ethylene**
- Exposure of unripe fruit to a miniscule dose of ethylene sufficient to stimulate the natural ripening process until the fruit itself starts producing ethylene in large quantities.

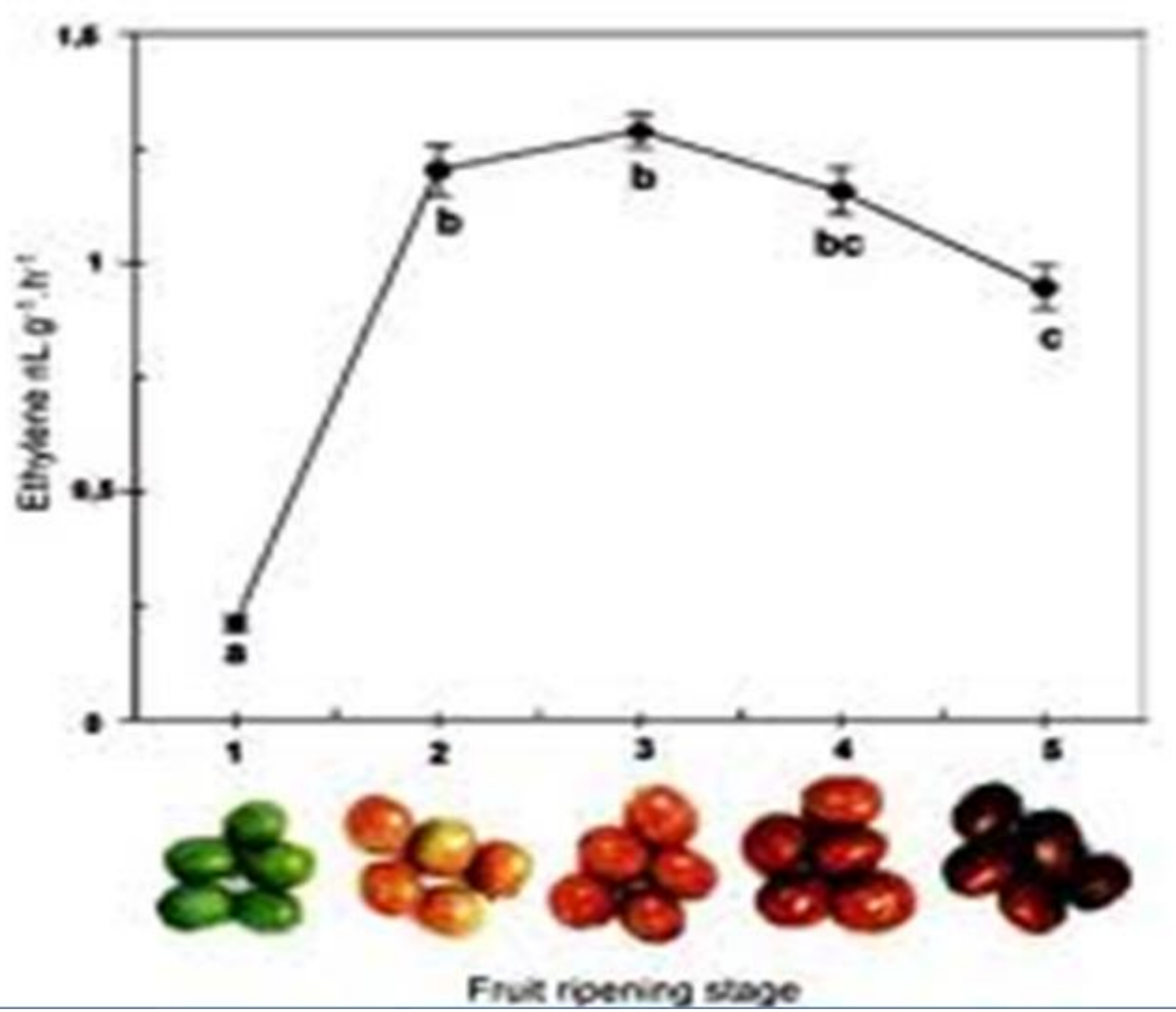

Fig: Ethylene production in *C. arabica* during ripening

Factors involved in regulation of ripening

Temperature

- Fruit harvested at right time generally ripen at any temperature
- Exposure to temperatures above 35°C has inhibited ripening in different fruits (Paull, 1990; Lurie, 1998).
- Garcia *et al.* (1995) found that hot water dipping of the strawberry (*Fragaria ananassa* Duch., cv. Tudla) reduced fruit decay, increased the soluble solids content and decreased titratable acidity.
- Heating mature green tomatoes for 2 or 3 d at 38°C reversibly inhibited ripening and decreased fruit decay in storage (Lurie and Sabehat, 1997).

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Humidity

- Relative humidity can influence water loss, decay development, incidence of some physiological disorders and uniformity of fruit ripening
- Hinders the development of aroma and flavor
- Proper relative humidity is typically 85 to 95% for fruits and 90 to 98% for vegetables.

Control of relative humidity

- Adding moisture (water mist or spray) to the air with humidifiers
- Sprinkling produce with water
- Wetting floors in storage rooms

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Radiations

- Act as inhibitors or stimulators of ripening process.

- Grapes ripe more quickly under treatments with infrared radiations.

- Bananas irradiated with X-ray exhibited a decrease in softening but an increase in skin blackening.

- Artificial UV-C radiation also delays fruit ripening (Maharaj *et al.*, 1999) and affects fruit softening (Ait Barka *et al.*, 2000)

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- Increasing shade markedly reduced ripening, causing reduction in sugar, phenol, and anthocyanin concentrations and increase in titratable acidity.

- Red light supplementation caused increased nitrate reductase activity in leaves and earlier fruit coloration

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Smoke

- Light a smoky fire in the ripening room.

- This can produce various gases, including acetylene, ethylene and carbon monoxide, which will initiate ripening.

- used in many developing countries.

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Damage

- Wounding the banana bunch stalks
- Stick is inserted into the stalk of jackfruit
- Cutting, scraping or ‘pinching’ papaya, or avocado, which can hasten ripening.

Chemicals

- Chemicals like calcium chloride, calcium nitrate, 2,4-D, and 2,4,5-T have been reported to affect the shelf life of fruits

- Storage life of citrus fruit is prolonged by spray of 2,4-D and 2,4,5-T

- Postharvest water dipping at 50°C for 5 min significantly increased the shelf life and maintained the quality of ber (Lal *et al.*, 2002)

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Contd….

- Dipping in a calcium (Ca) solution has been used as a firming agent to extend the postharvest shelf life of apples (Lurie and Klein, 1992; Conway *et al.*, 1999),

- Application of 1-MCP is best suited for apples to maintain the crunchy texture

- Use of 1-MCP is more challenging in mangoes because the requirement is to delay, not inhibit, ripening.

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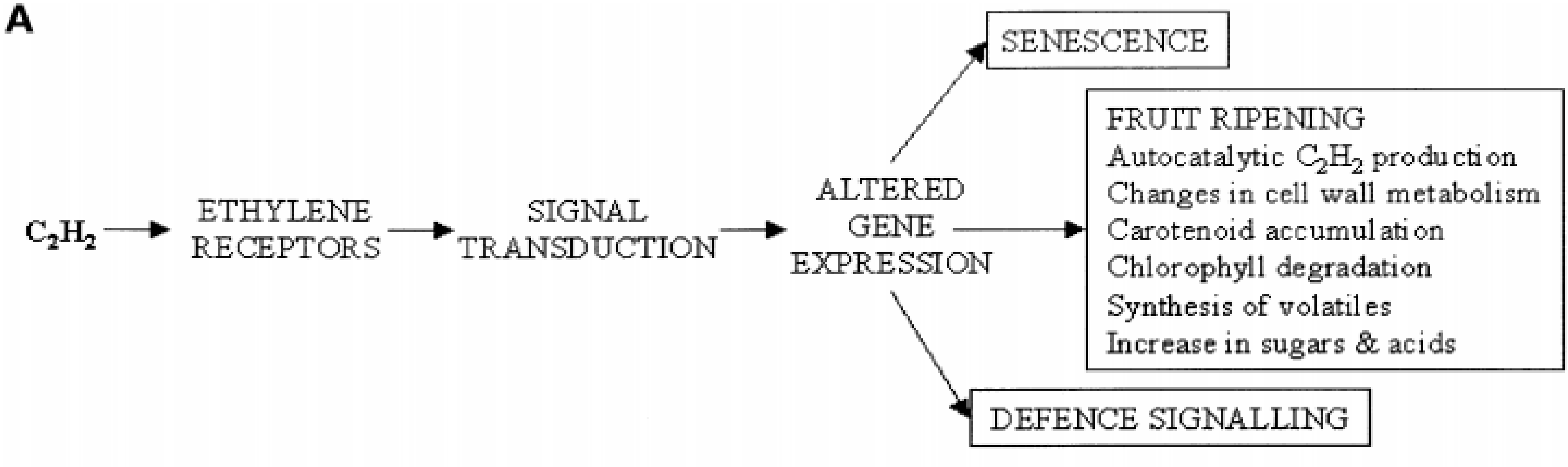
Growth substances

- **Ethylene** is gaseous plant growth substance which is involved in the regulation of many aspects of:

  -Growth and development

  -Fruit ripening

  -Senescence



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Control of ethylene production

- Reducing the storage temperature
- Reducing O_2 levels to less than 8%
- Treating with enzyme inhibitors of ACC synthase and ACC oxidase
- Genetic engineering (using antisense technology to prevent enzyme expression).

Ethylene blockage

- Treating with silver thiosulphate (commonly used in flowers);
- Hypobaric storage - keeping the commodity under vacuum;
- Elevating CO_2 to more than 12%
- Genetic engineering (blocking the ethylene receptor)

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Typical banana ripening process

Batch/shot process:

1. Induction of ethylene gas at once
2. Ventilated in 24 hour
3. Room should be sealed

Trickle/flow process:

1. Induction of ethylene slowly in the stream continuously.
2. Ventilated in each 6 hour
3. Sealed room is not necessary

1. Minimum air flow : 0.34 L/sec/kg of fruits
2. A RH range of 85-90% has been recommended at stage 2(green, trace of yellow)
3. But this should be reduced to 70-75% during the later colouring stages to avoid the skin splitting

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Methods to provide proper ethylene concentration in the ripening room

Large Gas Cylinders

- Ethylene is available in large steel cylinders where it is stored under pressure
- Use of large cylinders of the pure gas is discouraged as ethylene is highly flammable
- Diluted with nitrogen or other inert gases (mixture of 95% nitrogen and 5% ethylene)
- Application: Measured quantities of ethylene are introduced in ripening room at regular intervals or continuously and the flow is regulated through metering device or flow meter.

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Ethylene Generators

- Portable and placed inside ripening room.
- Ethyl alcohol is filled into the tank with ethylene generator and connected to electric power.
- Ethyl alcohol is heated in a controlled manner in the presence of catalyst that produc
- Gas is maintained i ntil colour break occurs in the fruits.

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ETHYLENE MANAGEMENT

Ethylene inhibitor

- AVG= Aminoethoxy-vinyl-glycine
- AOA= Amino oxyacetic acid
- 1-MCP= 1-methyl cyclo propane
- $AgNO_3$= Silver Nitrate
- $Ag(S_2O_3)_2^{3-}$=Silver thiosulphate
- Co^{2+}= Cobalt ion

Ethylene absorbant

- Potassium permanganate
- Celite-$KMnO_4$
- Silica gel-$KMnO_4$
- Alumina silicates-KMnO 4
- Activated charcoal
- Zeolites
- Sodium Permanganate

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1-MCP (1-Methylcyclopropane)

- Cyclopropane derivative (Cyclodextrin powder)
- Gaseous ethylene action inhibitor
- Non- toxic, Odourless gas
- Binds irreversibly to ethylene receptor
- Simple organic compound (C_4H_6)

1-MCP Mode of Action

- Works by tightly binding to the ethylene receptor site in fruit tissues, thereby blocking the effects of ethylene.

Application of 1-MCP:

Available in the market in the name of EthylBloc®(0.14%), SmartFresh™(3.3%), SmartTabs™(0.63%).

- When the product is mixed with water or a buffer solution, it releases the gas 1-MCP.
- Formulation Type: Powder
- Timing: Immediately after harvest.

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Principle of ethylene absorbent

- **These products remove unwanted ethylene gas mainly through the process of oxidation.**

- $3CH_2CH_2 + 2KMnO_4 + H_2O \longrightarrow 2MnO_2 + 3CH_3CHO + 2KOH$
- $3CH_3CHO + 2KMnO_4 + H_2O \longrightarrow 3CH_3COOH + 2MnO_2 + 2KOH$
- $3CH_3COOH + 8KMnO_4 \longrightarrow 6CO_2 + 8MnO_2 + 8KOH + 2H_2O$

➢ **$KMnO_4$ reacts with the ethylene gas and form MnO_2 Which is not harmful for the fruits.**

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BENEFIT

TMC ethylene absorbents

- **The Magic Cube is a Ethylene absorbing tubes and sachets which are used worldwide for the safe transportation and storage of fresh fruits, flowers and vegetables.**
- **TMC Ethylene absorbers have proven to be 2,3 times more effective than other ethylene adsorbing products that are currently used.**
- **This is due to the fact that TMC is based upon unique formula of Sodium Permanganate pellets instead of the more common Potassium Permanganate.**
- **It reduces the ethylene at a faster rate.**

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BENEFIT

HOW DOES IT WORK?

- **TMC pellets are made out of micro structure, impregnated with sodium permanganate.**
- **Relatively large amount of the Sodium Permanganate is distributed deep into the pore structure of the pellets.**
- **Before use, TMC pellets have a deep purple color, but after interaction with ethylene the color will change to dark brown.**
- **In the final stages what will be left is black manganese, an environmentally safe residue that can be disposed off.**

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BENEFIT

ETHYLENE ABSORBING SCREENS

- Ethylene Absorbing Screen functions similarly to Ethylene absorbing sachets.
- These screens are ideally applicable in places such as in refrigerated trucks.
- These are mainly helpful for delaying ripening during transportation.

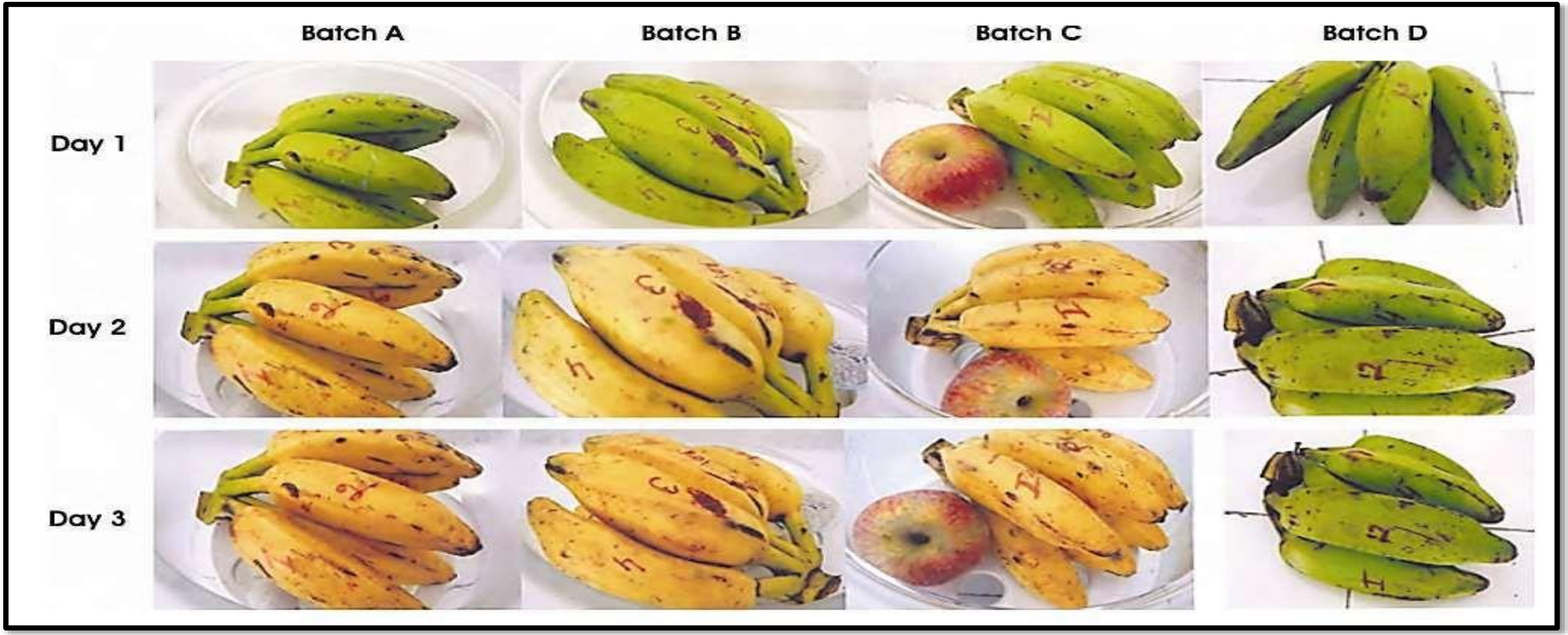

Fig 1. Banana fruits after exposure to different ripening agents for varying number of days

Alteration in the CO_2 and O_2 atmosphere

- Decreasing the level of CO_2 helps the ripening of the fruits (Selvaraj, 1993).

- Low level of O_2 prevents ripening of fruits as a result of reduced respiration and ethylene synthesis.

- Oxygen tension greater than one atmosphere tends to promote ethylene synthesis consequently promoting ripening.

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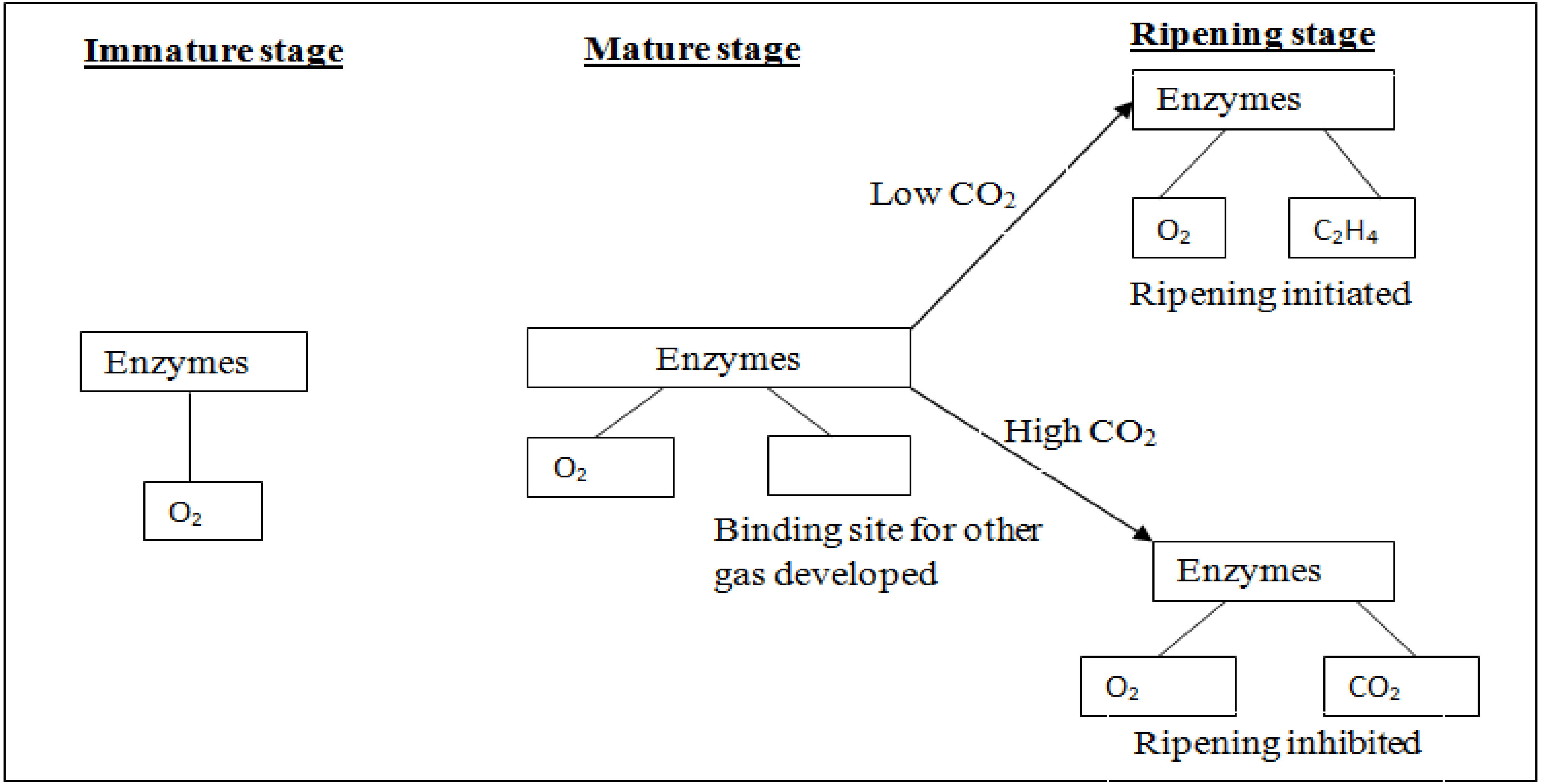

Fig: Effect of carbondioxide and oxygen gases on the ripening of fruit (Burg and Burg, 1967).

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Basic physiology difference between attached and detached plant organ

Physiological process	Attached organ	Detached organ
Absorption/ Uptake	Roots absorb water and minerals from the soil and translocation takes place	Does not have root to absorb water and minerals so no translocation
Photosynthesis	Photosynthesis takes place and translocation of food materials to other organs	Generally no photosynthesis though take place no translocation to other organs
Transpiration	Transpiration loss is supported by absorption means of temperature mgmt	No any supported means and cause weight loss and shriveling
Respiration	Break down of substrate and release of energy; loss of substrate is supported by photosynthesis	Breakdown of substrate and release of energy; loss of substrate is not supported by photosynthesis
Ripening and senescence	Co-factors or ripening inhibitors are regularly supplied by the plants so delay ripening and senescence	No co-factors or ripening inhibitors are regularly supplied so fast ripening and senescence

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Water loss

- The loss of water in harvested commodities cause great economic and quality loss
- Fresh horticultural commodities are unique packages of water
- In fact freshness is water and water sells
- Reserved food materials, water and structural materials are the major components of fruits, vegetables and flowers
- What ever may be the substrate final oxidation of the reserved food materials yields water, carbon dioxide and energy

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- External environment controls all the reactions
- Higher the amount of oxygen available higher will be the reaction and vice versa
- Amount of oxygen available depends upon the permeability of the surrounding tissue

Main sites of water loss in harvested organs are

- Epidermal layer:
  - cuticles and wax are continously deposited on the epidermal cell
  - Mature fruits and leaves have thicker cuticles and wax so loss less water than immature ones

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BENEFIT

Smart Application in Food Industry

Ch.2 Intelligent Packaging Technology

Mr. Wesam Sammar

الكلية الجامعية للعلوم التطبيقية
University College of Applied Sciences

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Introduction

Packaging : enclosure of products, items or packages in a wrapped pouch, bag, box, cup, tray, can, tube, bottle or other container form to perform one or more of the following functions:

- Containment
- Protection
- Preservation
- Communication

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BENEFIT

Why traditional packaging is no long sufficient?

1.Due to increasing customer experience expectations

2.Increasing product complexity

3.Minimising the solid waste

4.Reducing the carbon footprint of manufactured product

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Definition

A total packaging solution that monitors changes in a product or its environment and acts upon these changes .

Smart packaging

A type of packaging that changes the condition of the packaging to extend shelf life or to improve safety or sensory properties while maintaining the quality of the packaged food.

Active packaging

Intelligent packaging refers to a package that can sense environmental changes, and in turn informs the changes to the users

Intelligent packaging

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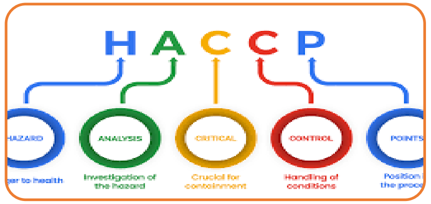
BENEFIT

Intelligent packaging

- The components of intelligent packaging do not have the intention to release their constituents into the food.



- It can also contribute to improving Hazard Analysis and Critical Control Points' (HACCP) and Quality Analysis and Critical Control Points'(QACCP) systems.

- Intelligent packaging provide timely information regarding the status of the food through a change within package system & facilate decision take

Intelligent packaging emphases the ability to sense and measure an attribute of the packaged food product, the atmosphere inside the package or the environment of shipping

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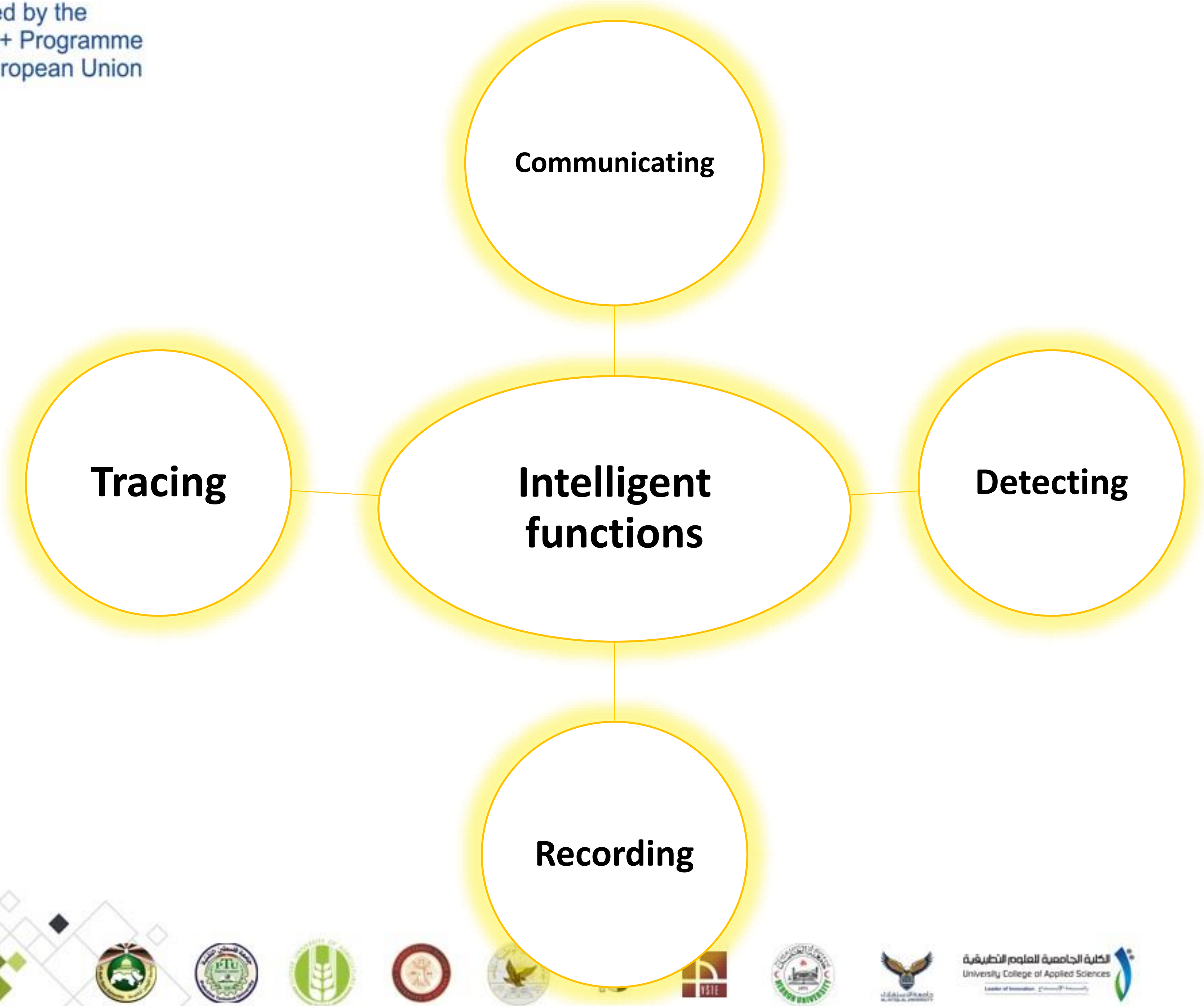

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BENEFIT

Technique of intelligent packaging

indicators

Intelligent technique

sensors

RFID

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Freshness Indicators

Package indicator that have the ability to sense the freshness of the food related to the environment inside or outside the package and inform the consumer regarding the quality of the food

Qualitative

Or Semi Quantitative

visual change

Inside/

Outside

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BENEFIT

Type of indicators

Gas indicator

Based on checking the concentration of gas (CO_2 O_2) to determining the quality of food

Time-Temperature Indicator

Determining the quality of food by monitoring the change in temperature during storage

pH Indicator

Determining the quality of food by showing colour change due to pH change

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BENEFIT

Time-temperature Indicator TTIs

- **Time temperature indicators (TTIs) are devices used for recording thermal history and indicating the remaining shelf life of perishable products throughout their storage, distribution and consumption.**
- **This is achieved by the irreversible change of colour resulting from the cumulative effects of time and temperature.**
- **TTI can provide visual information that is easily accessible, and thus, consumers can judge whether the food is safe and fresh or not.**
- **TTIs are relatively small and cost-effective and can reflect the time and temperature changes**
- **These device take place outside the package**

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BENEFIT

Type Of Time Temperature Indicator

Critical TI

Partial history TI

Full history TI

Show if the product heated above or cooled below a critical temperature

Indicate if a product has been subjected to temperature that impair product quality

Record the complete temperature profile along the food supply chain

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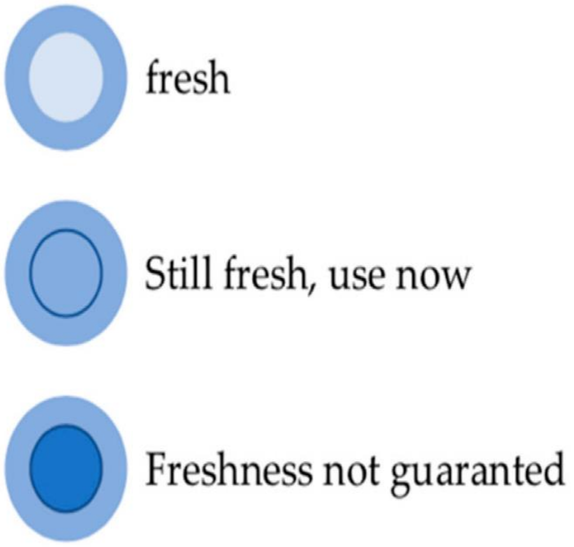
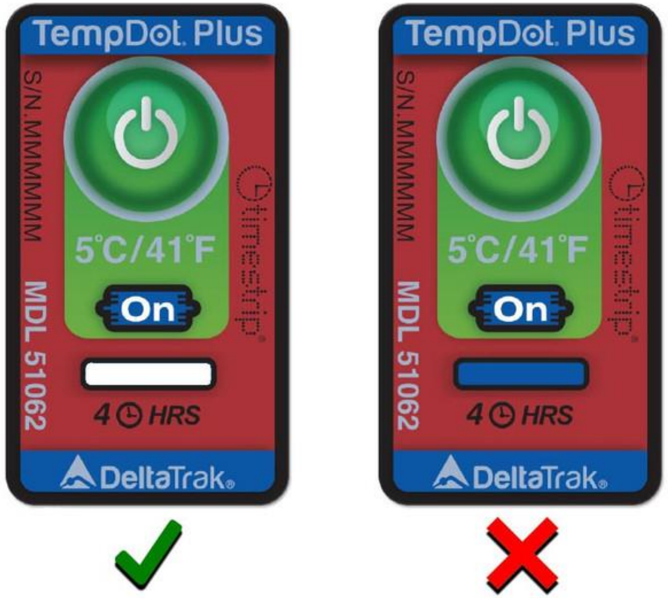
BENEFIT

Working principle of TTI

Principles	Category	Commercial Case
Polymerization	Chemical	Heatmarker Fresh_check
Diffusion	Physical	Templix Monitor Mark
Lactic acid bacteria	Biological	TRACEO
Acid-base reaction	Enzymatic	CheckPoint




TempDot Plus
S/N.MMMMMM
MDL 51062
5°C/41°F
On
4 HRS
timestrip
DeltaTrak
TempDot Plus
S/N.MMMMMM
MDL 51062
5°C/41°F
On
4 HRS
timestrip
DeltaTrak


3 MONTHS
LIFE IN SERVICE
timestrip
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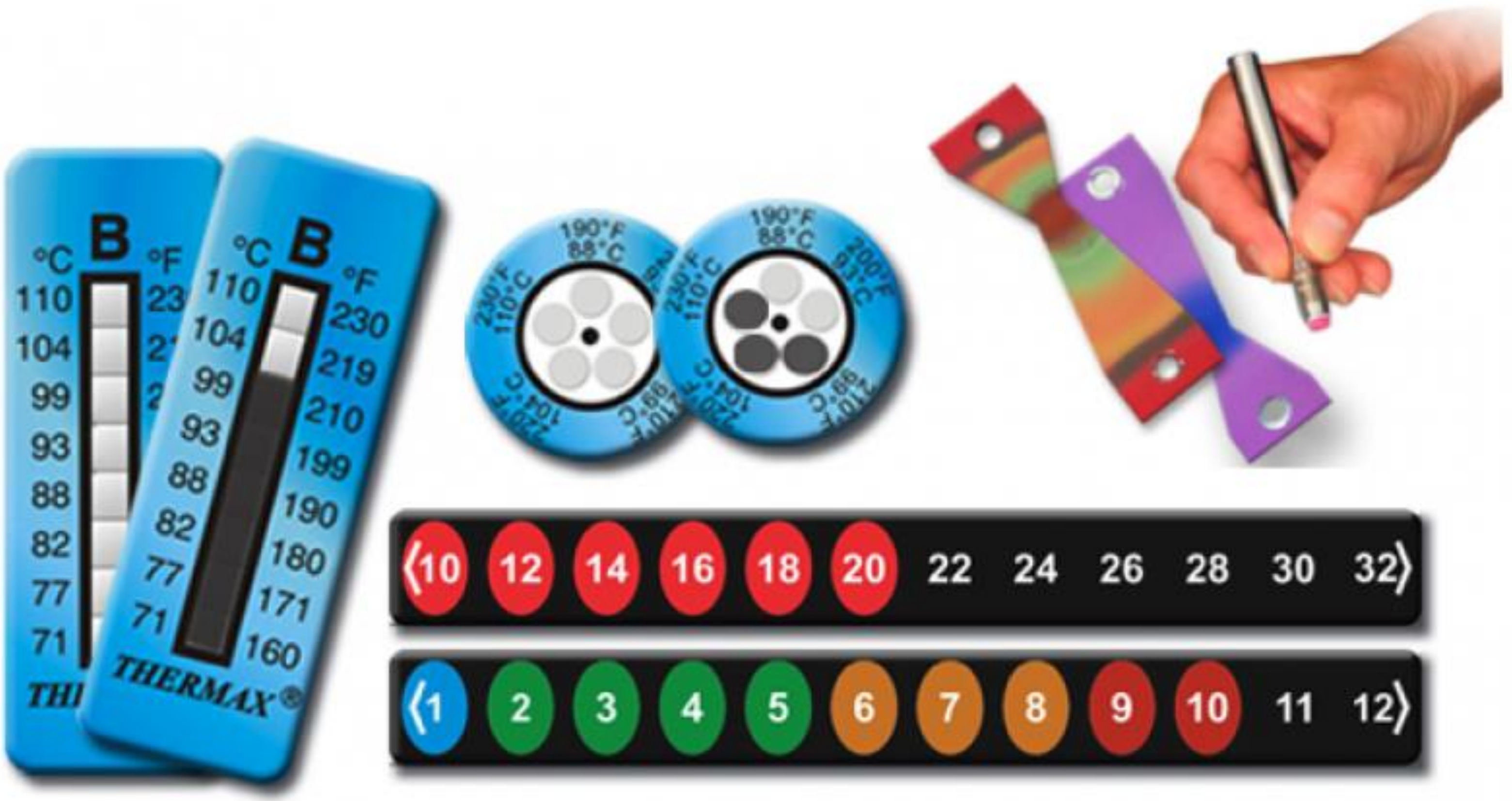
BENEFIT




PEEL TO
ACTIVATE
OliTec
TRAFFIC LIGHT SYSTEM
OliTec
TRAFFIC LIGHT SYSTEM
OliTec
TRAFFIC LIGHT SYSTEM

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BENEFIT

Obstacles to use TTI

migration of toxic substances

the inaccuracy of temperature monitoring

The price of the commercial TTI is relatively high. For example, the price of WarmMark is \$1.09, while 3MTM Monitor MarkTM TTI costs as much as \$2.45.

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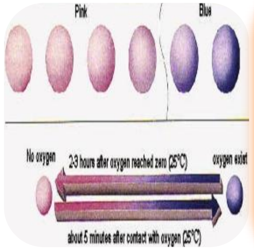
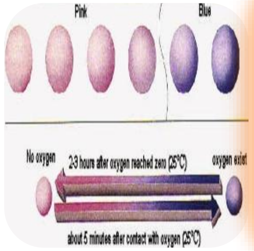
Gas indicator

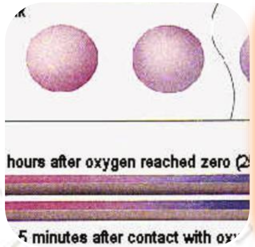
A device used to monitor the change in the inside atmosphere due to permeation phenomena across the package material



Gas indicator are also used to assess the efficacy of active packaging component



Most device based on redox dye, reducing component and alkaline compound



These indicator must be non toxic, non water soluble and take place inside the package

Hydrogen sulphide indicator

Hydrogen sulphide

- **Volatile compounds such as H2S can be detected with myoglobin-based chemical indicators**
- **It is used in the quality control of chicken and chicken products with MAP**
- **These indicators work on the principle of discoloration of myoglobin by hydrogen sulphide**
- **The release of h2s in fresh chicken product is an indication of microbiological activity &reduced freshness**

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Oxygen indicator

- Oxygen is essential for most organisms, and is a key element in life. However, oxygen is also the main reason for food spoilage.
- The popular method to keep food fresh is to reduce the oxygen content within the package via modified atmosphere packaging(MAP).
- In MAP the air is flush out, and replaced with either nothing, nitrogen or carbon dioxide, which results in very low oxygen contents(less than 0.1%)
- Oxygen indicator applied on MAP product to assure the presence of oxygen

Oxygen Indicator

The earliest colorimetric oxygen indicator is Mitsubishi Gas Corporation’s commercial, reversible, colorimetric oxygen indicator, Ageless-EyeTM applied either in pellet or label form

, it comprises a strong reducing agent and a redox-indicator, such as methylene blue, that is easily re-oxidised by oxygen from its chemically reduced, colourless form.

- Not cheap
- High O2 sensitivity
- Not easily handled or stored
- Continuous action

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BENEFIT

pH indicator

- pH is an important factor in determine the quality of the food
- Organic compound of natural or synthetic origin whose color change if the pH of the solution changes.
- pH change in food product occur due to release of microbial metabolites such as CO2, biogenic amine, organic acid,
- pH indicator consist of two parts, a solid support and a dye that is sensitive to pH change
- pH dye can be obtain from natural source (anthocyanin) and synthetic

Chemical synthetic dye

Methyl orange

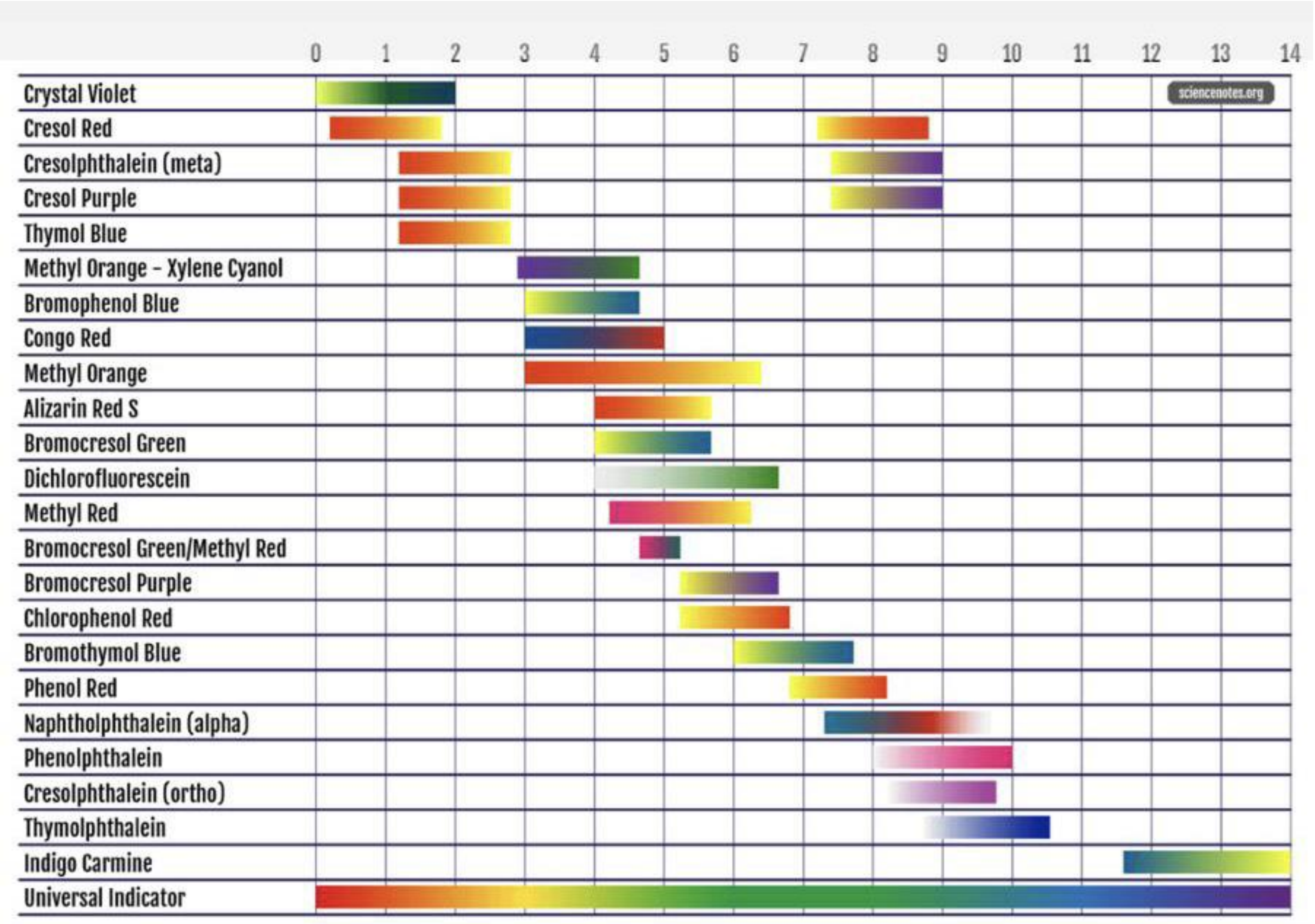
Bromocresol green

dichlorofluorescein

Methyl red

Bromocresol purpl

Chlorophenol red



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BENEFIT

Application of pH indicator

Ripeness indicator

Volatile amine indicator

pH indicator

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BENEFIT

Ripeness Indicator

These work on the principle of measuring the aroma components produced by fruits and vegetables as they ripen

- The label on the package changes color according to the degree of ripeness of the fruit

Pear

Kiwi

mango

melon

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Ripeness Indicator

Ripen guava

Ethanol

ADH

Acetaldehyde

Acetic acid

Decrease pH 4.6-3.9

Blue-Green

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BENEFIT

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Volatile Amines Indicator

Volatile amine produced when fish begin spoilage (trimethylamine, dimethylamine, ammonia)

Volatile amines are accumulating in the headspace of the packaged product

These volatile amines causes increase in pH and consequently color change of indicator from yellow to blue

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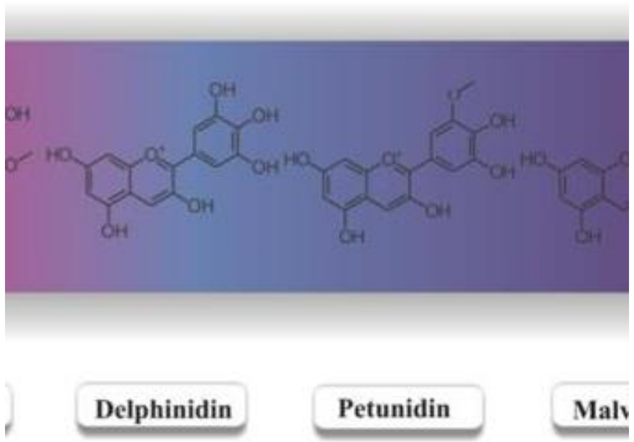
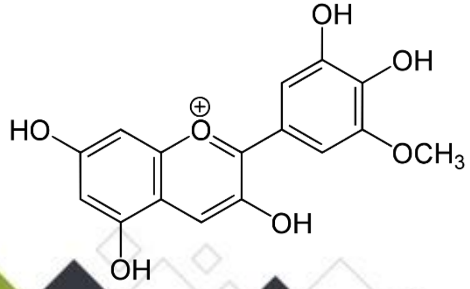
BENEFIT

Volatile amine indicator





Refrigerated fish

↓

Protein denature

Pse. spp ↓

Trimethylamine

colour of anthocyanin change from blue to green

pH increase above 7

Principle of Freshness Indicator

Metabolites	Food Product	Indicator
Glucose/lactic acid	Fermented food/meat	Colorimetric based on pH
Carbon dioxide	Fermented food/meat/seafood	Colorimetric based on pH
Oxygen	Meat/vegetable/fruit	Colorimetric based on pH
Biogenic amine	Fish/meat	pH-sensitive dye

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Advantage and Disadvantage

Advantages

1.Reduction in the loss of product

2.Monitoring & tracing food product during food supply chain

3.Protect the consumer against food borne illnesses

4.Facillate decision making by the consumer

Disadvantages

1.The price of intelligent technique is high 2.synthetic pH dye has toxicity

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BENEFIT

Smart Application in Food Industry

Ch.3 Smart application in pretreatment processing

Mr. Wesam Sammar

الكلية الجامعية للعلوم التطبيقية
University College of Applied Sciences

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BENEFIT

1) Pre-cooling

Pre-cooled -
Alive & Happy

Not-Precooled
Sick and Die

Effect of pre-cooling

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- Pre-cooling of the produce soon after their harvest (before storage/ shipment) is one of **the important components** of the cool chain, which ultimately affect the shelf life of the produce.
- Rapid precooling to the products lowest safe temperature is most critical for crops with having high respiration rates
- Purpose of precooling
    - **remove the field heat** from the produce.
    - To reduce moisture loss
    - To reduce ethylene production
    - To reduce respiration
    - Microorganism
    - To increase shelf life

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BENEFIT

Field heat removal

- Without a doubt, the most important factor affecting postharvest life is temperature.

- This is because temperature has a profound effect on the rates of biological reactions, eg., metabolism and respiration.

- Over the physiological range of most crops, ie.,0 to 30 °C (32 to 86 °F), increased temperatures cause an exponential rise in respiration. so good temperature is the single most important factor in delaying product deterioration; prompt cooling and maintenance of proper temperature are both essential.

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BENEFIT

- For many products, this means maintaining as low a temperature as possible without danger of freezing.
- The Van't Hoff Rule states that the velocity of a biological reaction increases 2 to 3-fold for every 10 °C (18 °F) rise in temperature.
- The temperature quotient for a 10 °C interval is called the Q_{10}.

Temperature (°C)	Assumed Q_{10}*	Relative velocity of deterioration	Relative postharvest-life	Loss per day (%)
0	-	1.0	100	1
10	3.0	3.0	33	3
20	2.5	7.5	13	8
30	2.0	15.0	7	14
40	1.5	22.5	4	25

$$^{*}Q_{10} = \frac{\text{Rate of deterioration at temperature } T + 10\ ^{\circ}\text{C}}{\text{Rate of deterioration at temperature } T}$$

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- Cooling requirement for a crop vary with the air temperature during harvesting, stage of maturity and nature of crop.
- selection of precooling methods depends on:
  - The temperature of produce at harvest
  - Physiology of produce

Different methods of precooling:

- cold air (room cooling, forced air cooling),
- cold water (hydrocooling),
- direct contact with ice (contact icing),
- evaporation of water from the produce (evaporative cooling, vacuum cooling) and
- combination of vacuum and hydrocooling (hydrovac cooling).

i) Room cooling :

- It is **low cost and slow method** of cooling.
- In this method, produce is simply loaded into a insulated cool room and cool air is allowed to circulate among the cartons, sacks, bins or bulk load.

Advantages:

- Produce can be **cooled and stored at the same** room thus saves on handling costs
- **No extra cost** for pre-cooling equipment
- Suits for crops, which are **marketed soon after harvest**

Disadvantages:

- It is **too slow method** of cooling
- **Space requirements** for room cooling are more as compared to storage, thus loss of storage capacity
- **Unsuitable for packed produce**
- Excessive water is lost from the produce due to slow cooling.

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ii) Forced-air cooling:

- Forced air-cooling is mostly used for wide range of horticultural produce
- This is the **fastest method** of pre-cooling
- Forced air-cooling **pulls hot air or pushes cool air** through the vents/holes in storage containers
- In this method **uniform cooling of the produce** can be achieved if the stacks are properly aligned.
- Cooling time depends on
  - (i) the airflow
  - (ii) the temperature difference between the produce and the cold air and
  - (iii) Amount of the produce

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Advantages:

- **A fast method** of pre-cooling (up to 90% faster than room cooling)
- **Suitable for a wide range** of highly perishable commodities.
- **Uniform cooling**, if products are properly aligned.
- Cooling times can be controlled for different types of produce by **controlling the air flow rate.**

Horticultural produce suitable for forced air cooling are: Grapes, Berries, Pears, peaches, Oranges, Strawberries tomatoes, and other tropical and subtropical fruits.

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iii) Hydrocooling :

- cleaning and precooling at same time
- The use of cold water is an **old and effective cooling method** used for quickly cooling a wide range of fruits and vegetables before packaging.
- **For the packed commodities it is less used** because
  - difficulty in the movement of water through the containers and
  - high cost involved in water tolerant containers.
- This method of cooling **not only avoids water loss** but may even add water to the commodity.
- Some chemicals (nutrients/growth regulators/ fungicides) can also be mixed with the water used in hydrocooling to prolong the shelf life by improving nutrient status of crop and preventing the spread of post harvest diseases.
- The hydrocooler normally used are of two types :
  - Shower type and Immersion type

Advantages :

- **Less energy** is used as compared to forced air cooling i.e. water removes heat about 5 times faster than air

- **Moisture loss** does not take place.

Disadvantages :

- Most of the **packages don’t tolerate wetting**
- **Wax layer** of some fruits like pear, plum, apple are removed by using spray type of hydrocooler

Horticultural produce suitable for hydrocooling are: Mango, peach, cherry, Asparagus etc. not suitable for berries, potato, onion etc

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iv) Vacuum cooling:

- Vacuum cooling takes place by **water evaporation** from the product at very low air pressure.
- In this method, the air is pumped out from a larger steel chamber in which the product is loaded for pre-cooling i.e. **vacuum is created**
- Removal of air results in the reduction of pressure of the atmosphere around the product, which further lowers, the boiling temperature of its water.
- As the pressure falls, the water boils quickly removing the heat from the produce.

Advantages :

- Fast and uniform cooling takes place.
- Most energy-efficient method.

Disadvantages :

- High capital cost
- Produce losses more moisture

To overcome the loss of water from the produce, another method of water spray vacuum is used, (modification of vacuum cooling), called hydro-vac cooling.

v) Package-icing :

- In some commodities, crushed or flaked ice is packed along with produce for fast cooling.
- However, as the ice comes in contact with the produce, it melts, and the cooling rate slows considerably.
- The ice keeps a high relative humidity around the product.
- Liquid icing distributes the ice throughout the container, achieving better contact with the product.
- Packaged icing can be used only with water tolerant, non-chilling sensitive products and with water tolerant packages (waxed fiber board, plastic or wood)

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7. Storage

Principle of storage:

Reducing the metabolic activities of the stored produce to meet the following activities

Objective of storage:

- Regulate the market in an orderly manner.
- Avoid glut and distress sale in the market, thus prolonging the market period.
- In long-term storage, making the food available in off-season.

A number of storage techniques (ground storage, ambient storage, refrigerated storage, air cooled storage, zero energy storage, modified atmospheric storage, hypobaric storage and controlled atmosphere storage) are being used

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BENEFIT

Tips for storage of high quality horticultural produce

- Store only high quality produce, free of damage, decay and of proper maturity (not over-ripe or under-mature)
- Know the requirements for the commodities you want to put into storage, and follow recommendations for proper temperature, relative humidity and ventilation
- Avoid lower than recommended temperatures in storage, because many commodities are susceptible to damage from freezing or chilling
- Do not over load storage rooms or stack containers closely
- Provide adequate ventilation in the storage room
- Keep storage rooms clean
- Storage facilities should be protected from rodents by keeping the immediate outdoor area clean, and free from trash and weeds

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- Do not stack containers beyond their stacking strength
- Monitor temperature in the storage room by placing thermometers at different locations
- Don’t store onion or garlic in high humidity environments
- Avoid storing ethylene sensitive commodities with those that produce ethylene
- Avoid storing produce known for emitting strong odors (apples, garlic, onions, turnips, cabbages, and potatoes) with odor-absorbing commodities
- Inspect stored produce regularly for signs of injury, water loss, damage and disease
- Remove damaged or diseased produce to prevent the spread of problems

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Methods of storage

Selection of storage techniques depends upon

- nature of the commodity
- storage period intended
- Cost
- Location

Ordinary storage

- No any control of environment

e.g. Potato store over the floor

Onion and garlic hang over

Pumpkin stored in dry shelf

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Field storage

- Storage of produce in trenches or pits
- Cabbage, sweet potato, ginger, turmeric, potato, carrots, beets etc can be stored in field
- Best in the area having less rainfall
- Best in temperate regions
- Low or no cost required
- Have no control of environment (natural control)
- Difficult to remove the produce when environment is in unfavorable condition

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BENEFIT

Controlled atmosphere (CA) storage

- Controlled atmosphere storage generally refers to keeping produce at decreased oxygen and increased carbon dioxide concentrations and at suitable range of temperature and RH
- The term imply, the addition or removal of gases resulting in an atmospheric composition different from that of normal air
- Thus the levels of carbon dioxide, oxygen, ethylene, and metabolic volatiles in the atmosphere may be manipulated
- 2-3% of CO_2 has been reported in case of apple
- In general 2-3% O_2 and 2-3% CO_2 is good compromise condition

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Modified atmosphere storage

- Principle is same as CAS
- Modification in atmosphere is achieved through produce
- To avoid excess CO_2 accumulation fresh hydrated lime can be used in bag @ 100 - 200 g per 10 kg of fruits
- Perforations of different size are available in package to provide ventilation
- In MAP (modified atmospheric packaging) produce is enclosed in polymeric films and is allowed to generate its own atmosphere **(passive MAP)** or air of known composition is flushed into the bag **(active MAP)** and depending upon gas / vapour transmission characteristics of the film on appropriate atmosphere develops in the package to prolong shelf life
- MAP is ideally combined with temperature control for maximum benefit

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Benefits of CA storage

- Slow down respiration and ethylene production rates, softening and retard senescence of horticultural produce

Harmful effects of CA storage

- Initiation or aggravation of certain physiological disorders can occur, such as blackheart in potatoes, brown stain on lettuce, and brown heart in apples and pears
- Irregular ripening of fruits, such as banana, mango, pear and tomato, can result from exposure to O2 levels below 2% or CO2 levels above 5% for more than 2 to 4 weeks
- Off- flavors and off-odors at very low O2 or very high CO2 concentration may develop as a result of anaerobic respiration and fermentative metabolism.

Table 6: Recommended CA or MA conditions for selected fruits and vegetables

Commodity	Temperature (°C)	% O_2	% CO_2
Apple	0-5	1-2	0-3
Banana*	12-16	2-5	2-5
Cherry, sweet	0-5	3-10	10-15
Mango*	10-15	3-7	5-8
Peach, clingstone	0-5	1-2	3-5
Pear, European	0-5	1-3	0-3
Asparagus	1-5	Air	10-14
Beans, green	5-10	2-3	4-7
Broccoli	0-5	1-2	5-10
Brussels sprouts	0-5	1-2	5-7
Cabbage	0-5	2-3	3-6
Cantaloupes	2-7	3-5	10-20
Cauliflower	0-5	2-3	3-4
Okra	7-12	Air	4-10
Onions (bulb)	0-5	1-2	0-10
Pepper (bell)	5-12	2-5	2-5
Radish (topped)	0-5	1-2	2-3
Tomatoes (green) ripe	12-20 10-15	3-5 3-5	3-5 3-5

* CA is especially beneficial during transit

(Source : Adel A. Kader, 2002)

Cellar storage

- Underground storage
- Commonly used in hilly regions
- Used to store citrus and apple
- 15°C less than ambient temperature
- Constructed in such a way that all the sides of the storage are covered with earth except entrance
- Prepared in north facing slope
- Spray of water is done to increase RH of the storage

Rustic storage

- Used for storage of seed tuber
- Suitable in the high hills
- Diffused lights are allowed to the tubers
- Potato stored in this storage is not suitable for eating purpose
- Robust green sprouts can be seen in the tubers

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BENEFIT

Zero energy storage

- Can be prepared in any place where RH is comparatively low
- Suitable in dry areas
- 10-15°C low temperature than ambient temperature
- 90-95% RH can be maintained

Cold storage

- Reducing the temperature in the store to reduce metabolic activities
- working principle of cold storage is same as refrigerator

Working principle of refrigerator

- Consists of three basic components
    - Compressor: consists of ammonia gas which is highly compressed to increase its temperature
    - Condenser: highly heated gas is cooled and change into liquid by condenser
    - Evaporator: cooled gas is allowed to mist into the evaporator
    - Thermo-expansion valve:
    - Insulated wall:

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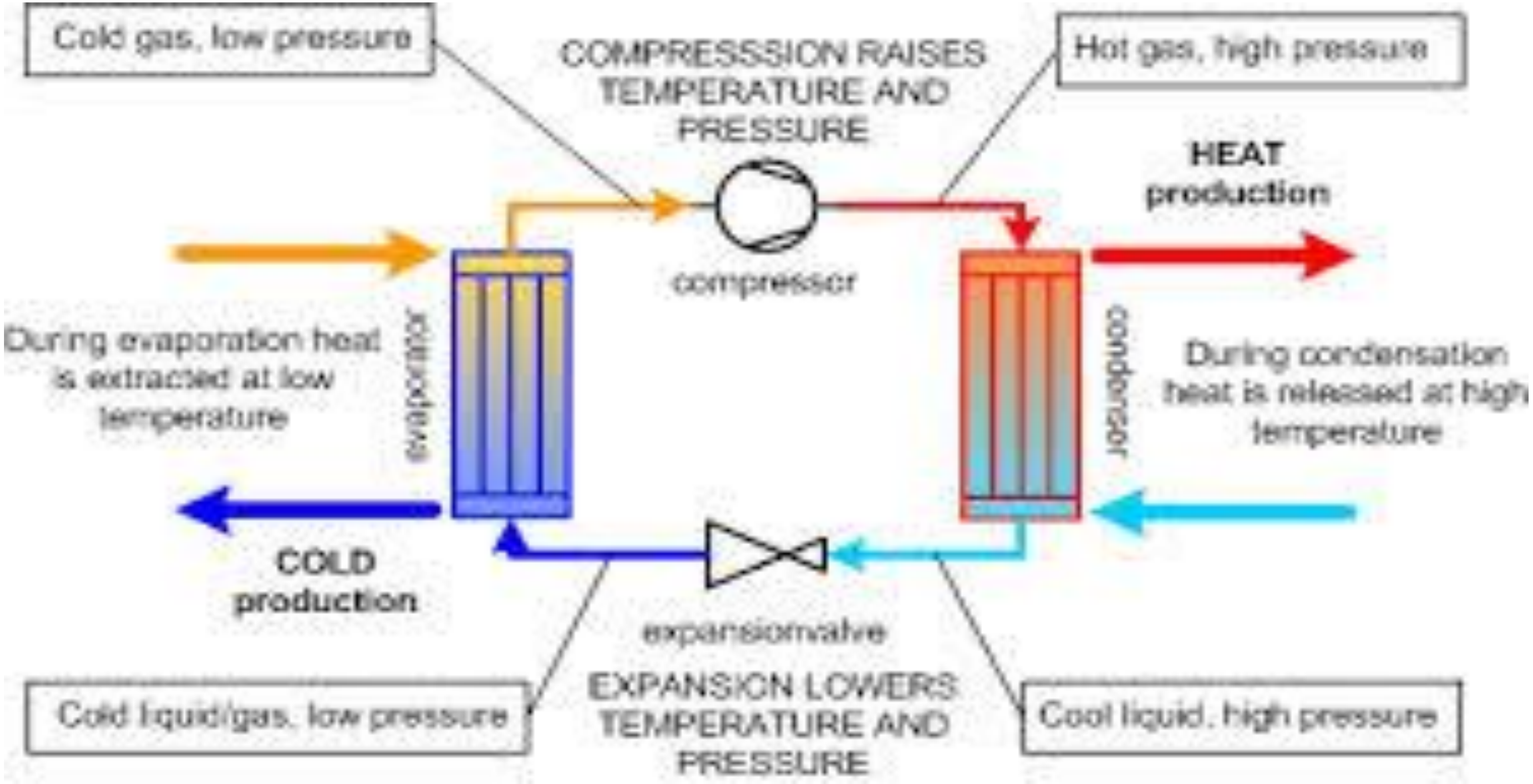

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BENEFIT

Factors affecting storage

- **Temperature**
  - Higher temperature higher metabolic activities
  - Rate of reaction within physiological temperature range increase exponentially with increase in temperature
  - Chemical reaction approx. doubles with 10°C rise in temp
  - lower limit of physiological temperature is above freezing temperature
  - And higher limit of physiological temperature is around 30°C
  - At higher temperature ethylene cannot act, color cannot develop, enzyme cannot perform functions so metabolic injury occurs
  - Safe storage temperature is above freezing temperature care should be taken for chilling sensitive cultivars

- Relative humidity
  - Higher RH lower water loss
  - Very high RH favors fungus growth
  - 90% RH is best but for onion 65-75% and for leafy vegetables 98-100%
- Ventillation
  - Excessive ventilation results wilting and shrinkage while inadequate may cause decay of produce
  - Necessary to manage temperature
  - For gaseous exchange
- Stage of maturity
  - Should be harvested at right time for longer shelf life

Recommended temperature and RH for some commodities

Commodity	Temp	RH	Storage life
Apple	1-4	90-95	3-8 months
Banana	12-15	85-90	3-5 wks
Grape	0-1	90-95	2-3 months
Guava	8-10	85-90	2-3 wks
Lime	8-10	90	6-8 wks
Mango	12-15	85-90	3-4 wks
Papaya	8-10	90	1-2 wks

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2.1. Raw Material Preparation

- ***At the time of harvest or slaughter***, most foods are likely to contain **contaminants**, to have components which are **inedible** or to have variable physical characteristics (for example shape, size or colour).

- ***It is therefore*** necessary to perform one or more of the unit operations of cleaning, sorting, grading or peeling ***to ensure*** that foods with a uniformly high quality are prepared for subsequent processing.

- These mechanical separation procedures, which are applied ***near the beginning*** of a process, are a highly cost-effective method of improving the quality of the raw material.

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2.1.1. Cleaning

- **Cleaning** is the unit operation in which contaminating materials are removed from the food and separated to leave the surface of the food in a suitable condition for further processing.

- **Cleaning should take** place at the *earliest* opportunity in a food process ***both to prevent*** damage to subsequent processing equipment by stones, bone or metals, and ***to prevent*** time and money from being spent on processing contaminants which are then discarded.

- ***In addition,*** the early removal of small quantities of food contaminated by ***micro-organisms*** prevents the subsequent loss of the remaining bulk by microbial growth during storage or delays before processing.

  Cleaning is thus an effective method of reducing food wastage, improving the economics of processing and protecting the consumer.

-

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❑ Wet cleaning

- **Wet cleaning** is ***more effective than*** dry methods for removing soil from root crops or dust and pesticide residues from soft fruits or vegetables.
- It is also ***dustless*** and ***causes less damage*** to foods than dry methods. Different combinations of detergents and sterilants at different temperatures allow flexibility in operation.
- **However,** the use of warm cleaning water may accelerate chemical and microbiological spoilage ***unless careful control*** is exercised over washing times and subsequent delays before processing.
- It also produce large ***volume of effluent*** often with high concentrations of dissolved and suspended solids.
- There is then a requirement ***both*** to purchase clean water and to either pay for high effluent disposal charges or build in factory water treatment facilities.
- ***To reduce costs***, recirculated, filtered and chlorinated water is used whenever possible.

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❑ Dry cleaning

- **Dry cleaning** procedures are **used for** products that are *smaller, have greater mechanical strength and possess a lower moisture content* (for example grains and nuts).

- After cleaning, the surfaces are dry, to aid preservation or further drying. *Dry procedures generally* involve smaller cheaper *equipment than wet* procedures do and produce a concentrated dry effluent which may be disposed of more cheaply.

- In addition, plant cleaning is simpler and chemical and microbial deterioration of the food is reduced compared to wet cleaning.

- **However,** additional capital expenditure may be necessary to prevent the creation of dust, ***which not only creates*** a health and explosion hazard but also recontaminates the product.

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2.1.2. Sorting

- **Sorting is** the separation of foods into categories on the basis of a measurable *physical property*.
- *Like cleaning*, sorting should be employed as early as possible to ensure a uniform product for subsequent processing.
- The **four main** *physical properties* used to sort foods are size, shape, weight and colour.
- The **shape** of some foods is important in determining their suitability for processing or their retail value.
- Shape sorting is accomplished either *manually* or *mechanically* (for example the belt-and-roller sorter or the disc sorter) or by *image processing*.

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2.1.2. Sorting…Cont'd

- **Size sorting** (termed *sieving or screening) is the separation of solids into two or more* fractions on the basis of differences in size.
- **Size sorting** is particularly important when the food is to be ***heated*** or ***cooled*** as the rate of heat transfer is in part determined by the size of the individual pieces and variation in size would cause over-processing or under-processing.
- Additionally, foods which have a uniform size are said to be preferred by consumers.
- **Equipment:** Screens with either fixed or variable apertures are used for size sorting. The screen may be stationary or, more commonly, rotating or vibrating.

2.1.2. Sorting…Cont’d

- Manual sorting by **colour** is still widely used but is increasingly expensive in both labour costs, operator training and the space required for sorting tables.

- There has *therefore been* considerable development of machine vision sorting systems which are said to have lower operating costs and greater accuracy than manual methods.

- These include *monochrome* (black and white), *bichrome* (4100 shades of red and green) and *trichromatic* or full colour (262 000 shades of red, green and blue, with optional infrared).

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2.1.2. Sorting…Cont'd

- Each is controlled by a programmable logic controller which has pre-set programs for different products that are easily changeable by operators using a video display. They are **used for example**, to sort potatoes for defects and blemishes by identifying dark areas on the potato surface.
- **Weight sorting** is more accurate than other methods and is therefore used for more valuable foods (for example eggs, cut meats and some tropical fruits).
- **Aspiration and flotation** sorting use differences in density to sort foods and are similar in principle and operation to aspiration and flotation cleaning.
- Grains, nuts and pulses are sorted by aspiration. Peas and lima beans are sorted by flotation in brine (specific gravity, 1.1162– 1.1362). The denser, starchy, over-mature pieces sink whereas the younger pieces float.

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2.1.3. Grading

- **Grading** is often used interchangeably with sorting but strictly means '**the assessment of overall quality of a food using a number of attributes**'. Sorting (that is separation on the basis of one characteristic) may therefore be used as part of a grading operation but not vice versa.
- **Grading is** carried out by operators who are trained to simultaneously assess a number of variables. For example, cheese and tea, which are assessed for flavour, aroma, colour, etc.
- In some cases, **the grade of food is** determined from the results of laboratory analyses (for example wheat flour is assessed for protein content, dough extensibility, colour, moisture content and presence of insects).
- In general, ***grading is more expensive than sorting*** owing to the higher costs of skilled operators. **However,** many attributes that cannot be examined automatically can be simultaneously assessed, and this produces a more uniform high-quality product.

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2.1.4. Peeling

- **Peeling** is used in the processing of many fruits and vegetables to remove unwanted or inedible material, and to improve the appearance of the final product.

- The **main consideration is** to minimise costs by removing as little of the underlying food as possible and reducing energy, labor and material costs to minimum. The peeled surface should be clean and undamaged.

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BENEFIT

Smart Application in Food Industry

Ch.4 Smart Food Production Technology

Mr. Wesam Sammar

الكلية الجامعية للعلوم التطبيقية
University College of Applied Sciences

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Smart food

- Smart foods are those that have been developed through the invention of new or improved processes, for example, as a result of man-made materials/ingredients or human intervention; in other words, not naturally occurring changes.
- Smart foods may:

- have a function, other than that of providing energy and nutrients;
- perform a particular function never achieved by conventional foods;
- have been developed for specialised applications, but some eventually become available for general use.

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Smart foods include:

1. Modified starches.
2. Functional foods, e.g. cholesterol lowering spreads, probiotic yogurts, fortified eggs.
3. Meat analogues, e.g. textured vegetable protein (TVP), myco-protein and tofu.
4. Encapsulation technology, e.g. encapsulated flavours in confectionery
5. Modern biotechnology, e.g. soy bean, tomato plant, modified enzymes, e.g. chymosin.

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Modified Starch

- Starches that have been altered to perform additional functions.
- Modified starch is used as a fat replacer in low-fat meals.
- Pre-gelatinised starch is used to thicken instant desserts without heat.
- To prevent ‘drip’ after a pie is defrosted, modified starch is used in the sauce.

- Starches that have been altered to perform additional functions.
- Modified starch is used in ‘cup-a-soups’ to improve mouth-feel, thicken the drink/sauce with the addition of boiled water, and blend uniformly with no lumps.
- The noodles in ‘pot snacks’ are pre-gelatinised, so boiled water will re-heat and 'cook' them.

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Functional Foods

- Foods that contain an ingredient that gives health promoting properties.
- Some eggs contain Omega-3 fatty acids, known to benefit heart health.
- Specially formulated spreads help to lower cholesterol levels in the body.
- Probiotic drinks are designed to improve the health of the large bowel.

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Encapsulation Technology

- The coating of a particle with an outer shell.
- Jellybeans use encapsulated flavours for enhanced sensory appeal.
- Some breads use encapsulated leavening agents to prevent premature release and reaction.
- Specially formulated ‘sports’ bars are fortified with encapsulated nutrients.

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Genetically Modified Foods

- Specific changes to a plant or animal at a genetic level.
- Potatoes can be altered to reduce the absorption of fat during frying.
- Maize is modified to control pests, minimising crop damage.
- Chymosin, a modified enzyme, is used to produce ‘vegetarian’ cheese.

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Meat Analogues

- Ingredients that mimic the organoleptic properties of meat.
- Myco-protein is used in fillets to provide a ‘chicken like’ texture.
- Tofu absorbs flavours, so is used as a meat alternative in stir-fries.
- TVP is used in vegetarian shepherd’s pie to provide the main source of protein.

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BENEFIT

Automation in Food Industry

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Introduction To Automation in Food Industry

*The current level of automation in the food industry has been described as "islands of automation".

*Food industry presents many unique challenges to complete automation, the industry has been successful in putting many automatic processes into place. The next significant development will be to integrate these "islands of automation" into an overall system of plant automation, from receiving raw materials to shipping finished products

Introduction To Automation in Food Industry

*Nonetheless, the food industry now ranks among the fastest growing segments for plant automation. For example, the food industry is among the top ten in using machine vision technology, a key component in plant automation. However, most systems are isolated, batch-type operations that target a specific task. In order for automation to be successful, it must be integrated into the overall manufacturing system design and provide on-line, continuous control capability

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AUTOMATIC MATERIAL HANDLING SYSTEM

- Automatically controlled operations of an apparatus, Process or system by mechanical & electric devices that take the place of human labor.
- AMHS uses route and process step information provided by (MES) Manufacturing execution system to move material using conveyers, vertical elevators, and autonomous vehicles.
- Identification of material is accomplished using various technologies such as RFID Barcoding OCR

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BARCODING

- They speed up the check-out process, help to track stock and reduce shoplifting.
- Barcodes on food packing is a great way to monitor, track, and ensure that every single product that goes on the supply line is of extremely high quality.
- Barcoding ensuring that you don’t lose any products along the way.

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OPTICAL CHARACTER RECOGNITION-OCR

- The electronic or mechanical conversion of images of typed, handwritten or printed text into machine-encoded text.
- AI- OCR read invoices & receipts.
- Application in food industry

- Real time production tracking
- Label verification
- Date code accuracy & Legality
- Automatic warehouse, Picking & Shipping data Management.

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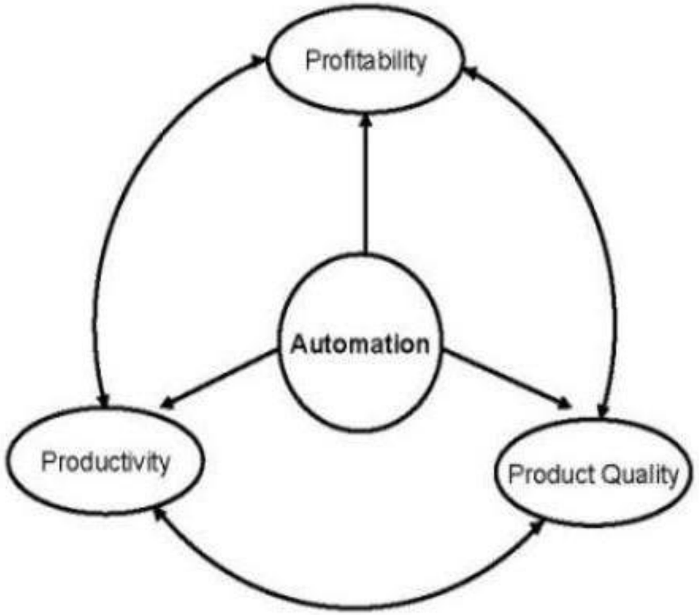
Automation In Food Industry



Plant Automation

- Improved Productivity
- Improved Product Quality
- Improved Profitability

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Automation In Food Industry

Improved Productivity

Plant productivity may be defined as the quantity of end products manufactured per unit of operating parameters – plant size, number of workers, time of operation, etc

Improved Profitability

Automation helps to improve productivity and product quality. Both of these contribute directly to improve profitability. Another important factor that makes automation extremely critical for the food industry is the need to comply with food safety and environmental regulatory agencies

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Automation In Food Industry

Improved Product Quality

Quality assurance is one of the most important goals of any industry. The ability to in an expanding market share. Quality–assurance methods used in the food industry have traditionally involved human visual inspection

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Uniqueness of the Food Industry

*One of the most important reasons for increased interest in automating the food industry is its cost structure. Food processing is highly labor-intensive, with labor costs at anything up to 50 percent of the product cost. Improving productivity and reducing labor costs will therefore have a significant impact on profitability

*Excellent examples of automation include processing and packaging Food products. Such as Dairy ,Bakery ,Beverage ,Etc..,

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Tools Of Automation In Food Industry

1. Computer Vision Systems
2. On-line Sensors
3. Expert Systems
4. Robot Technology
5. Computer Integrated Manufacturing
6. Flexible Manufacturing Systems
7. Systems Engineering

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Tools Of Automation In Food Industry

Computer Vision Systems

Computer vision is the science that develops the theoretical and algorithmic basis by which useful information about an object or scene can be automatically extracted and analyzed from an observed image, image set, or image sequence.

Computer vision applications currently range from simple inspection to vision-guided robotic assembly Such as Gauging ,Verification , Flow detection ,Identification, Recognition , Locating

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- People would have a hard time trying to accurately evaluate a fruit’s size with the naked eye, while a computer vision system can measure a precise diameter of an any commodity in a blink of an eye.
- For fruits and vegetables, increasing the sorting speed by 10 times compared to humans Packaging
- Automated visual check of a filling level and package labeling is another important application of computer vision in the food industry
- A visual system can check the freshness of a packed product with the aid of a special ink changing its color with time and at a different speed depending on the temperature.

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Tools Of Automation In Food Industry

Online Sensor

Sensor is an object whose purpose is to detect events or changes in its environment, and then provide a corresponding output. A sensor is a type of transducer; sensors may provide various types of output, but typically use electrical or optical signals.

Classification Of Sensor are of Many Types –Nano Sensor ,Bio sensor ,Chemical Sensor ,Optical Sensor Etc..

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BENEFIT

Tools Of Automation In Food Industry

Robot Technology

These technologies deal with automated machines (robots for short) that can take the place of humans in dangerous environments or manufacturing processes, or resemble humans in appearance, behaviors, and or cognition. Robots Technology have some kind of mechanical construction, a frame, form or shape designed to achieve a particular task Within the Specific Time .

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Tools Of Automation In Food Industry

Computer Integrated Manufacturing

Computer-integrated manufacturing (CIM) is the manufacturing approach of using computers to control the entire production process. This integration allows individual processes to exchange information with each other and initiate actions.

Generally In Many Food Industry SAP (Computer Application) Is Widely used In the Integrated Process

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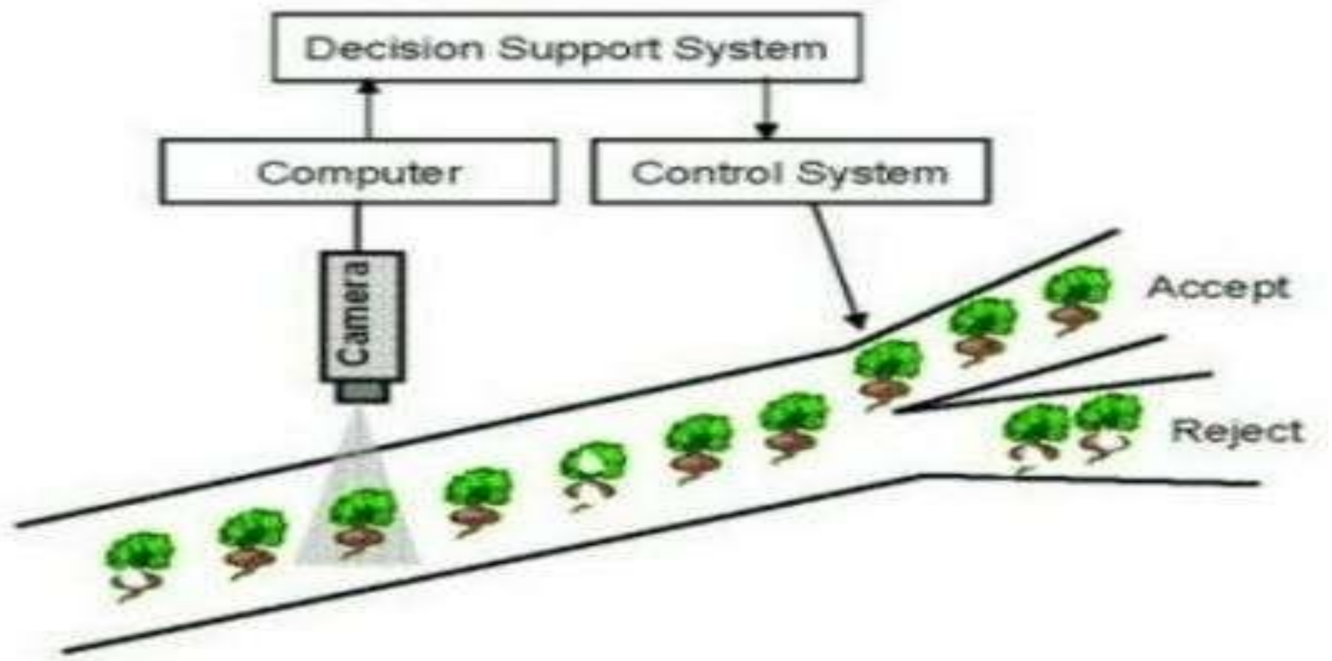
BENEFIT

Tools Of Automation In Food

Schematic representation of on-line food quality evaluation using a computer vision system.



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BENEFIT

Few Advantages of Automation

*Increased throughput or productivity.

*Improved quality or increased predictability of quality.

*Improved robustness (consistency), of processes or product.

*Increased consistency of output.

*Reduced direct human labor costs and expenses

*Reduce the Time Of Processing High Utility

*Safer working conditions.

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Few Disadvantages of Automation

*Lower skill levels of workers.

*High initial investment.

*Retrenchment or unemployment.

*Not suitable for short product life cycle

*Not economically justifiable for small scale production

*High Maintenance of Automation

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BENEFIT

Few Industries Of Automation

*ITC

*Parle

*Britannia

*Nestle

*Amul

*Coca Cola

*Pepsi

*Pedigree

*Con Agro

*Heritage

*Dairy Industry

*Bakery Units

*Oil Industry

*And So Many Industries

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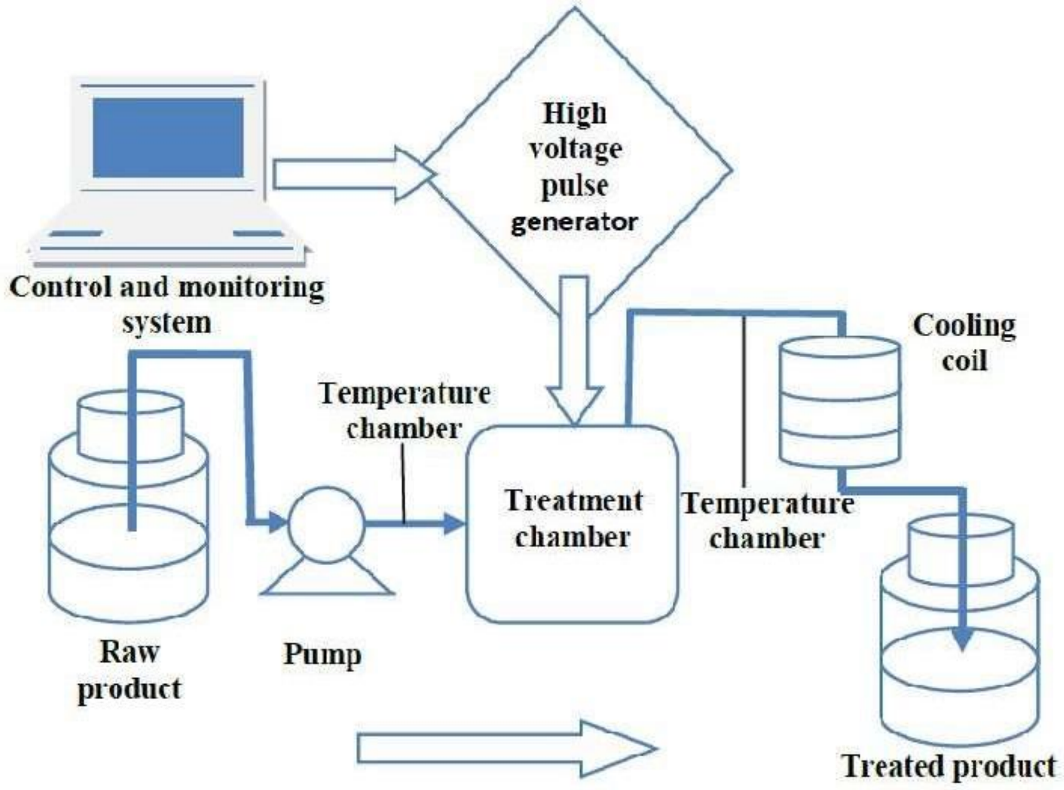
Few Flow Diagram Of Food Industry –Automation



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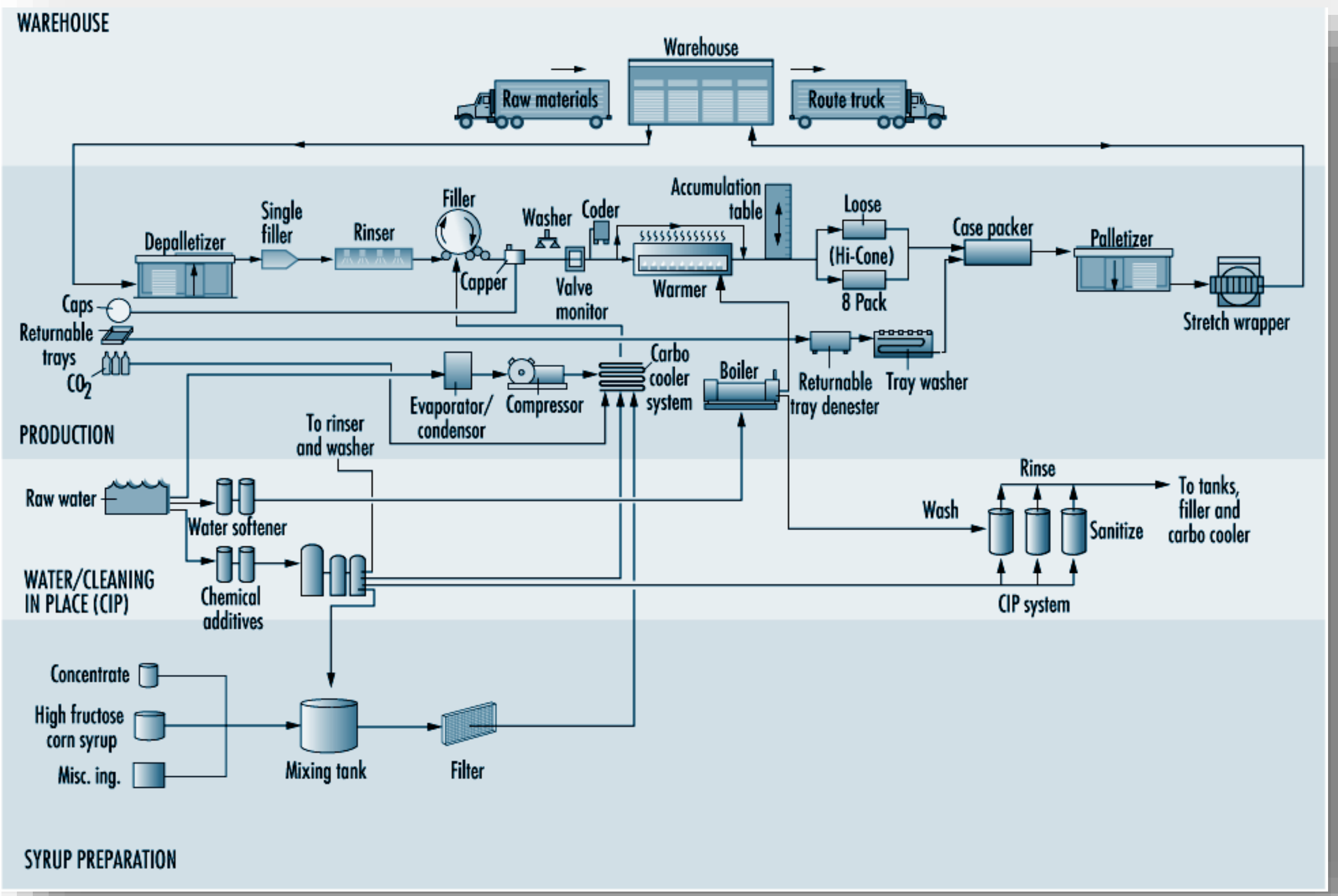
BENEFIT

Few Flow Diagram Of Food Industry –Automation



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BENEFIT

Few Images Of Automation In Food Industry

Few Images Of Automation In Food Industry

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BENEFIT

Few Images Of Automation In Food Industry

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BENEFIT

Smart Application in Food Industry

Ch.5 Novel Non thermal Food Processing

Mr. Wesam Sammar

الكلية الجامعية للعلوم التطبيقية
University College of Applied Sciences

What is Food Processing?

- **Food processing is the transformation of raw ingredients, by physical or chemical means into food, or food into other forms.**

- **Food processing combines raw food ingredients to produce marketable food products that can be easily prepared and served by the consumer.**

Why it should be processed ?

Food Processing

- Pathogens/ toxin removal
- enables transportation
- Suits our life style
- can also add extra nutrients
- Increases shelf life
- Improves the taste of the food

Traditional Processing

- **Addition of salt, sugars, preservatives, antioxidants, naturally occurring antimicrobial substances .**
- **Also by the processes like drying, freezing, refrigerated storage, smoking, food concentration, canning etc.**



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Why Non-thermal?

- ✓The main problem with the thermal processing of food is loss of volatile compounds, nutrients, and flavor.
- ✓To overcome these problems non-thermal methods came into food industries to increase the production rate and profit.
- ✓The non-thermal processing is used for all foods for its better quality, acceptance, and for its shelf life.
- ✓The new processing techniques are mostly employed to the liquid packed foods when compared to solid foods.
- ✓Since the non-thermal methods are used for bulk quantities of foods, these methods of food preservation are mainly used in the large scale production.
- ✓The cost of equipments used in the non-thermal processing is high when compared used in thermal processing.
- ✓After minimizing the investment costs of non-thermal processing methods, it can also be employed in small scale industries.

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BENEFIT

Novel Food Processing Technologies

- High Pressure Processing
- Microwave heating Pulsed
- Electric Field Pulsed Light
- Technology Ohmic Heating
- Ultrasonics Radiofrequency
- heating Infrared heating
- Pulsed X-rays
- Irradiation
- Oscillating Magnetic Field

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HIGH PRESSURE PROCESSING (HPP)

- **High Pressure Processing is also known as “High Hydrostatic Pressure” or**
- **High pressure processing (HPP) is a promising “non-thermal” technology that has been developed with the aim of obtaining microbiologically safe food products while avoiding undesirable changes in the sensory, physicochemical, and nutritional properties of foods.**
- **HPP has become one of the innovative food processing technologies most accepted by consumers.**
- **In HPP, the product is packaged in a flexible container (usually a pouch or plastic bottle), the food product to be treated is placed in a pressure vessel capable of sustaining the required pressure, the product is submerged in a liquid which acts as the pressure-transmitting medium.**

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- High pressure processing is carried out with intense pressure in the range of 100 – 1000 Mpa with or without heat, allowing most foods to be preserved with minimal effect on taste, texture and nutritional characteristics.

  - Non-thermal processing technology (combination with heat possible)
  - First research in 1890s –milk pathogens
  - First commercialized in Japan in the early 1990s for pasteurization of acid
  - High pressure treated foodstuffs have been marketed in Japan since 1990, in

  Europe and the United States since 1996 and Australia since 2001
- Rapid commercialization since 2000

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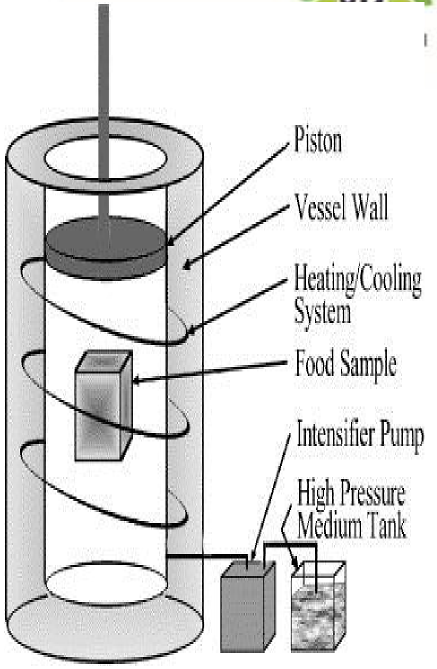
Principle

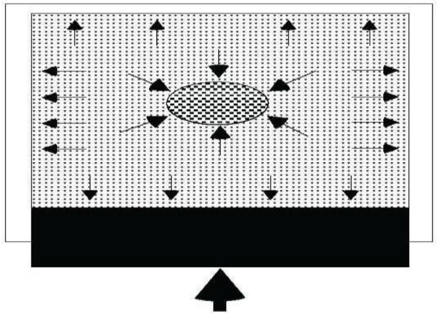
➢ **Le Chatelier's principle: Any phenomenon (phase transition, change in molecular Configuration, chemical reaction) accompanied by a decrease in volume is enhanced by pressure. Accordingly, pressure shifts the system to that of lowest volume.**

➢ **Isostatic principle: high pressure is applied in an "isostatic" manner such that all regions of food experience a uniform pressure, unlike heat processing where temperature gradients are established.**

The food products are compressed by uniform pressure from every direction and then returned to their original shape when the pressure is released. The products are compressed independently of the product size and geometry because transmission of pressure to the core is not mass/time dependant thus the process is minimized

If a food product contains sufficient moisture, pressure will not damage the product at the macroscopic levels as long as the pressure is applied uniformly in all directions

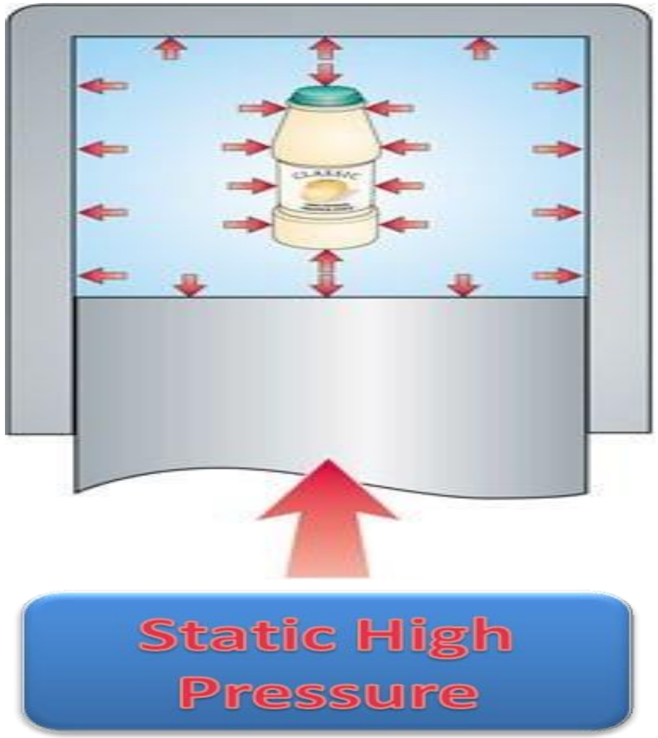




Why High Pressure Processing?

Features:

- Application of high pressures can cause:
➢ Inactivation of Parasites, Plant cells.
➢ Vegetative micro-organisms.
➢ Some fungal spores.
➢ Many foodborne viruses.
➢ Enzymes are selectively inactivated.
➢ Macromolecules can change conformation.
➢ Small molecules (eg: flavors) are generally unaffected
- High pressure is instantaneously and uniformly applied to the sample.
- Compression is fully reversible.



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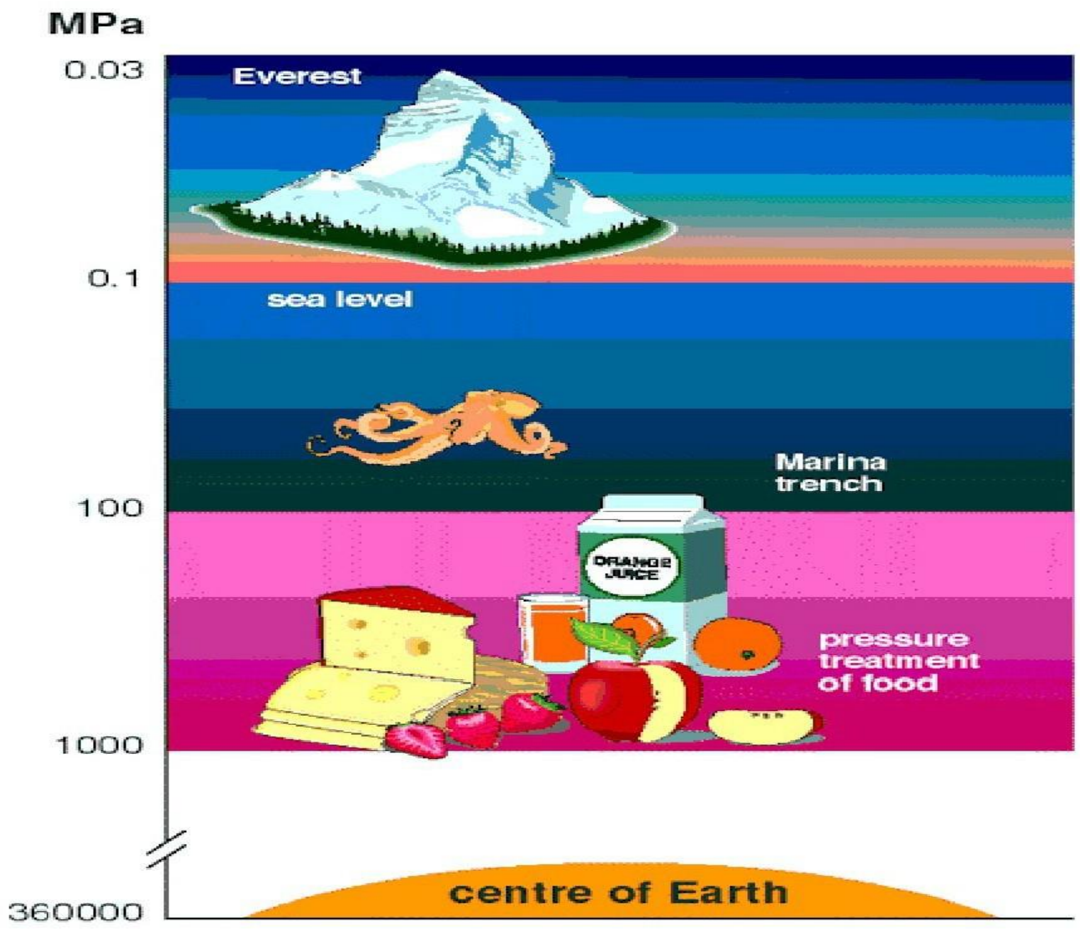
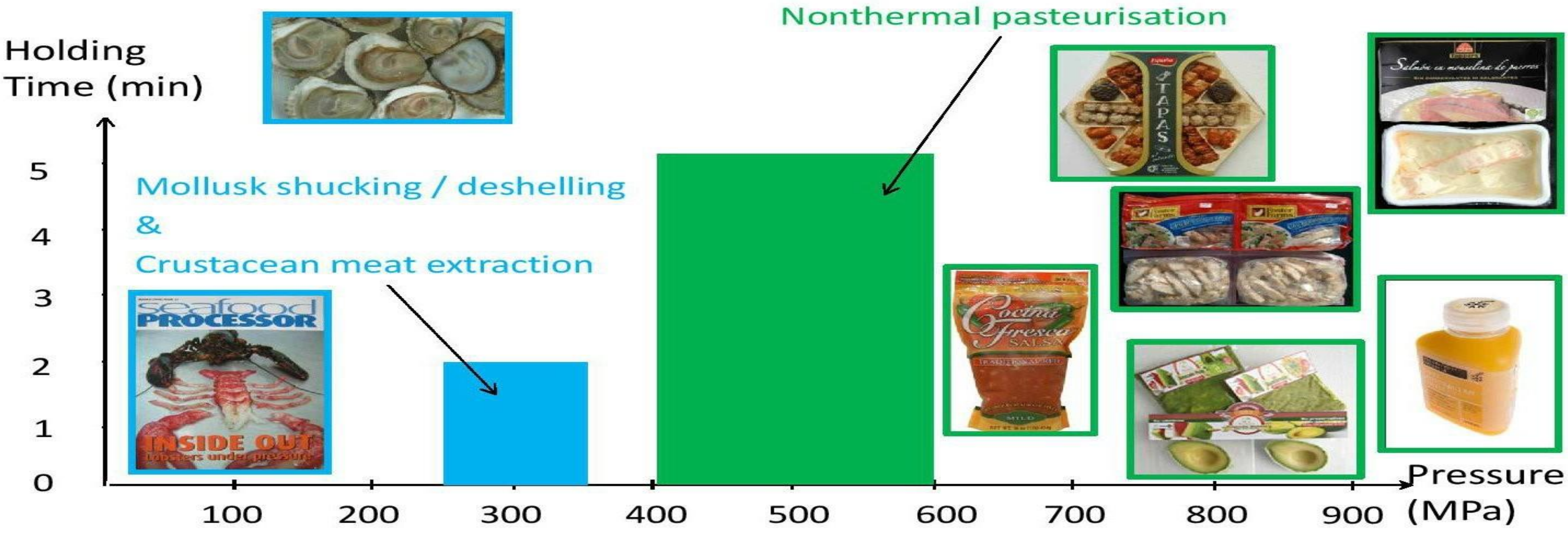
BENEFIT

High Pressure – How much Pressure?

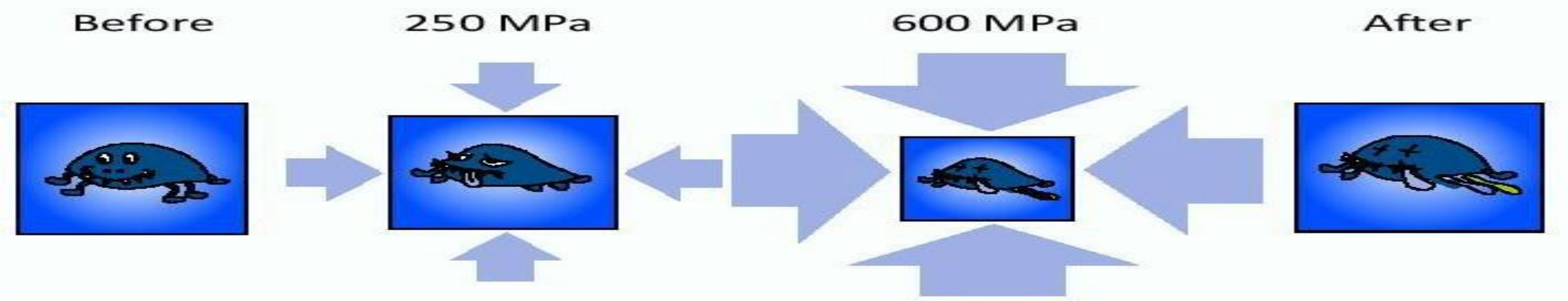
- Pressures altitudes exerted at highest (0.01 to 0.1 MPa) and deepest part of the oceans (10-100 MPa) are usually considered as High pressures.
- For food processing, 200-1000MPa pressure is required.
- For inactivating milk enzymes; alkaline phosphatase and protease about 1000 MPa is needed (as per research articles).
- Usually, 600MPa is the optimum pressure for processing commercial food products.



Pressure & Holding time Combination for HPP



Effect of pressure on microorganisms



High pressure can kill microorganisms by interrupting their cellular function without the use of heat that can damage the taste, texture, and nutrition of the food.

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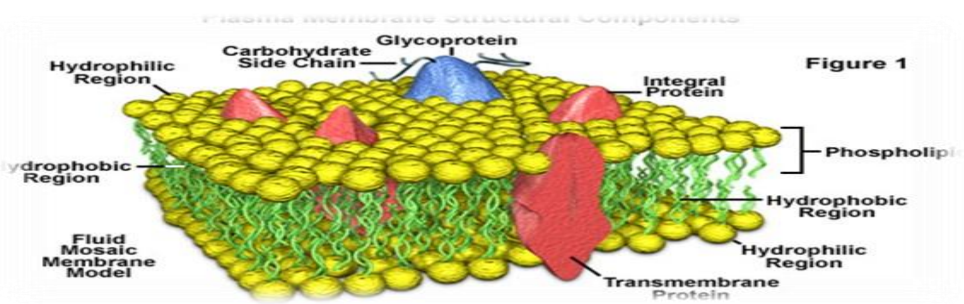
Microbial Efficacy

- Inactivates most vegetative pathogenic and spoilage microorganisms at pressures above 200 Mpa at RT.
- causes damage to cell membranes and denatures intracellular proteins leading to cell death.
- Inactivation of key enzymes, including those involved in DNA replication and transcription is also mentioned as a possible inactivating mechanism.
- The process can also sub-lethally stress or injure bacteria.
- Reduced pH is generally synergistic with pressure in eliminating microorganisms.
- Bacterial spores >Gram positive > Gram negative > Moulds, Yeast (pressure resistant)



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Processing

HPP

HPP systems are available in two types:

- ➢Batch process
- ➢Semi-Continuous process

- **In-container processing:**
- Applied to all solid and liquid foods
- Minimal risk of post processing contamination and Easier cleaning.

- **Bulk processing:**
- Simple material handling
- Great flexible in choice of container

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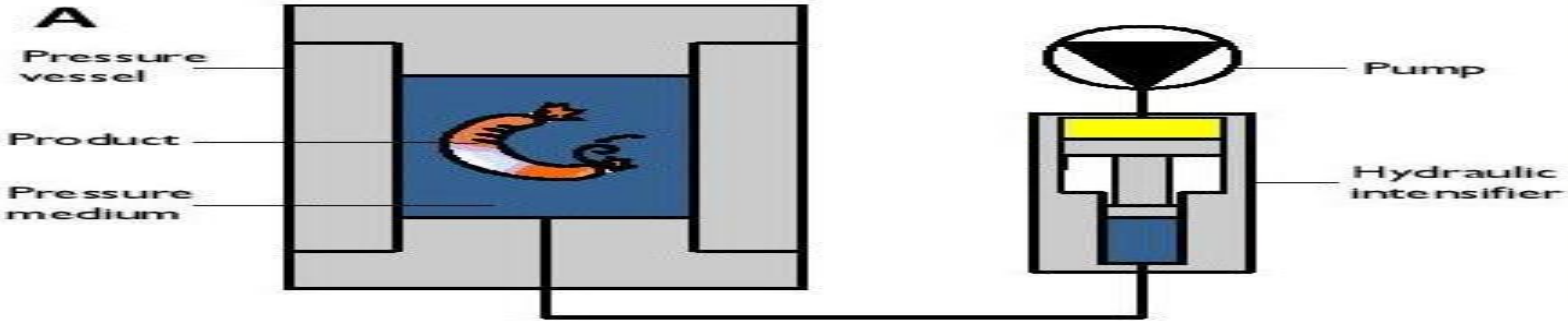
Processing

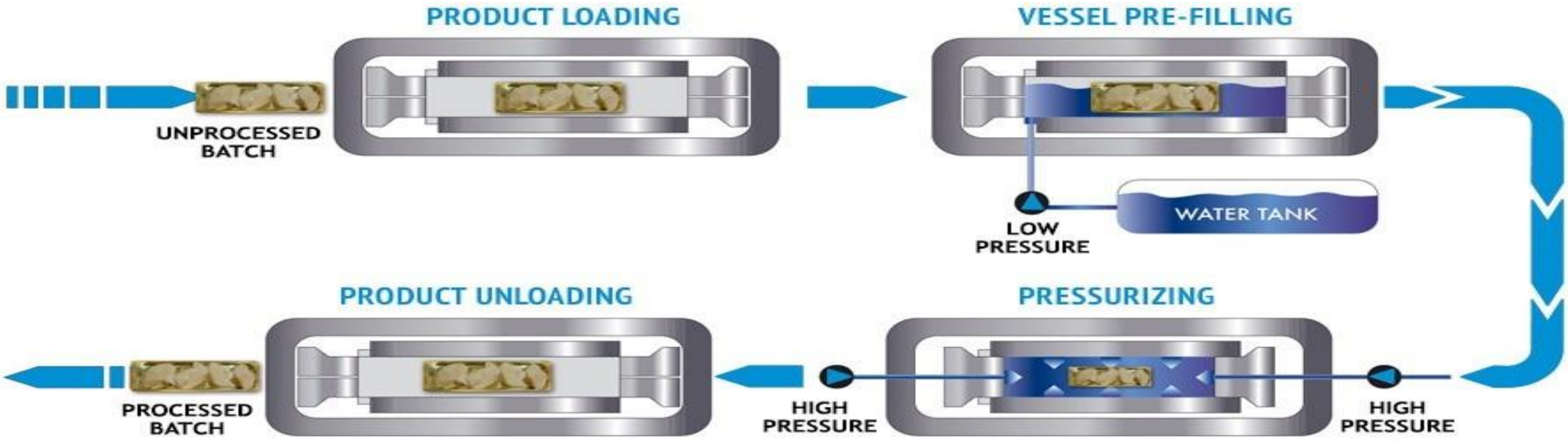
HPP

A typical HPP batch system consists of four/five key components:

1) Pressure vessel
2) High pressure intensifier pump
3) a system for controlling and monitoring the pressure
4)a product-handling system for transferring product to and from the pressure vessel
5)Compressing medium like water, glycol solutions, silicone oil, sodium benzoate



Processing


PRODUCT LOADING
UNPROCESSED
BATCH
VESSEL PRE-FILLING
LOW
PRESSURE
WATER TANK
PRODUCT UNLOADING
PRESSURIZING
PROCESSED
BATCH
HIGH
PRESSURE
HIGH
PRESSURE

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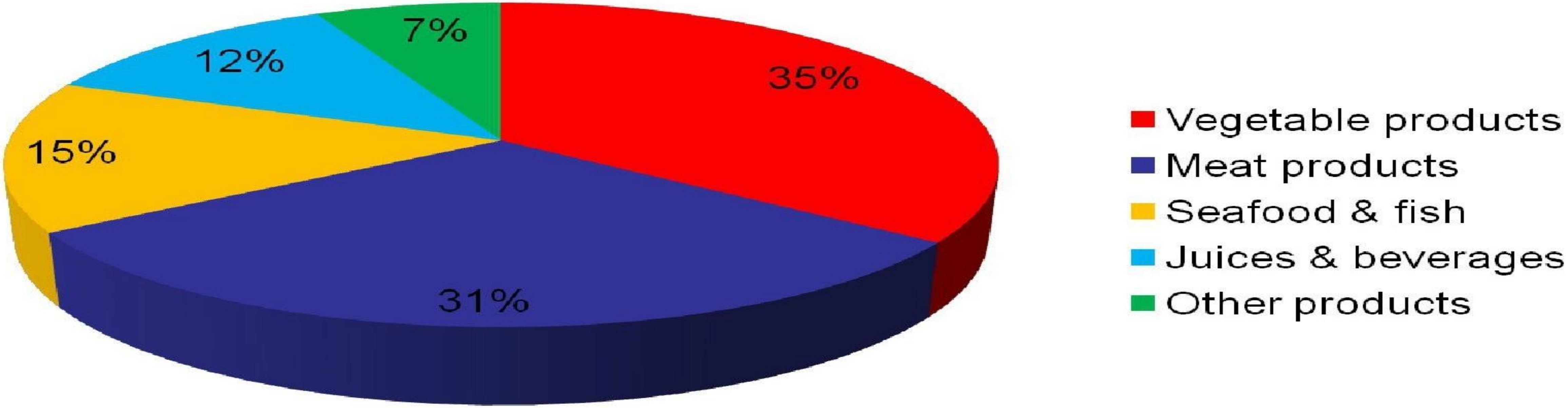
BENEFIT

Product wise application



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Foods suitable for HPP

Low-medium moisture, semi-solid/solid foods, vacuum packaged:

- Dry-cured or cooked meat products
- Cheese
- Fish, seafood, marinated products
- Ready to eat meals, sauces

High moisture, solid foods, vacuum packaged:

- Fruits, marmalades/jams
- Vegetables

High moisture, liquid foods in plastic bottle/flexible packaging:

- Dairy products
- Fruit juices
- Bioactive beverages

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Foods unsuitable for HPP

Solid foods with air included

- Bread and cakes
- Mousse

Packaged foods in completely rigid packaging

- Glass packaging
- Canned foods

Foods with a very low water content

- Spices
- Dry fruits
- Powders

Applications of HPP

Fruits and Vegetables:

➢ Shelf life extension.

➢ Inactivate microorganisms and quality-deteriorating enzymes

➢ Higher sensorial, functional and nutritional values while improving food safety.

➢ Puree, coulis, sauces, juices, smoothies, chunks, slices, ready- to-eat products, these are only some examples of a wide range of fruit and vegetable products that can be processed by HPP.

➢ One of the most successful commercial application of HPP nowadays is definitely preservative-free guacamole (avocado puree with spices) because the process maintains avocado flavor, texture, green color without sacrificing food safety or shelf life (upto 6 weeks under chilled conditions).

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Applications of HPP

Meat and Fish Industry:

- Extends shelf life with no effect on flavor or nutrients.
- Inactivate microorganisms and quality-deteriorating enzymes.
- Maintaining high sensorial and nutritional qualities and improving food safety without the need of additives or artificial preservatives.
- Sliced ham, turkey or chicken cuts, ready-to-eat products, whole pieces of cured ham, these are only some examples of products.
- One of the most successful commercial application of HPP nowadays is easy shell opening of molluscs, easy meat extraction of crustacean products and helps in increasing the yield upto 45%.

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Applications of HPP

Dairy Industry:

- ➢Increased shelf-life (3 to 10 times longer than the same product without HPP stored at same temperature).
- ➢Product Freshness.
- ➢No impact on sensory, nutritional, or functional properties.
- ➢Effective elimination of spoilage and pathogenic microorganisms.
- ➢High Pressure Process Technology works especially well on acidic dairy products such as yogurt because most pressure- tolerant spores are unable to survive in environments with low pH levels. The treatment is very effective on both solid and liquid dairy products. Since high pressure acts quickly and evenly, neither the size of a product's container nor its thickness.

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BENEFIT

Products	Pressure (Mpa) (1-5mins)	Shelf life (at 4 deg C)	Inhibits (pathogens and spoilage)	Advantage
Meat and meat products (sliced, marinated, whole) 31%	500-600	More than 90 days (45 days without HPP)	Listeria, Salmonella , E. coli, moulds , yeast etc.	Effective in eliminating pathogenic micro-organisms.
Dairy products (milk , cheese) 6%	400-600	3-10 times	Yeast , moulds, E. coli etc.	No impact on sensory, nutritional and functional properties
Sea food (Molluska, ready to eat) 16%	350 - 400	2 times	Salmonella, Vibrio, Anisakis etc	Shucking and meat extraction
Fruits and Vegetables (juices , sauces, onions) 47%	400-600	3-10 times	Spoiling microbes (yeast etc) and pathogens.	Healthier food rich in vitamins, minerals etc

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New trends in applications of HPP

HPP is the best option to preserve and respect the functionality of thermosensitive bioactive components present in colostrum such as immunoglobulins, lactoferrin and growth factors.

Physico-Chemical effects of HPP

Effects on Food Color & Flavor:

- Fresh or marinated meat: Iron in the myoglobin changes from ferrous to ferric and globin is denatured-the red color is lost.
- Cooked meat color meat is largely unaffected.
- Cooked meals are not affected.
- Fruits and Vegetables: Slight modification
- Fruit juices: Little or no affect.
- Flavors are mostly unaffected. Effects on Food

Texture:

- Slight softening in foods with cell wall structures. Effects on Fats and

Lipids:

- Reversible crystallization

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Physico-Chemical effects of HPP

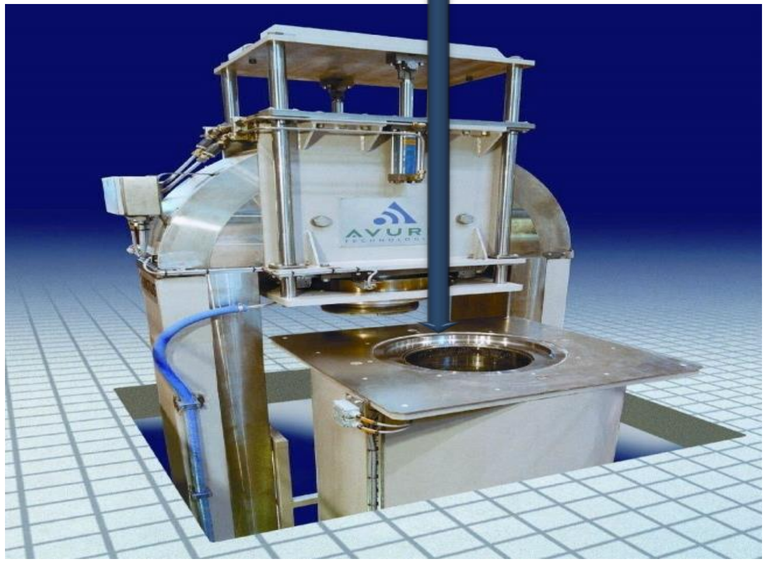
Effects on Proteins and Enzymes:

- ➢Inhibition or stimulation of the enzymatic activity (depending on processing conditions).
- ➢Proteins are partially denatured in products where proteins have not been previously modified by other process such as heating, drying and fermentation etc.
- ➢Pressures affects hydrophobic bonds and electrostatic interactions.
- ➢Pressure denaturation is complex, at pressures >200 Mpa denaturation usually irreversible.

HPP Equipments

HPP equipment are of two types.

- **Horizontal Model**
- **Vertical Model**



HPP Equipments

The standard in HPP industrial equipment:

- ➢ **Horizontal design for traceability and easy installation.**
- ➢ **Special design for food industry (stainless steel, cleanable)**
- ➢ **Automatic loading/unloading system**
- ➢ **Working pressure up to 600 MPa (6000 bar).**

HPP Packaging requirements

- Flexible packaging (>15% volume contraction)
- Extra tight seals.
- Rounded and reinforced edges.
- Minimal head space.
- Modified Atmospheric Packaging (MAP) possible
- Tear strength, puncture resistance and surface smoothness generally not affected by HPP.
- Often flexible pouches or bottles are inserted in secondary cardboard containers after processing.

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HPP Packaging Materials

- Plastic-Laminated Materials
  - Nylon/Coextruded Ethyl Vinyl Alcohol (EVOH)
  - Nylon/pp
  - Nylon/ Aluminum Oxide (ALOx) /CPP
  - PET/PE
- Aluminum foil-Laminated Pouches
  - PET/Al/PP
  - Nylon/Al/PP
- Deposited coatings of Silicon Oxide (SIOx) Blenders of polymers
- Nano composite materials

Nylon

Coextruded EVOH

Aluminum Foil

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HPP Regulatory Status

- USDA has approved HPP as an intervention method for listeria contaminated pre-packed ready-to-eat (RTE) meat products.
- U.S. Food & Drug Administration (FDA) has accepted the commercial use of HPP for application of low acid foods.

USDA FDA

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Uses

- **Increased product shelf life: even for food which is sensitive to heat**
- **Low-temperature preservation method: no loss in product quality compared to heat pasteurization.**
- **Enhanced food safety: due to inactivation of spoilage organisms and relevant food borne pathogens**
- **Processing in final consumer packaging is possible, free preservation of food by using only pressure**
- **Production of “natural”, safe, value-added food with a superior quality**
- **Homogenous effect of HPP: Results are independent of product size and geometry**
- **Further benefits like large yield increase compared to traditional processes .**

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Conclusion

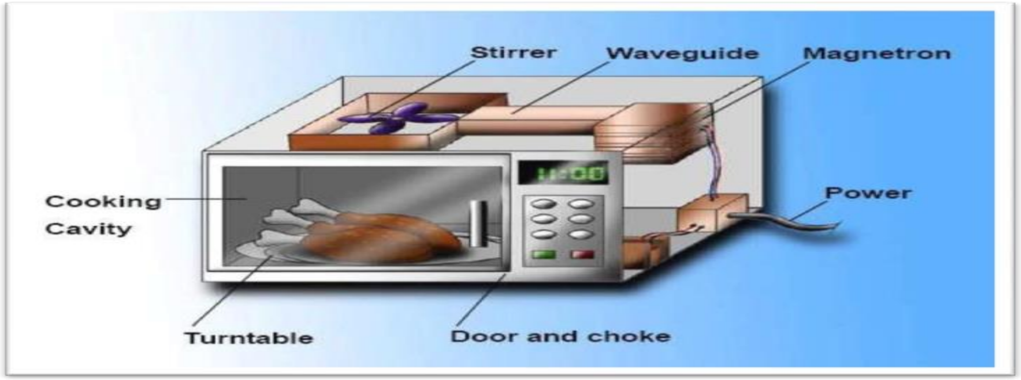
- Consumers: HPP is a consumer acceptable, environmental friendly, scientifically recognized method to achieve higher quality in certain foods
- Processing: Pressure transmission is instantaneous, uniform, short processing times, assured safety in whole pack, suitable for solids and liquids
- Quality: Retains flavor and nutrition
- Environmentally: Safe and no process by-products, no emissions
- Packaging: Package design, geometry and format should be

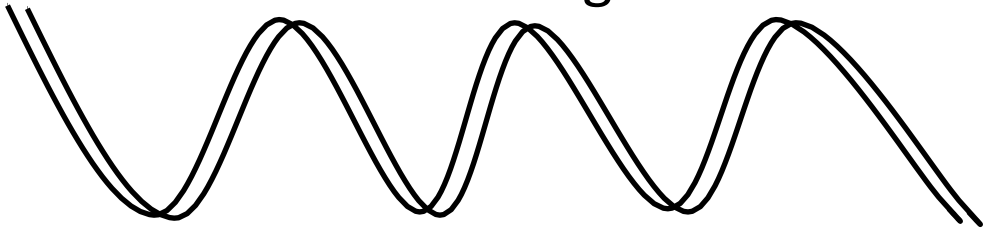
  tailored for HPP, Packaging generally films and laminate structure MAP survive HPP well, but and HPP at high temperature can cause delamination and defects.

Microwave Heating

- Refers to the use of electromagnetic waves of

- certain frequencies (2450MHz and 915MHz) to generate heat in material.
- Container with food is placed in a microwave oven
- And then a oven is activated, the food at the edge of the container heats faster and a temperature gradient develops between the centre and the edges





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Mechanism

✓ **Dipolar interaction:**

- **Polar molecules such as water molecules (dipole) inside the food will rotate according to the alternating electromagnetic field.**
- **The rotation of water molecules would generate heat for cooking**

✓ **Ionic interaction:**

- **Ionic compounds (i.e. dissolved salts) in food can also be accelerated by the electromagnetic field and collided with other molecules to produce heat**

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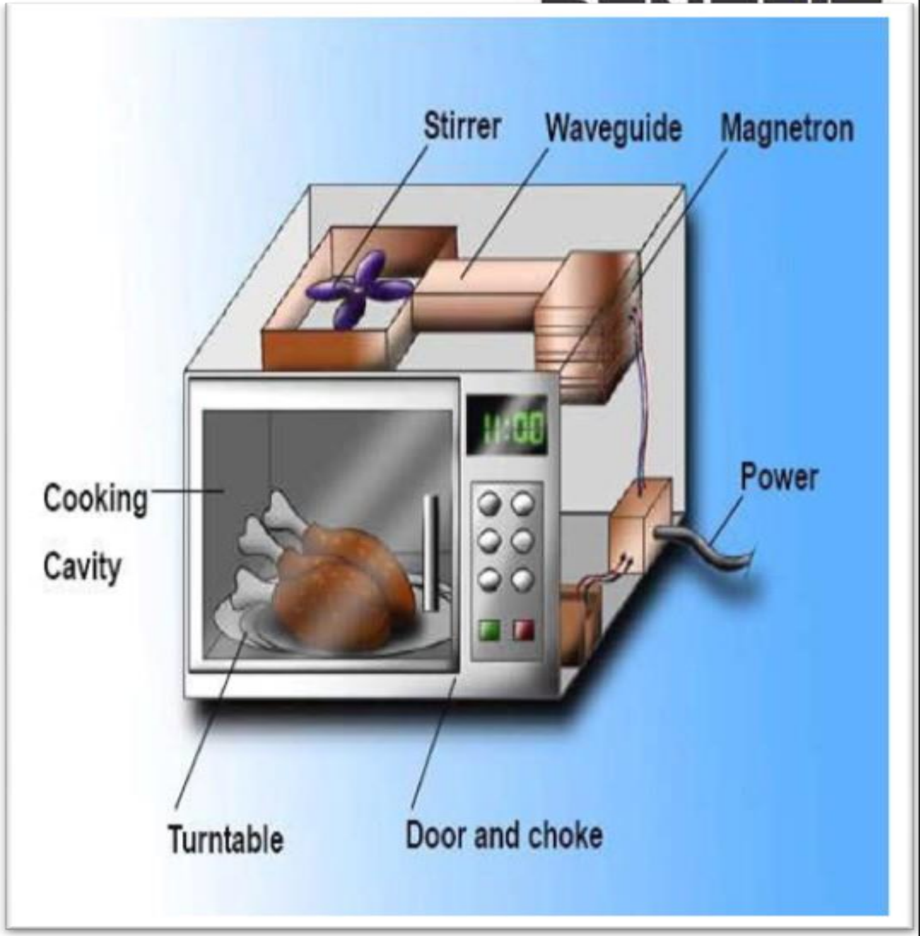
Basic Components

- **Power supply and control: It controls the power.**
- **Magnetron: It is a vacuum tube in which electrical energy is converted to an oscillating electromagnetic field.**
- **Waveguide: It is a rectangular metal tube which directs the microwaves generated from the magnetron to the cooking cavity.**
- **Stirrer: Distribute microwaves from the waveguide and allow more uniform heating of food.**
- **Turntable: It rotates the food products through the fixed hot and cold spots inside the cooking cavity.**
- **Cooking cavity: It is a space inside which the food is heated when exposed to microwaves**
- **Door and choke: The door and choke are specially engineered that they prevent microwaves from leaking through the gap between the door and the cooking cavity.**



Materials:

✓ Plastic containers, high density polyethylene, papers and boards.

Application:

✓ Baking, concentration, cooking, curing, drying, finish drying, freeze drying, pasteurising, sterilizing, tempering and thawing.

PULSED ELECTRIC FIELD (PEF) TECHNOLOGY

- **PEF is a non-thermal food preservation technology that involves the discharge of high voltage electric pulses (up to 70 kV/cm) into the food product, which is placed between two electrodes for a few microseconds.**
- **An external electric field is used to exceed a critical transmembrane potential of one volt.**
- **This result in a rapid electric breakdown and conformational changes of cell membranes, which leads to the release of intracellular liquid, and cell death.**
- **PEF treatment shows changes in tissue structure leading to weight increase and greater water holding capacity and less loss during cooking.**

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Mechanisms of Microbial Inactivation

Electrical Breakdown:

- **The normal resisting potential difference across the membrane is 10 mV and is proportional to the field strength and radius of the cell. The increase in the membrane potential leads to reduction in the cell membrane thickness.**

Electroporation:

- **The plasma membranes of cells become permeable to small molecules after being exposed to an electric field, and permeation then causes swelling and eventual rupture of the cell membrane**

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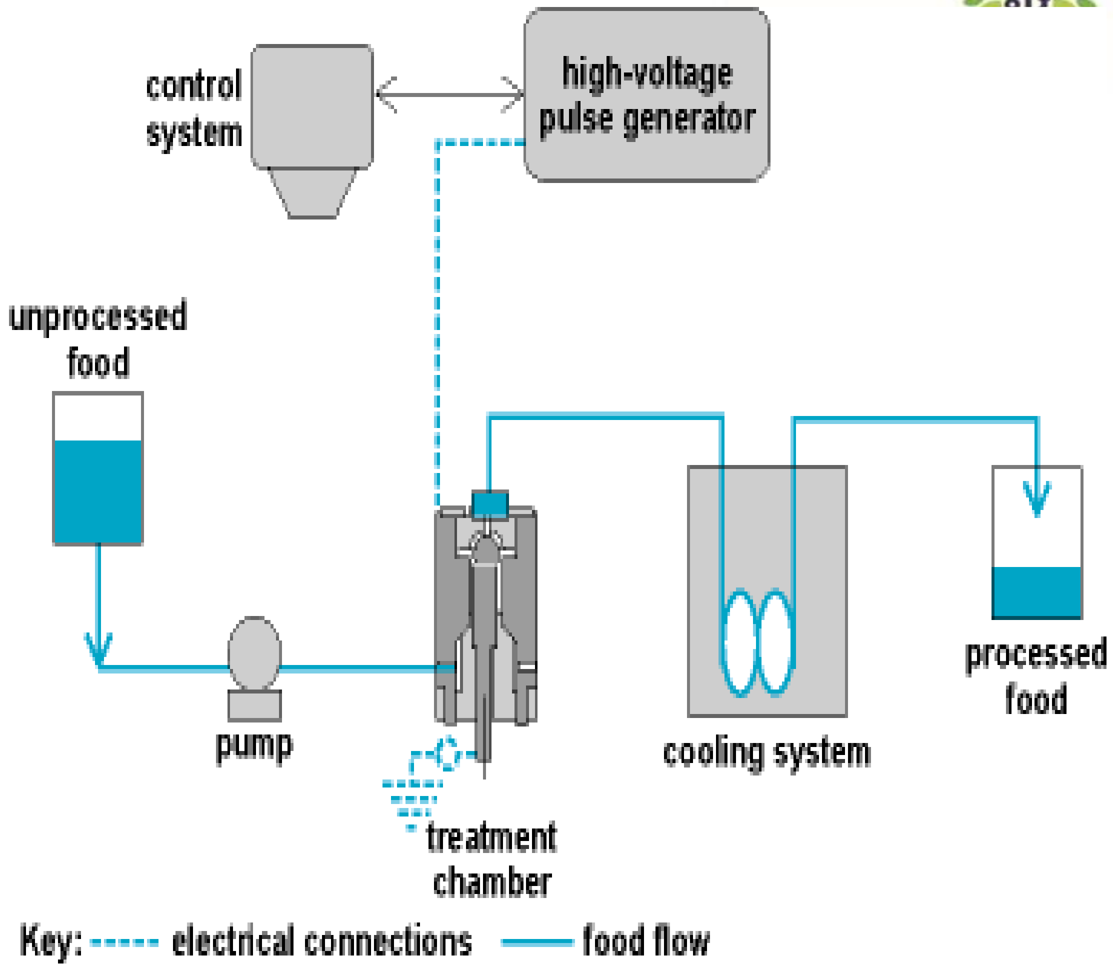
- A power supply: this may be an ordinary direct current power supply or a capacitor charging power supply.
- An energy storage element: either electric (capacitive) or magnetic (inductive).
- A switch which may be either closing or opening.
- A pulse shaping and triggering circuit in some cases.
- A treatment chamber: a wide variety of designs have been developed.
- A pump to supply a feed of product to the chamber.
- A cooling system to control the temperature of the feed and/or output material



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Applications:

PEF is used in processing of apple juice, orange juice, processing of milk, liquid whole eggs, baking applications and processing of green pea soup.

Advantages:

- Kills vegetative cells.
- Colours, flavours and nutrients are preserved.
- Short treatment time

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Pulsed Light (Or) High Intensity Light Technology

- High Intensity Light Technology can be used for the rapid inactivation of microorganisms on food surfaces, equipments and food packaging materials.
- light wave lengths ranging from ultra violet to near infra-red in short intense pulse.
- Pulses of light used for food processing applications typically emit one to twenty flashes per second of electromagnetic energy
- The principle involved in generating high intensity light is that a gradual increase of low to moderate power energy can be released in highly concentrated bursts of more powerful energy
- The key component of a Pulsed Light unit is a flash lamp filled with an inert gas
- A high-voltage, high-current electrical pulse is applied to the inert gas in the lamp, and the strong collision between electrons and gas molecules cause excitation of the latter, which then emit an intense, very short light pulse
- It is generally accepted that UV plays a critical role in microbial inactivation.
- The treatment is most effective on smooth, nonreflecting surfaces or in liquids that are free of suspended particulates.
- In surface treatments, rough surfaces hinder inactivation due to cell hiding.

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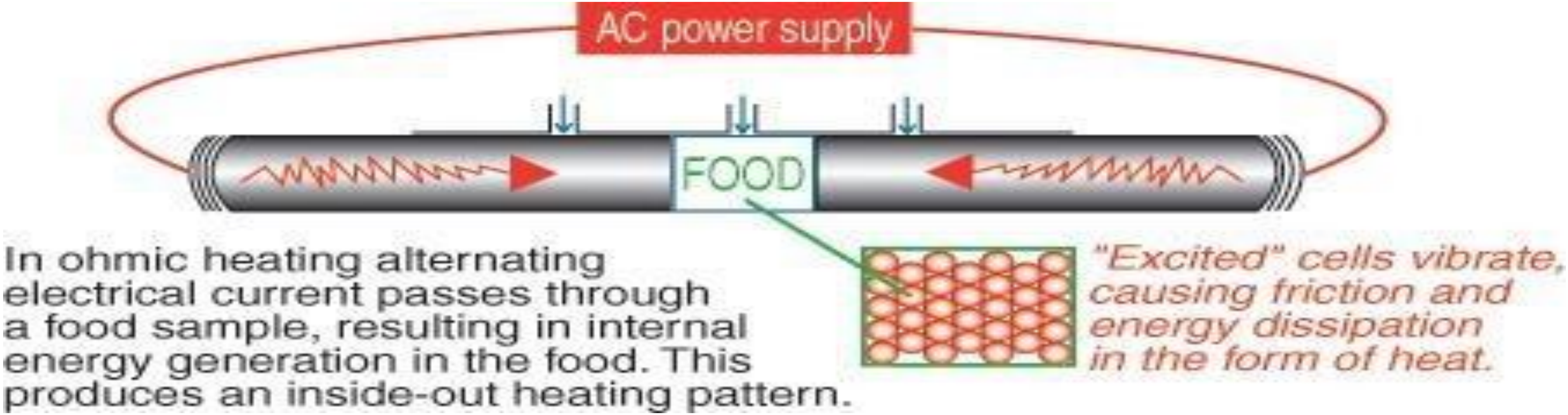
Ohmic heating

- **Ohmic heating is an advanced terminal processing method wherein the food material which serves as an electrical resistor, is heated by passing electricity through Which result in rapid & uniform heating**
- **Electrical resistance heating or joule heating or electro-heating**



Important benefits

1. Fast Processing
2. Homogeneous Treatment
3. More effective method

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BENEFIT

Smart Application in Food Industry

Ch 6 Active Packaging Technology

Mr. Wesam Sammar

University College of Applied Sciences

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PACKAGING

- Packaging is the technology of enclosing or protecting products for distribution, storage, sale, and use
- Packaging maintains the benefits of food processing after the process is complete, enabling foods to travel safely for long distances from their point of origin and still be wholesome at the time of consumption.
- The primary purpose of food packaging is to protect the food against attack from oxygen, water vapour, ultraviolet light, and both chemical and microbiological contamination.

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Functions of Packaging

- product containment
- preservation and quality
- presentation and convenience
- protection during Distribution and Processing
- provide storage history

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BENEFIT

ACTIVE PACKAGING

- Active packaging refers to the incorporation of certain additives into packaging film or within packaging containers with the aim of maintaining and extending product shelf life.

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USES

- to preserve the quality of food during the shelf life
- to increase the food safety
- to extend the shelf life of the product
- to decrease the food loss
- to reduce use of food additives
- as a marketing tool
- to develop new products

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TYPES OF ACTIVE PACKAGING

- Sachets and pads which are placed inside of packages, and active ingredients that are incorporated
- Directly into packaging materials.

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BENEFIT

Sachets and Pads

❖ Kept inside the Packets

Disadvantages

- cannot be used in liquid foods.
- cannot be used in package made of flexible film, as the film will cling to the sachet and prevent it from performing its function.
- risk of accidental ingestion by consumers

Materials Containing Active Components

- incorporating the scavenger into the packaging material itself

- More efficient

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APPLICATIONS

1. Oxygen Scavengers
2. Carbon Dioxide Generating System
3. Ethylene Scavengers
4. Flavour and Odour Absorber/Releaser
5. Antioxidants
6. Humidity Control
7. Antimicrobial Packaging

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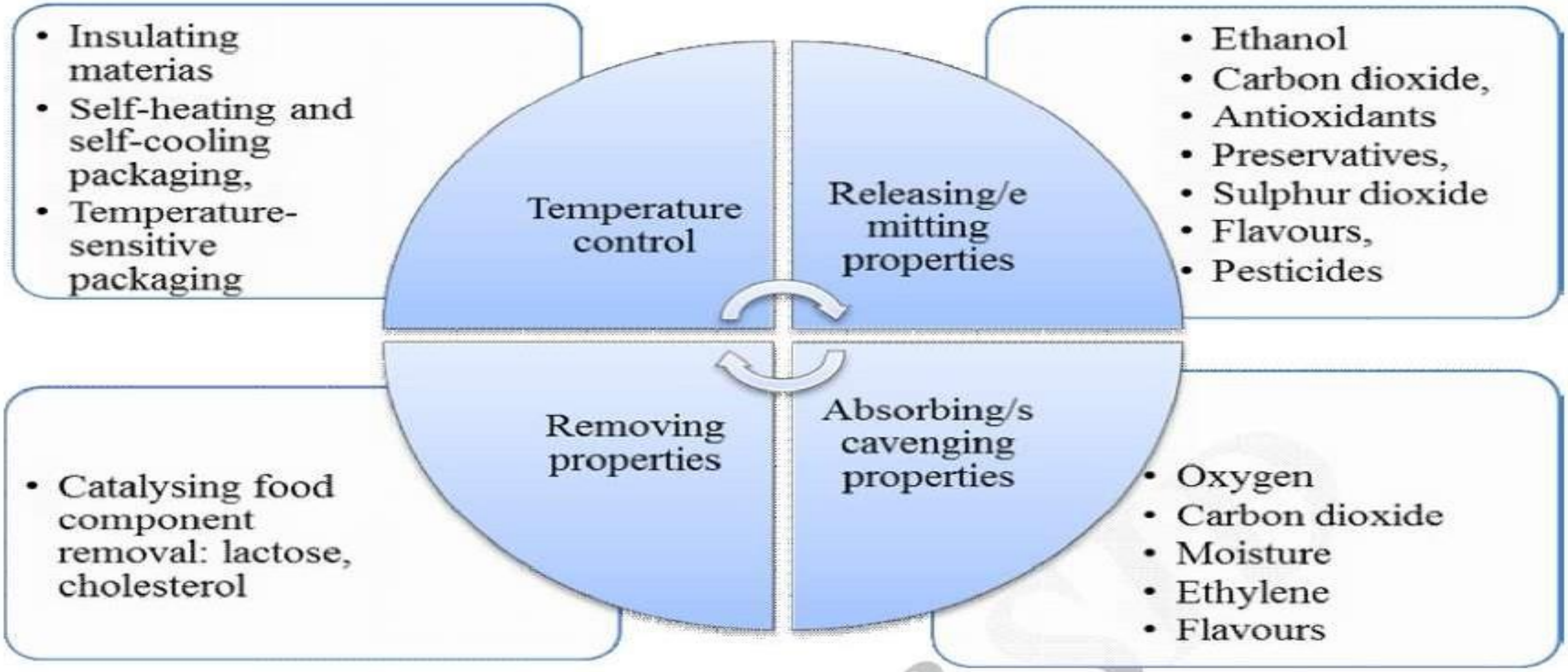

Fig.1. Examples of active packaging applications for use within the food industry.

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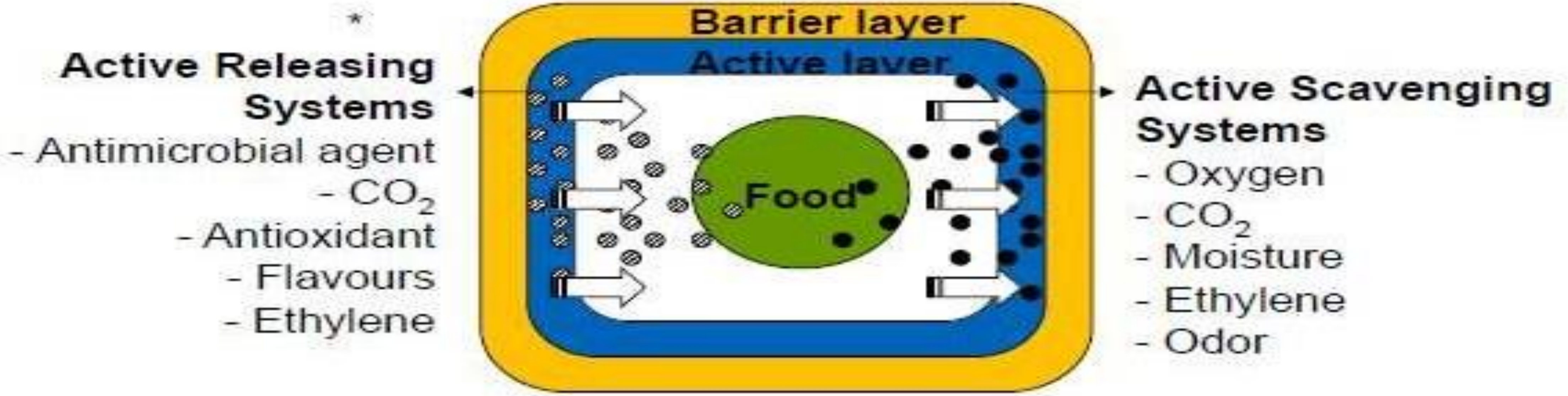
BENEFIT



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BENEFIT

Oxygen Scavengers

- presence of oxygen in food packages

-accelerates the spoilage of many foods.

-cause off-flavour development

-colour change

-nutrient loss

-microbial attack

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Mechanisms of action of Oxygen Scavengers

- a.) Oxidation of iron and iron salts
  - oxidation of iron and ferrous salts (provided in the packet) that react with water provided by food to produce a reaction that moisturizes the iron metal in the product packaging and irreversibly converts it to a stable oxide.
  - The iron powder is contained within small oxygen permeable bags that prevent contact with food.

$$4Fe(OH)_2 + O_2 + 2H_2O \rightarrow 4Fe(OH)_3$$

- b.) Oxidation of ascorbic acid and unsaturated fatty acids (oleic, linoleic).

- c.) Oxidation of photosensitive colouring matter.

- d.) Enzymatic oxidation by Glucose oxidase

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TYPES

❖ OXYGEN SCAVENGERS

- materials incorporated into package structures that chemically combine with, and thus effectively remove, oxygen from the inner package environment
    - eg:- ferrous compounds, catechol, ascorbic acid and its analogues, ligands, oxidative enzymes such as glucose oxidase, unsaturated hydrocarbons and polyamides

❖ OXYGEN INTERCEPTORS

- blocks the adverse effect of oxygen in the air on the food, before the oxygen can enter the food.

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❖OXYGEN ABSORBERS

- absorbers remove oxygen by physically trapping the oxygen and not through chemical reaction

❖ANTIOXIDANTS

- compounds that react with lipid or peroxide radicals or, in light, with singlet oxygen, and that are themselves oxidized to generate what are generally innocuous nontoxic compounds
    - BHA—butylated hydroxyanisole
    - BHT—butylated hydroxytoluene
    - PG—propyl gallate

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ADVANTAGES

BENEFIT

- prevent oxidation phenomena: rancidification of fats and oils and consequent emergence of off-odours and off-flavours, loss or change of colours characteristic of food, loss of oxygen-sensitive nutrients
- prevent the growth of aerobic microorganisms.
- reduce or eliminate the need for preservatives and antioxidants
- slow down metabolism of food.

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Carbon Dioxide Generating System

- High level of CO_2 (10-80%) inhibits surface microbial growth and extends shelf life

- EXAMPLES

1. ferrous carbonate
2. mixture of ascorbic acid and sodium bicarbonate

- Fresh meat, poultry, fish, cheeses and strawberries

Ethylene Scavengers

- A chemical reagent, incorporated into the packaging film, traps the ethylene produced by ripening fruit or vegetables.
- pink colour-indicator of the extent of reaction and shows when the scavenger is used up.

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BENEFIT

- apples, bananas, mangos, tomatoes, onions, carrots.

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Examples

- activated alumina, vermiculite, and silica gel that have been impregnated with potassium permanganate (KMnO4).
- Activated charcoal alone or after impregnation with bromine.
- bentonite, Kieselguhr, and crystalline aluminosilicates, e.g., zeolites, have been reported capable of adsorbing ethylene

Flavour & Odour Absorber/Releaser

- Addition of essences and odours
  - increase the desirability of the food to the consumer
  - improve the aroma of fresh product itself
  - enhance flavour of food when the package is opened.

- flavours and aromas are released slowly and evenly in the packaged product during its shelf life or release can be controlled to occur during opening the package or food preparation.

- Gradual release of odours can offset the natural loss of taste or smell of products with long shelf lives

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BENEFIT

Examples

- substantial quantities of limonene could be removed by acetylated paper, following earlier work involving cellulose acetate gel beads
- unpleasant smelling volatile amines, such as trimethylamine, associated with fish protein breakdown are alkaline and can be neutralised by various acidic compounds

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Antioxidants

- The oxidation of lipids in food leads to
  - reduction in shelf-life due to changes in taste and odour
  - deterioration of texture & functionality of muscle foods
  - reduction in nutritional quality
- avoided by use of oxygen scavengers and antioxidant agents in the packaging.
- oxidation can be avoided by eliminating radicals(oxo, hydroxyl, and superoxide) as soon as they are formed.

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BENEFIT

Examples

- A varnish with natural antioxidant of rosemary
- Antioxidant active film- conservation of fresh meat
  - enhance the stability of myoglobin and fresh meat against oxidation processes.

- Migration of α-tocopherol
  - delay in lipid oxidation in whole milk powder

- . Antioxidants can be used for oil, nuts, butter, fresh meat, meat derivatives, bakery products, fruits and vegetables.

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Humidity Control

- Condensation or 'sweating' is a problem in many kinds of packaged fruit and vegetables.
- When the condensation inside packages is controlled, the food remains dry without drying out the product itself.
- sensitive products such as flowers and table grapes
  – reduce growth of meld.

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Examples

- Silica gels

- Molecular sieves (Zeolites)

- Cellulose fibre pads (Soaker pads) in the bottom of meat, poultry, and fresh produce trays.

Antimicrobial Packaging

- prevents growth of micro-organisms

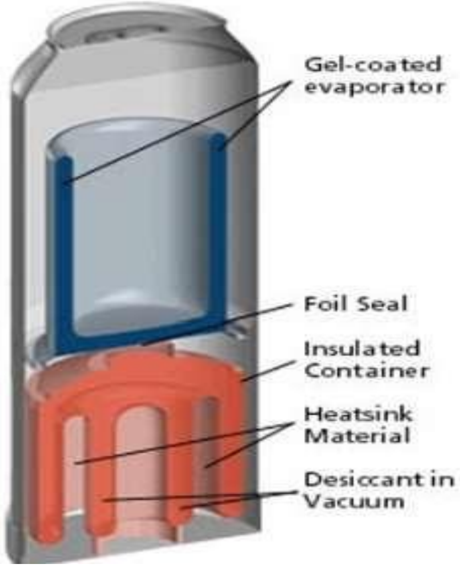
❖ EXAMPLES

- ethanol, carbon dioxide, silver ions, chlorine dioxide, antibiotics, organic acids, essential oils and spices, etc

- Packaging systems that release volatile antimicrobials also include chlorine dioxide, plant extracts, sulphur dioxide, essential oils, carbon dioxide release systems

- classified into two types:
- those containing antimicrobial agents that migrate to the surface of the package material and thus can contact the food,
- those that are effective against food surface microbiological growth without migration of the active agent(s) to the food.

Self Heating Packaging



Self Cooling Packaging

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Active Packaging –The Future

These packaging technologies anticipated to grow significantly over the next 10 years, due principally to:

- Consumer demands for meat and other food products which are premium qualities and which provide adequate shelf-life, safety, convenience and information
- Reduction in packaging material costs as formats grow in popularity/sales volume, and as newer and cheaper formats emerge through research and development

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- Greater demands by retailing outlets for extended product shelf-life

- Concerns regarding product authenticity and bio-terrorism

- Growing efforts to reduce unnecessary product/package wastes

University College of Applied Sciences

Organisation: **Hebron University**

Course title: Poultry Production & Management (52240)

Course type: **Developed course**

Disclaimer

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BENEFIT

Environmental Management In Broiler Houses

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Economic Value of Proper Environmental Management

- It is well established that effectively managing environmental conditions reduces the cost of production.

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Environmental Management Objective & Methods

- Supplemental heating is important during the brooding phase, but adequate ventilation is necessary & required throughout the whole growing period.
- Thus, ventilation is the most important tool in managing the in-house environment for best bird performance.
- The primary goal of ventilation in hot weathers is to control temperature in poultry houses while its goal is to prevent wet, caked litter and ammonia problem in winter.

Environmental Management Objective & Methods

- At each stage of the bird development, there is one optimum performance temperature zone in which the bird makes best use of feed energy for growth.
- Within this broad "thermal comfort zone" there will be a narrow temperature range (within 2 or 3 C) in which the bird makes best use of feed energy for growth. This is the optimum performance zone.
- Providing this optimum temperature – along with adequate feed and water – assures that the bird's welfare and economic performance are maximized.
- If the temperature is too low, birds increase their feed intake but have to use more of that feed energy to keep their bodies warm. If temperature is too high, they reduce feed intake to limit heat production.

Environmental Management Objective & Methods

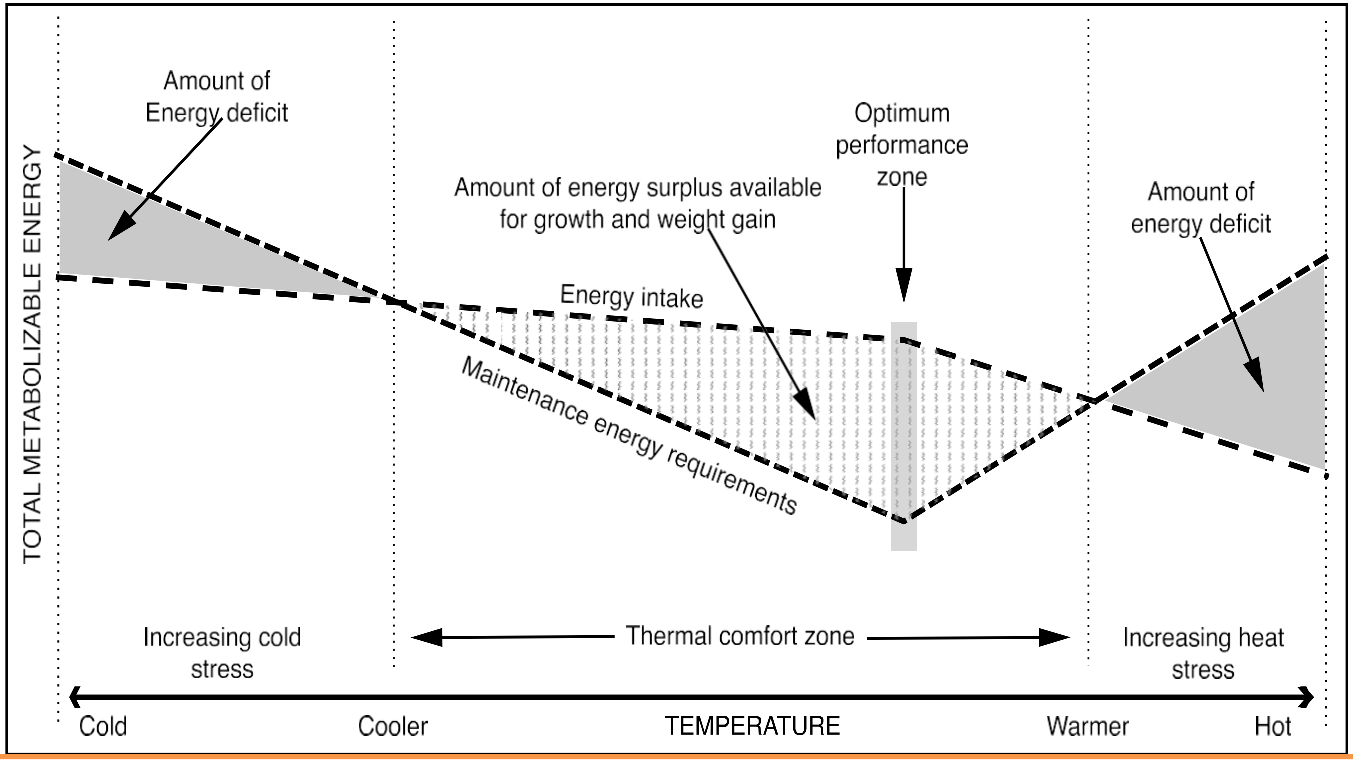

Figure 1. Optimum Performance Temperature Zone – At each stage of a bird's development, there is one narrow temperature range where maintenance energy requirements are lowest and the bird can make maximum use of feed energy for growth. If temperature goes just a few degrees outside the optimum performance zone, cooler or warmer, birds will be using a higher proportion of their feed energy for body maintenance and less for growth.

Environmental Management Objective & Methods

- Adequate ventilation prevents heat build-up and keeps birds in their optimum performance zone, first by exhausting warm air from the house and replacing it with cooler outside air, and in most well-equipped modern housing by effective (wind-chill) cooling through tunnel ventilation, and by lowering the actual air temperature through evaporative cooling.
- The target temperature for best broiler performance changes daily during the growing period. Thus, ventilation must be adjusted accordingly.

(35C at Day 1 to 24C at Marketing, Assuming RH 60-70%)

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Environmental Management Objective & Methods

- At all stages, monitor bird behavior to ensure that the bird is experiencing adequate temperatures.
- Proper in-house environment must be uniform: pockets of dead air, drafts, cold spots, or hot spots can lower flock performance.

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Economic Benefits of Environmental Control

- Birds most efficiently convert feed to meat when they are given consistently optimum environmental conditions, with temperature being the most critical factor.
- Small temperature differences can have a significant effect on returns to the owner.
- During the brooding phase, even brief chilling can seriously hurt flock performance.
- For example, university research in the United States showed that exposing day-old chicks to an air temperature of 12.8C° for only 45 minutes reduced 35-day weights by about 113 gm. After the brooding phase, bird performance is more quickly hurt by high than by low temperature.

Climatic Factors In-Housing & Ventilation Decsions

- The major factor influencing type or style of housing is climate.
- Different climatic conditions call for different ventilation and heating strategies, and affect the possible or desirable bird stocking density.
- Generally, extreme conditions require more and more sophisticated inside environmental control equipment and management.
- Where seasonal variations in weather are pronounced, a house may require ventilation systems for hot and cold weather.

Climatic Factors In-Housing Ventilation Decisions

- In a given situation, housing and ventilation choices must be based on calculating the benefits of providing technology to cope with:

1. Prevailing weather, or prevailing seasonal weather – that is, conditions which generally persist over at least several months; and
2. Weather extremes likely to be encountered.

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Extremally Cold Climates

- In extremely cold climates, dry conditions may cause birds to lose more heat; temperature setpoints may need to be higher, but minimum ventilation must be maintained.
- During extreme cold conditions, managers are often tempted to reduce ventilation time to reduce fuel costs. This can be a serious mistake, since performance losses caused by inadequate cold-weather ventilation can outweigh additional fuel costs.

Cold Climate

- In areas of pro- longed winter temperatures consistently below 50°F and with moderate summer temperatures, tunnel ventilation and evaporative cooling are not usually needed to cope with bird heat.
- In cold climates ventilation is needed to help prevent excessive moisture build-up in the poultry house.
- Houses typically will need a “minimum ventilation” setup augmented with additional fan (and air inlet) capacity to exhaust bird heat during warm weather.

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Moderate Climate

- Even in moderate climates, tunnel ventilation is usually recommended if temperatures consistently rise into or above 75-86°F range.
- Tunnel ventilation provides high–volume, rapid house air exchange and a high velocity “wind chill” air flow which gives a somewhat lower effective temperature experienced by the birds.
- As temperatures rise into the 95°F range, the wind chill effect begins to disappear, and evaporative cooling must be added to provide actual air temperature reduction.

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Hot Climate

- Higher bird densities can usually be maintained reliably even in very hot climates by tunnel ventilation with evaporative cooling.
- In tropical or subtropical areas where temperatures are consistently in the 95- 100°F range, high density housing and open sided, naturally ventilated housing are generally not feasible.
- In hot climates with low humidity (such as high altitude desert facilities) the low humidity contributes to ascites and lowers growth rate.
- The combination of high humidity and high temperature is particularly difficult for birds. However, in properly designed tunnel ventilated houses the effects of humidity are minimized over naturally ventilated housing.

How Birds Work & What They Need?

- Early in the growing period, the main concern usually is keeping birds warm enough. As the birds grow, too much warmth is a more common problem.

Birds Produce Heat & Moisture

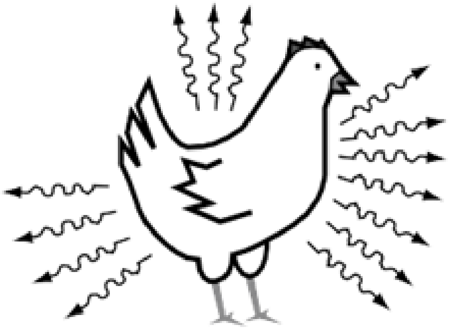
- Large numbers of birds contribute large amounts of heat and moisture to a poultry house. In-house

  air temperature and humidity both rise as a growout

  progresses.
- A 20,000 four-pound birds will add around 400,000 Btu’s per hour of heat to the house.
- A 20,000 four-pound birds will add around 1,000 gallons of water to the house per day.

Effect of Temperature & RH on Birds

- Temperature and humidity work together to determine bird comfort, but for simplicity in the following paragraphs we'll look at temperature first, then humidity, and then explain how their interaction affects birds.
- Birds do not sweat and so cannot cool themselves in this way. They shed almost all excess body heat by direct body-to-air heat transfer. In times of heat stress, they begin panting in order to get rid their bodies of more heat.



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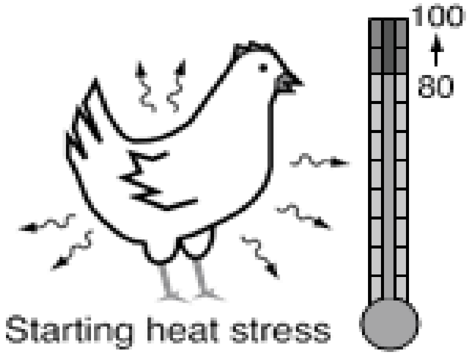
Effect of Temperature & RH on Birds

- If you see birds lifting their wings, they're trying to expose more of their bodies to the air to get rid of excess heat.
- For fully-feathered birds, as the air temperature rises above around 80ºF, birds' heat-shedding ability becomes less effective. As they begin to experience heat stress they slow down or stop eating. If heat accumulation in their bodies isn't stopped, they eventually will die.



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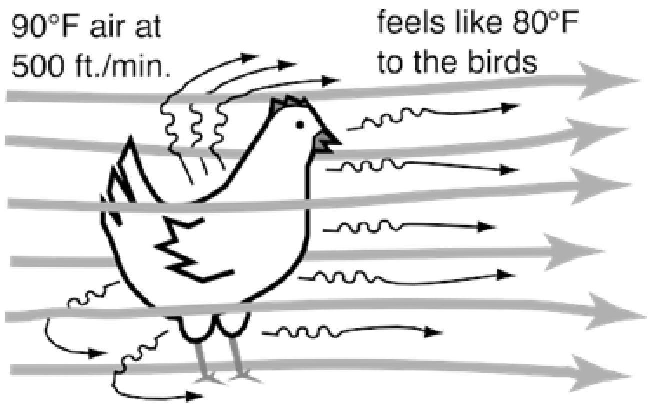
Effect of Temperature & RH on Birds

- For air temperatures up to the low 80°F range, ventilation usually can remove warmed- up in-house air at the proper rate to keep birds within their comfort range.
- Fast-moving air over birds creates a wind-chill effect that can be very beneficial, especially for larger birds. However, younger birds are more sensitive to wind-chill effects and may be chill-stressed.



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Effect of Temperature & RH on Birds

- Keeping birds cool at night helps them stand high daytime heat.
- Birds can tolerate higher day- time temperatures if they are able to cool off during the night. The effect is most pronounced when nighttime temperatures drop 25 degrees F below daytime highs. Running fans at night to move air over the birds can help by reducing the nighttime “effective” temperature.

Effect of Temperature & RH on Birds

- Panting indicates birds are over-heated and are trying to shed additional body heat.
- This cooling method works best when the air is relatively dry. If the air is already holding a great deal of moisture, it can’t readily evaporate the birds’ moisture, and the evaporative cooling effect doesn’t work as well.
- An old rule of thumb says that:
- If RH%+Ambient Temp. in F> 160 or more, then the birds have trouble shedding their excess body heat.
- Example, (70% RH+ 85F = 155) the birds will be reasonably comfortable. But if the relative humidity goes to 80% (85 + 80 = 165), you’re likely to be losing feed efficiency because of overheating.

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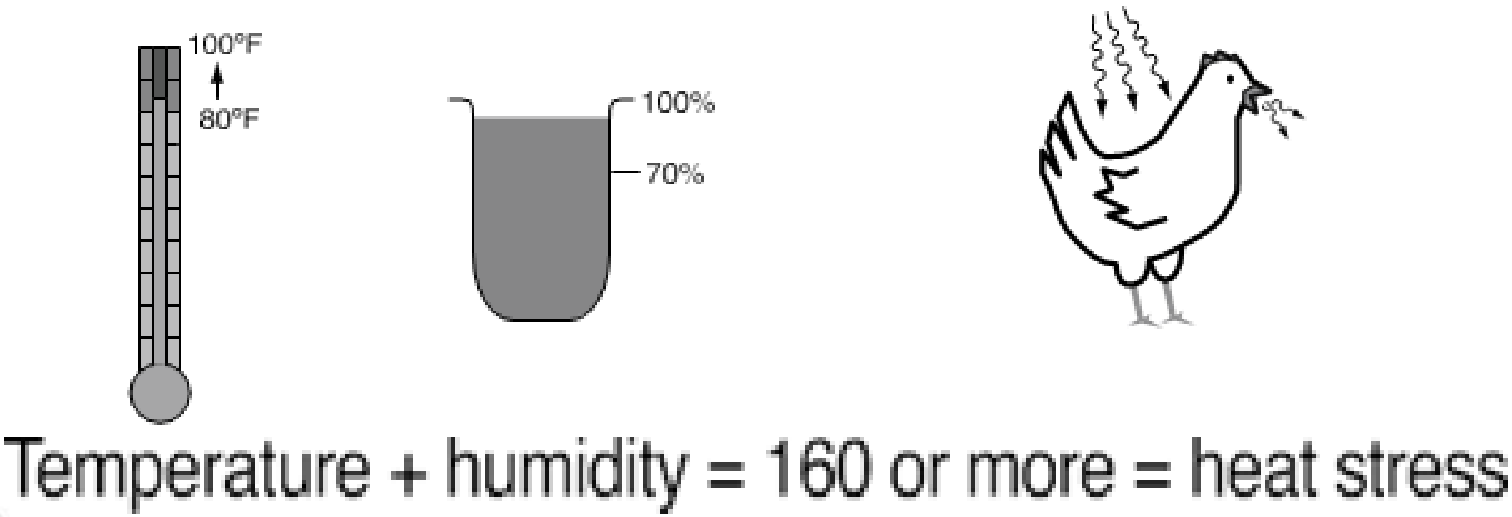
Effect of Temperature & RH on Birds

- Temperature and relative humidity work together; high relative humidity can cause problems even at relatively low air temperatures.
- A rough guide to whether the combination of temperature and relative humidity will stress birds is to add the numbers. If the temperature is above 80F and the temperature and relative humidity add up to 160 or more, birds are likely to be stressed.



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Effect of Temperature & RH on Birds

- Note that this rule works only in conventional open-sidewall ventilation or in cold-weather power ventilation when air is not moving over the birds. It does not apply to tunnel ventilation because of the wind-chill effect.

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How Relative Humidity Works

BENEFIT

- When water evaporates, it passes into the air as water vapor. You can’t see it, but gallons and gallons of water are floating around in the air all the time.
- Relative humidity indicates how close the air is to holding all the moisture it can before condensation occurs.
- If the air is holding half its maximum water vapor capacity, that’s 50% relative humidity. If the air is holding three-fourths of its capacity, that’s 75% relative humidity.
- Warm air can hold a lot more moisture than cold air. This means that warmer air can absorb a lot more moisture from the birds and the litter without approaching saturation than would be possible with colder air.

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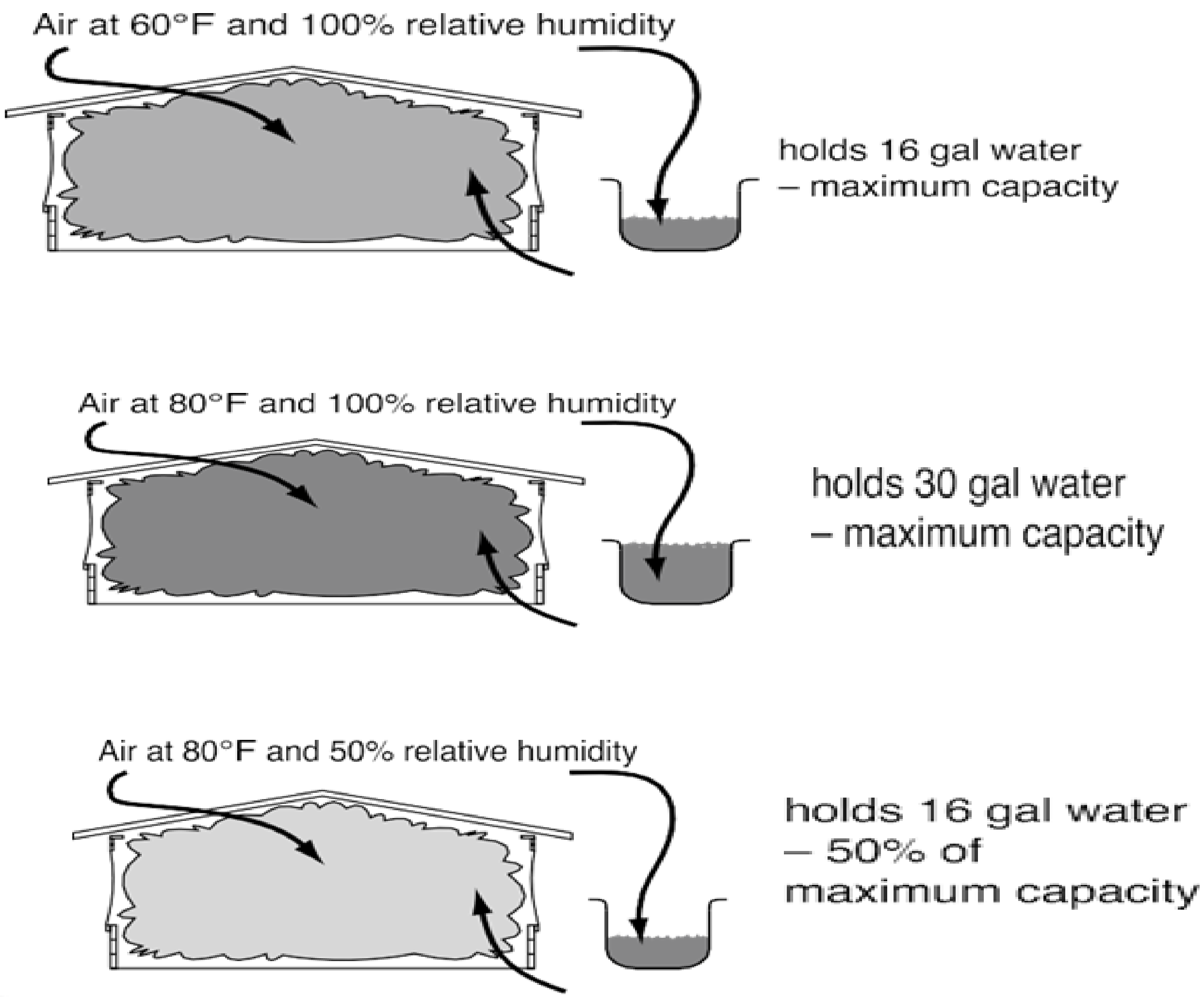
How Relative Humidity Works

- Warmer air holds much more moisture. A 20 degree F change in temperature can double (or cut in half)

the relative humidity of air.

- As air temperature rises, the amount of water a given amount of air can hold increases.
- An approximate rule of thumb is that a 20 degree F rise in air temperature cuts relatively humidity in half. That is, raising the air temperature increases the absorbency of the air.
- At 80°F the air is more absorbent and can hold almost twice as much water vapor as the same air at 60°F.

How Relative Humidity Works



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Ventilation Basics

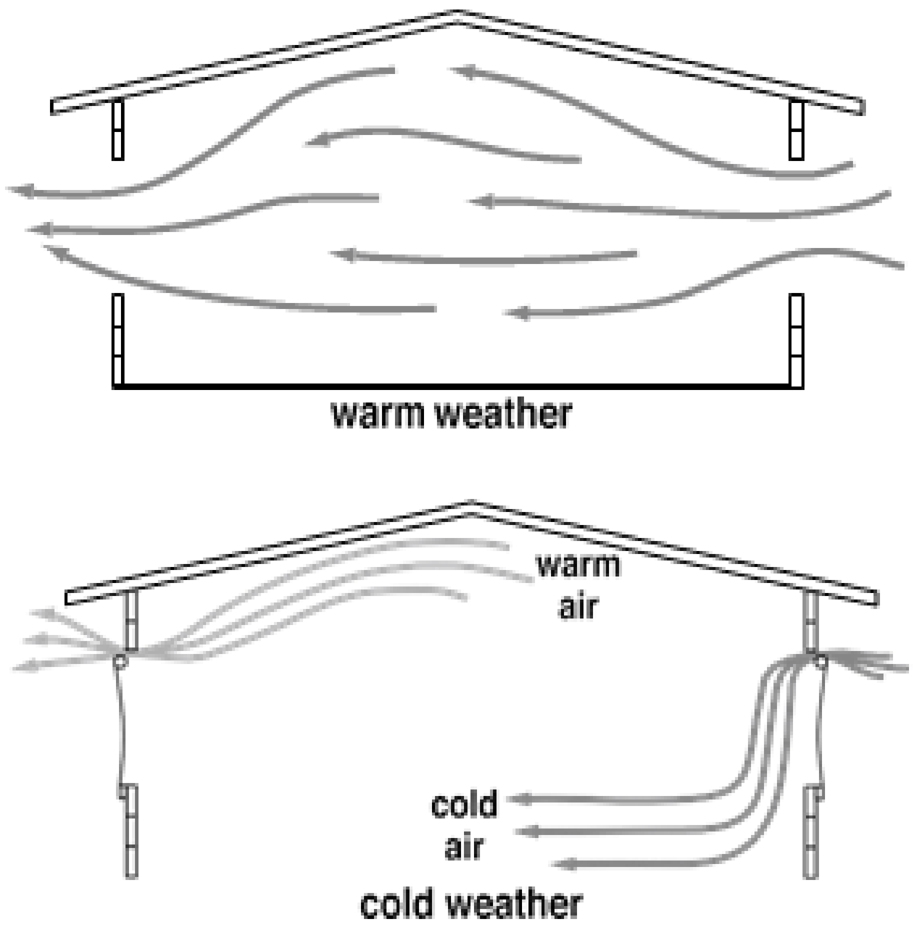
BENEFIT

- **There are two basic ventilation types:**
- **Natural ventilation and**
- **Fan-powered ventilation**

Natural Ventilation (curtain ventilation)

- Natural (curtain) ventilation works well only when outside conditions are near what is needed inside the poultry house.
- On warm to hot days with little wind, circulation fans may be used to provide some wind chill cooling effect. Foggers or misters can be used with circulation fans to add a second level of cooling.
- In hot weather, strong winds are needed to achieve an acceptable air exchange rate; in cool weather, cold outside air is likely to drop directly onto the birds which chills the birds and creates wet litter. At the same time, warmer air escapes from the house, resulting in large temperature swings تأرجح.
- In cool weather, Stirring fans can help improve conditions in a curtain-ventilated house.

Natural Ventilation (curtain ventilation)



Fan Powered Ventilation

- Fan-powered ventilation uses fans to bring air into and through the house.
- Powered ventilation generally allows control over both the air exchange rate and the air flow direction, depending on the configuration of fans and air inlets.
- Fan-powered ventilation systems can use either positive or negative pressure (more common).
- In negative pressure ventilation, exhaust fans pull air out of the house. This creates a partial vacuum (negative pressure) inside the house, so that outside air is drawn into the house through inlets in the house walls or under the eaves creating more uniform conditions in the house.

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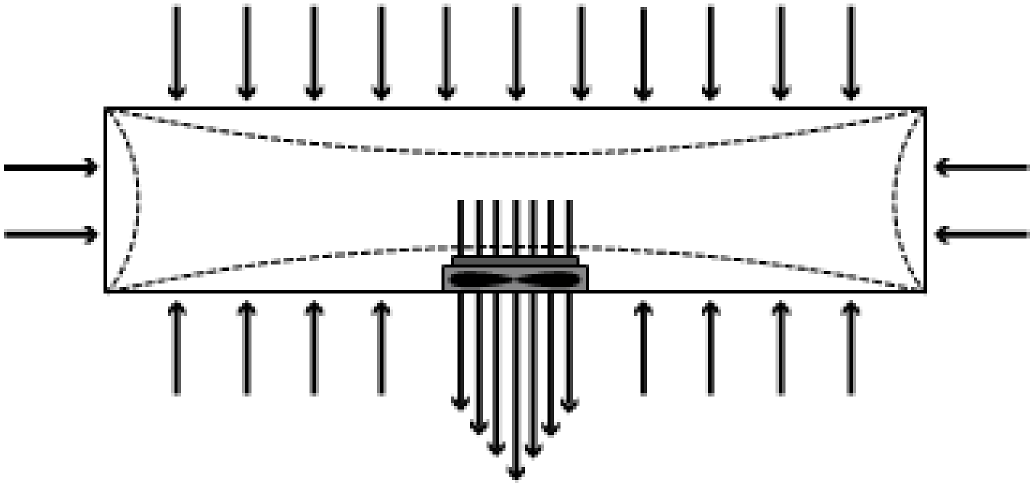
Fan Powered Ventilation



Fan Powered Ventilation

- Having a tightly sealed house is critical for successful control of in-house conditions in negative- pressure ventilation.
- If the tunnel ventilated house was not tightly sealed then, air leaks will:

- chill birds during cool weathers,
- create moisture problems,
- and detract from optimum rearing temperature environments. &
- will reduce wind velocity and wind-chill cooling during summer.

Types of Negative-Pressure Ventilation Operation

- Fan-powered, negative-pressure poultry house ventilation can be operated, with different fan and air inlet setups, in three different modes, according to the ventilation needs to be addressed:

1- Minimum ventilation (also called just "power ventilation" or even "power vent") – operated on a timer and used for cooler weather and/or smaller birds.

2-Transitional ventilation – operated on thermostat or temperature sensor and used for heat removal when wind- chill (tunnel) cooling is not needed or desirable.

3-Tunnel ventilation – used for warmer weather and/or larger birds; operated on thermostat or temperature sensor.

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How Minimum Ventilation Works?

- The purpose of minimum ventilation is to bring in just enough fresh air to exhaust excess moisture and ammonia in cold weather or during brooding.
- And, to do this without chilling the birds. Typically, from two to six 36-inch exhaust fans are used, with the location of fans and air inlets varying as described below.

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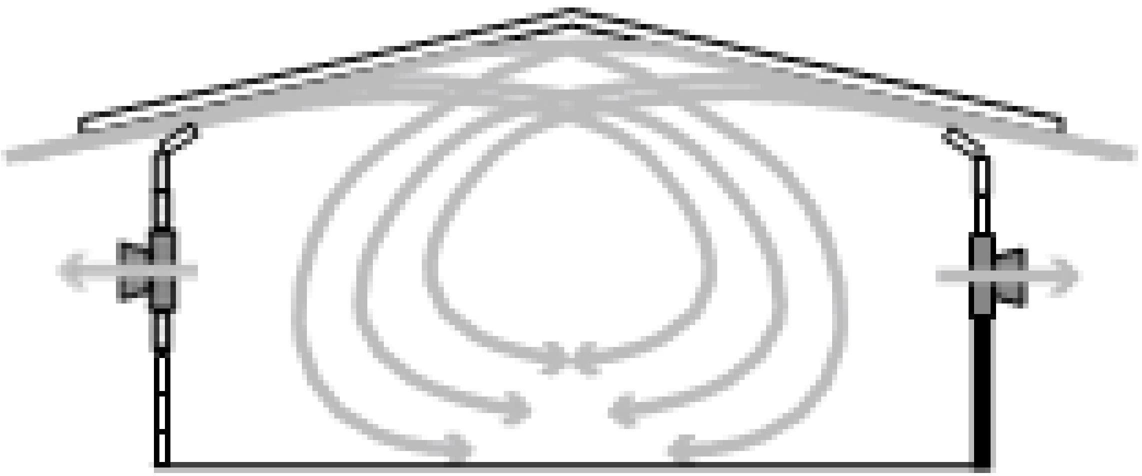
How Minimum Ventilation Works?

- Four common variations on fan/inlet setups for minimum ventilation:

1- Exhaust fans on sidewalls and air inlets around the perimeter (high on sidewalls or in ceiling). This setup works well in cool weather and for use in tunnel ventilated houses operating in transitional mode



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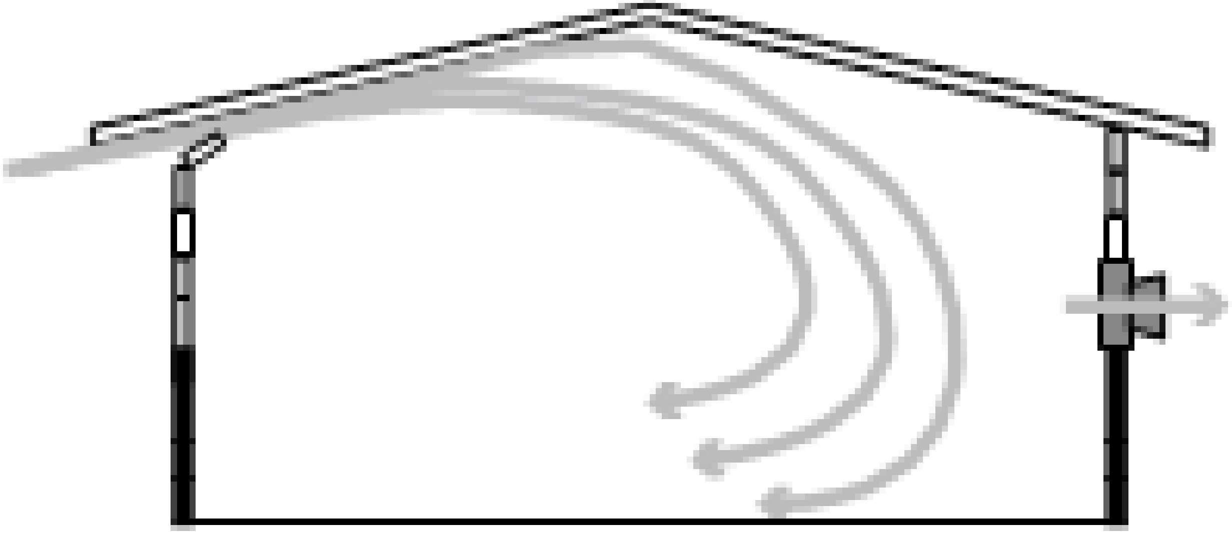
How Minimum Ventilation Works?

2- Exhaust fans on one side of building and air inlets on the other. Commonly called "cross ventilation," this setup is most popular in areas where tunnel ventilation is not needed.



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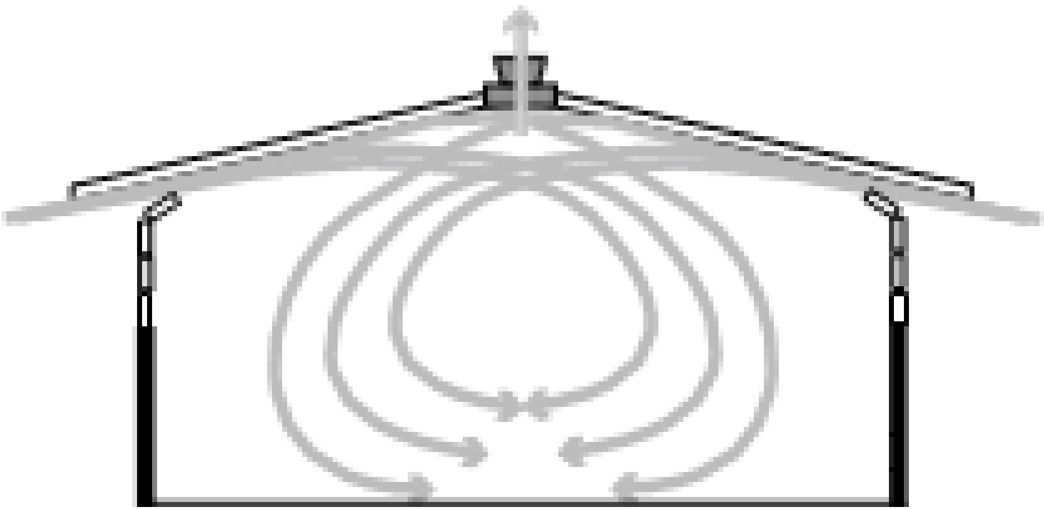
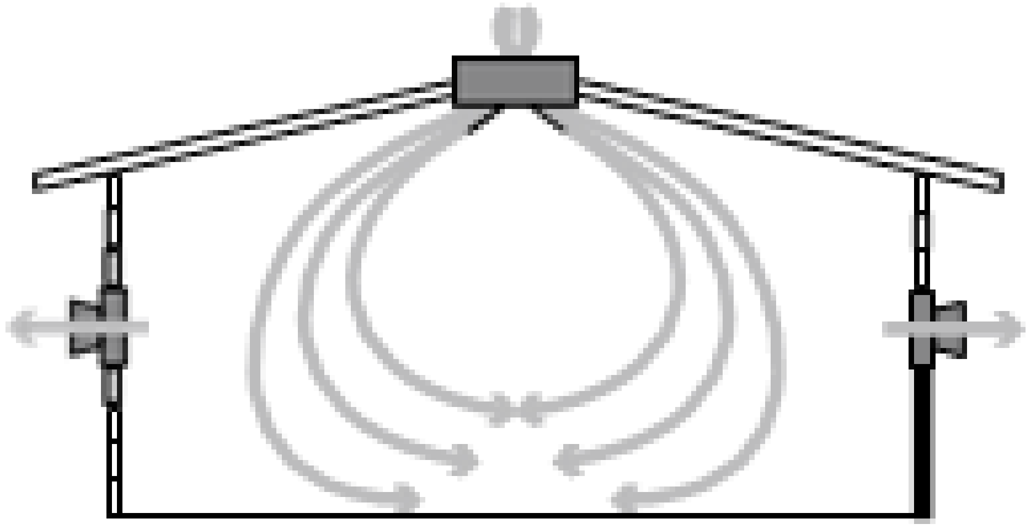
How Minimum Ventilation Works?

3- Exhaust fans in the roof and air inlets in the sidewalls. Often called “ridge extraction,” this type of setup is also most used in cooler climates.



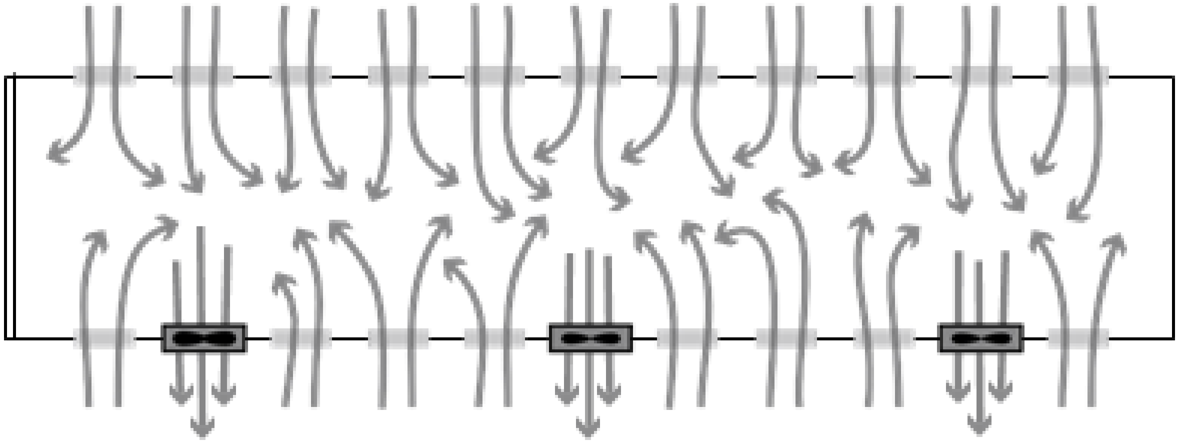
How Minimum Ventilation Works?

4- Exhaust fans in the sidewalls and air inlets in the apex of the roof. Often called “reverse flow” ventilation, this setup is similar to setup #1 above except for the location of the air inlets.



How Minimum Ventilation Works?

- The goal of minimum ventilation is to bring air in evenly and at high velocity through inlets spaced around the house above bird level, so that cold outside air mixes with in-house air, as shown in this plan view diagram. This air flow pattern prevents cold outside air from dropping onto the birds.



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How Minimum Ventilation Works?

- To get the airflow pat- tern needed in minimum ventilation, the air inlet area must be matched to the fan capacity being used.
- If the air inlet area is too small (for the number of fans running), fans will have to work against too-high static pressure and will not deliver the air exchange rate needed.
- If air inlets are opened too wide, static pressure drops too low, and air will come in mostly or only through inlets closest to the fans, creating non-uniform air flow and poor conditions for birds.
- Using cool-weather adjust- able perimeter air inlets actuated by a static pressure controller gives best minimum ventilation airflow.
- Minimum ventilation is timer-controlled, not temperature controlled.

How Transitional Ventilation Works?

- The change from minimum to transitional ventilation is basically a switch from timer-driven to temperature-driven ventilation.
- That is, whenever temperature sensors or thermo- stats override the minimum ventilation timer to keep fans running, the minimum ventilation setup will be running in the transitional ventilation mode. some of the tunnel fans can be used to bring large amounts of air in through perimeter inlets, without putting air directly on the birds.
- As with minimum ventilation, transitional ventilation inlet area should be matched to fan capacity and inlet opening

adjustments made by an automatic static pressure-

operated controller.

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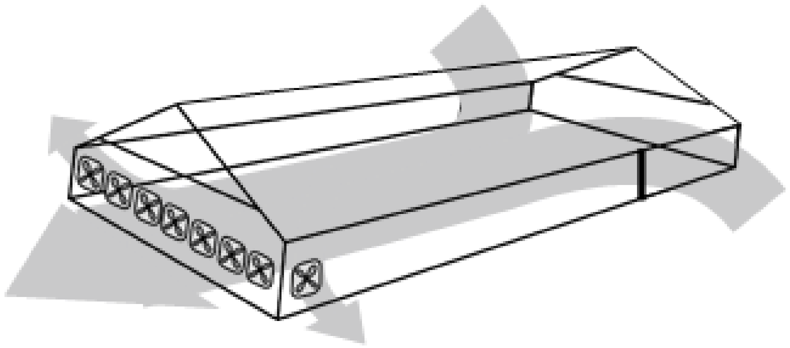
How Tunnel Ventilation Works?

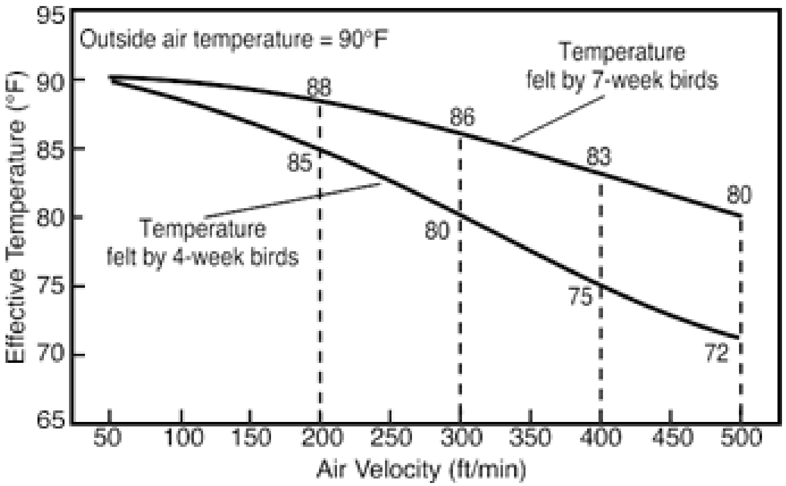
BENEFIT

- The goal of tunnel ventilation is to keep birds comfortable in warm to hot weather by using the cooling effect of high-velocity airflow.
- The tunnel setup is especially suited to warmer areas and where larger birds (1.9-3.8 kgs) are being grown.
- The purpose of tunnel ventilation is to achieve maximum cooling by the wind-chill effect of high-velocity airflow.
- Full tunnel mode operation, with all fans running may produce a complete house air exchange in under one minute.



How Tunnel Ventilation Works?

- The "effective" temperature created by the wind-chill effect must be estimated, and varies according to bird age/size and actual air temperature.
- The wind-chill effect created by high- velocity air flow is much greater for younger birds.



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How Tunnel Ventilation Works?

- The high-velocity airflow of the tunnel setup makes it well suited to adding evaporative cooling. This can be done either with in-house foggers or with evaporative cooling pads placed outside the air inlets.
- Used alone, the wind-chill effect of tunnel ventilation becomes less pronounced as air temperatures rise much above 90°F, and above 100°F the air begins to warm instead of cool the birds.
- Adequate tunnel inlet area is essential. More area is needed for pad cooling (as explained below). Tunnel houses also must be tight, since any air leaks will spoil the desired airflow pattern.

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How Evaporative Cooling Works?

- Evaporating just one gallon of water into the air takes 8,700 Btu's of heat out of that air.
- The two major setup choices for tunnel-house EC are in-house foggers and wetted pads (spray-on or recirculating) mounted over the tunnel air inlets.
- Either setup can do a good job, but recirculating pad systems are becoming predominant.
- These high-efficiency systems demand less management attention and do not risk wetting birds or litter.

How Evaporative Cooling Works?

- **How well EC works –that is, how much cooling it produces – depends on three factors:**
  1. The starting outside air temperature – the higher this is, the more degrees of cooling are possible, other things being equal.
  2. The relative humidity (RH) of the outside air – the lower the better.
  3. How efficient the system is in evaporating water – typical systems range from 50% to 75% efficient.

How Evaporative Cooling Works?

- **The possible evaporative cooling under different conditions:**

Starting air temperature (˚F)	System efficiency	Resulting air temperature (˚F) for given relative Humidity		
		40%RH	50% RH	60%RH
100	50%	90	92	94
	75%	84	87	90
95	50%	85	87	89
	75%	80	83	85
90	50%	81	83	84
	75%	76	79	81

- For example, if it is 95°F outside at 50% relative humidity, a 75% efficient EC system will give 12 degrees of cooling, to 83°F. If the tunnel wind-chill gives another 10-12 degrees of effective cooling, fully-feathered birds will feel like they are in 71°-73°F air.

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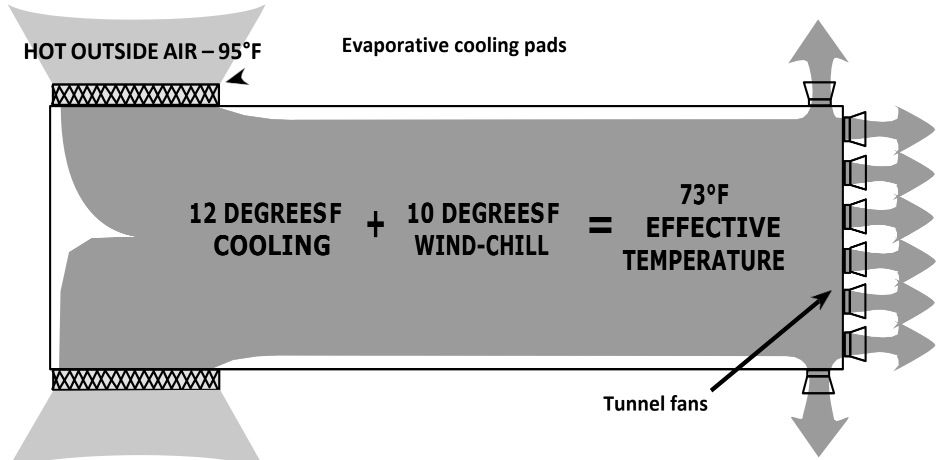
How Evaporative Cooling Works?

- Evaporative cooling is very practical if there is at least an average 20-degree F difference between night- time low temperatures and daytime highs.
- Basic principles of tunnel plus evaporative cooling are shown here, representing typical results possible with a well-designed high-efficiency evaporative cooling and tunnel ventilation system with wind speed at 500 feet per minute or more.



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How Evaporative Cooling Works?

- Research studies and industry experience show mod- ern environmental control technologies can provide a significant performance advantage.
- Performance factors recorded for tunnel + EC vs conventional curtain-ventilation houses in U.S. Southeast in summer.

58-day broilers	Broiler weight (lbs)	Feed conversion	% Livability	% Condemnations	Live cost (cents/lb)
Tunnel+EC	7.2	2.18	92.4	1.71	21.8
Conventional	6.85	2.24	88.1	1.90	22.5

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How Evaporative Cooling Works?

BENEFIT

- Research under controlled conditions has shown that high wind speed is especially beneficial for performance of larger birds.

Air velocity	Bird weight (lbs)	Gain in preceding week (lbs)	Feed conversion for that week
After 4th week:			
600 fpm	2.826	1.276	1.495
400 fpm	2.803	1.252	1.482
still air	2.720	1.167	1.521
After 5th week:			
600 fpm	4.284	1.458	1.712
400 fpm	4.235	1.432	1.698
still air	3.936	1.216	1.804
After 6th week:			
600 fpm	5.737	1.453	1.966
400 fpm	5.559	1.324	2.080
still air	4.847	0.911	2.469
After 7th week:			
600 fpm	7.065	1.328	2.277
400 fpm	6.654	1.096	2.610
still air	5.588	0.721	3.026

Choosing Fans

- Having good fans is essential for a successful ventilation program. The key consideration is airflow capacity–that is, the cfm’s (cubic feet per minute) a fan delivers.
- You should be sure the fans you install deliver the cfm’s that are needed.

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Fan Performance Factors

BENEFIT

- Fan capacity (cfm’s) varies according to the static pressure the fan is working against.
- In free air (as with a stirring fan), with zero static pressure, a fan will move the greatest amount of air.
- In negative-pressure ventilation fans have to pull air from the inlets through the house and exhaust it to the outside, and so have to work against a certain amount of resistance, which we call static pressure.
- As static pressure goes up, fan airflow capacity goes down. A fan’s airflow ratio (cfm at 0.20 inches ÷ cfm at 0.05 inches) indicates how well it maintains airflow capacity at higher static pressure.
- Airflow ratios range from around 0.65 to 0.90. Higher is better.
- Fan efficiency also usually goes down as static pressure goes up.

Fan Shutter Factors

- Fan shutters must close tightly to avoid air leakage; and must be kept clean to maintain rated fan capacity.
- If louver-type shutters are used, a commitment must be made to keep them clean. Enough dirt can accumulate on these shutters in a week to reduce airflow by 25%.

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Integrated Control System Decision Factors

BENEFIT

- An integrated electronic control system provides consistent control of the in house environment 24 hours a day, 7 days a week.
- Such systems add significant cost, but can pay off in improved bird performance by limiting temperature swings above and below the target optimum to a much narrower range.
- A good controller will have a range of capabilities – being operator-friendly is a must.

A good system will be easy to learn, which usually means having a good display screen and being menu-driven. It should be capable of keeping heating and ventilation systems from fighting each other, and moving the house automatically from heating to minimum ventilation to transitional to tunnel and evaporative cooling (and back).

- A good controller will be able to keep in-house temperature on target plus or minus 2 degrees F.

Integrated Control System Decision Factors

- A controller with data collection and display can be very helpful in trouble- shooting and improving management practices.

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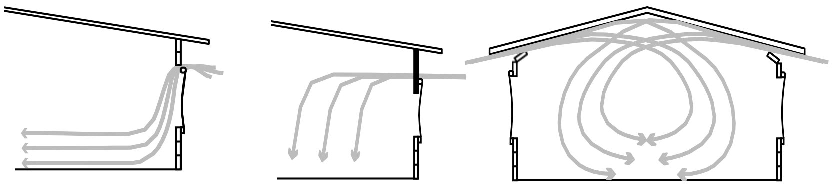
Air Inlet Design Considerations



During minimum or transitional ventilation, it is important to avoid putting cold outside air directly on the flock. Adjustable inlets located high around the perimeter of the house accomplish this goal, directing air into the house above bird level so it mixes with warm in-house air before contacting birds.

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Evaporative Cooling: Foggers or Pads?

- Recirculating pad evaporative cooling systems provide more cooling than fogging systems, are easier to manage, and do not risk wetting the house down.

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How Much Pad Is Needed?

- A reasonable goal is to achieve the desired cooling efficiency with the least pad area required, and at the same time keep house static pressure from rising above 0.10 inches.
- The most common mistake made in pad EC systems is not having enough total installed pad area.
- Not having enough pad area also means lower cooling efficiency because air velocity through the pad will be too high. The lower the air velocity through a wetted pad, the higher the cooling efficiency.

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HOW Much Pad Is Needed?

BENEFIT

- The formula for determining the pad area, assuming we know the installed fan capacity and the design air velocity needed through the pads is:

Installed tunnel fan capacity (cfm) ÷ Recommended air velocity through pads (ft/min) = Total pad area required (sq ft)

House Orientation

- The best house orientation for optimum in-house conditions is with the roof ridge running at least approximately east-west.
- In winter this allows the low winter sun to hit the sun-facing sidewall in the middle of the day and contribute to house heating. In summer, when you want to minimize heat build-up, the midday sun is much higher in the sky, so the eave overhang keeps sun from hitting the sun-facing sidewall for most of the day.

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Insulation Requirements

- Insulation to save heating fuel in winter & to provide cold in summer is essential; batt, board, and loose-fill insulation are superior.
- Insulation under the roof or above the ceiling is essential in warm weather to keep solar heat from radiating down onto the flock.
- Ventilation systems, even with evaporative cooling, cannot be expected to handle such an additional heat load. Radiant heat is especially dangerous because it goes directly to the birds without directly warming the inside air.

Keys To Managing A modern Tunnel House

- Tunnel ventilation was invented to provide growers with a tool to keep birds eating and gaining weight in warm to hot weather.
- There are actually three basic ventilation modes used in most “tunnel” houses:

➢ Minimum mode for cold weather and small birds (brooding),

➢ Transitional mode for moderate weather & medium-size birds when heat removal is needed, and

➢ Tunnel mode for additional cooling in hot weather.

Keys To Managing A modern Tunnel House Cont.

- Managing a modern tunnel house year-round for top bird performance first of all requires being able to judge which ventilation mode is best for the birds at any given moment; and then making the fine-tuning adjustments to keep temperature and other air quality factors as close to optimum as possible.
- **Integrated electronic control systems** now make the management job easier, since they can automatically switch modes and adjust ventilation rates as conditions change.
- However, even the smartest controller is not infallible, and must be monitored. Even more important, the controller settings themselves must be determined by a knowledgeable human.

Keys To Managing
A modern Tunnel House Cont.

- There is just no substitute for a good poultry husbandman who is in the house frequently, watching the birds and making the control adjustments they need for best performance and welfare.

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Which Ventilation Mode Is Needed?

- The key to making the right ventilation mode decision is knowing how much, if any, heat needs to be removed from the house, and whether outside air should be allowed to flow directly over the birds.

The basics:

MINIMUM VENTILATION:

- We do not need to remove heat from the house, and do not want outside air to contact the birds directly. Either the birds are too small and/or outside air is too cold.
- Fans are on a timer, not a thermostat, and the ventilation goal is to prevent moisture build-up and provide fresh air.
- We want to stay in minimum ventilation as long as it is possible to keep birds comfortable this way.

Which Ventilation Mode Is Needed? Cont.

- **TRANSITIONAL VENTILATION:**

Starts when birds grow larger and/or outside air gets warmer so that in-house air temperature rises and we begin to need to exhaust excess heat from the house. We need a higher air exchange rate. But we still do not want outside air to contact the birds directly.

- The first stage of transitional ventilation is often simply by a temperature sensor overriding the timer to run the minimum ventilation fans, and in some systems by bringing additional (non-tunnel) fans and air inlets on.
- Even more heat removal can be accomplished by using some number of tunnel fans to bring air in through sidewall air inlets (hybrid transitional mode).
- Transitional mode should be maintained as long as we can adequately remove the excess heat from the house in this way.

Which Ventilation Mode Is Needed? Cont.

- **TUNNEL VENTILATION:**
  - We switch to tunnel mode only when it is no longer possible to keep birds comfortable using the transitional setup. That is, we need to be cooling the birds by the wind-chill effect of tunnel ventilation.
  - We have to be very careful in switching from transitional to tunnel mode when birds are under four weeks old, because they experience a greater wind- chill and may be stressed by the sudden drop in the effective temperature.
  - We want to be in (and stay in) tunnel only when birds need wind-chill to stay in their comfort range.

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Keys to Managing Minimum Ventilation

KEY #1:

- Even when heat removal is not needed, ventilation is essential to maintain air quality.
- House heat lost during minimum ventilation is insignificant compared to the benefits gained.

KEY #2:

- While air quality must not be sacrificed to save heating fuel, it is extremely important to keep young birds from being chilled.
- Young birds especially must be kept warm; pre-heat house and litter before chick placement, and monitor temperature at bird level.

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Keys to Managing Minimum Ventilation

KEY #3:

- Minimum ventilation should be operated on a five-minute timer. As birds grow larger and put out more moisture and heat, system on-time and/or number of fans on needs to be increased.
- A rule of thumb for determining timer settings is that the minimum ventilation rate needed for starting chicks is about 0.10-0.20 cfm per bird, depending on outside air temperature.
- In-house relative humidity and lit- ter moisture, along with bird behavior, serve as guides in setting the minimum ventilation rate.

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Keys to Managing Minimum Ventilation

KEY #4:

- A critical factor for successful minimum ventilation is making sure that incoming cold air mixes uniformly with and is warmed by in-house air before coming in contact with the birds.

KEY #5:

- Switch to transitional mode only when heat removal is needed and minimum ventilation cannot keep birds comfortable.

Keys to Managing Transitional Ventilation

KEY #1:

- To be successful with transitional ventilation, it is essential to have the sidewall inlets on a static pressure controller.
- It is very difficult or impossible to manually adjust the size of the inlet openings to keep the proper static pressure as the number of fans running changes.

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Keys to Managing Transitional Ventilation

KEY #2:

- We never want to switch to tunnel ventilation while it is still possible to maintain bird comfort in transitional ventilation mode.
- For large birds in a well-designed house, if the outside temperature is more than ten degrees F cooler than the inside target, then we should be able to maintain target temperature with transitional ventilation.
- Switching from transitional to tunnel ventilation too soon can hurt bird performance severely

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Keys to Managing Transitional Ventilation

KEY #3:

- There is no problem with switching from one ventilation mode to another – minimum, transitional or tunnel – as conditions change.
- A flock may need transitional ventilation during the night and in the early morning, but some form of tunnel during the heat of the day. The question is, What will keep the birds performing best?

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Keys to Managing Transitional Ventilation

KEY #4:

- In judging the time and need to switch to tunnel, we must keep the wind-chill effect in mind.
- If we are using maximum transitional ventilation capacity – running, say, four tunnel fans – and switch into tunnel mode, the birds will experience a drop in the "equivalent" or "effective" temperature, which may be quite a bit lower than the thermometer reading.
- When birds are younger and more sensitive to wind-chill, the effective temperature drop may be difficult for them to cope with.

Keys to Perimeter Inlet Management

- In cold weather, perimeter air inlets are the tool to help blend cold outside air with warm inside air.
- Proper perimeter inlet management can cut heating fuel bills as much as 20%.
- Inlets control direction of air movement and affect the velocity of air entering the house, and thus air mixing.
- In cold weather, inlets are the tool to help blend cold outside air with warm inside air to save fuel and maintain precise temperatures.
- Good inlet management prevents all the hot air from being in the top of the house.
- In houses with poor inlet management, as much as 15 to 20 degrees difference in floor and ceiling temperature are observed. Good inlet management can keep this temperature difference to 5 degrees.

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Keys to Perimeter Inlet Management Cont.

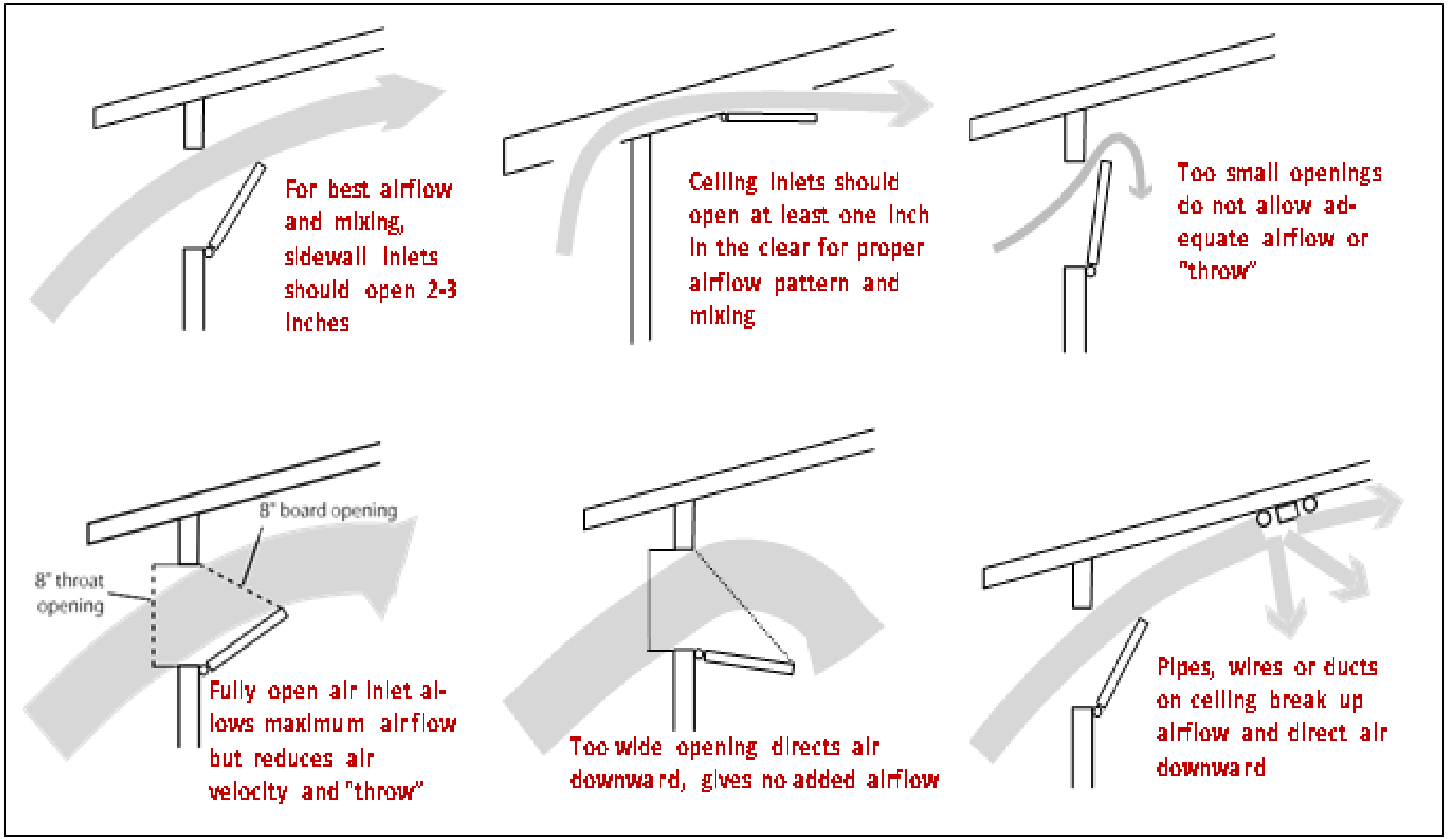
KEY #1:

- Inlet management starts with making sure the house is tight, with no air leaks around doors, curtains, torn insulation, etc. to rob from the inlet air stream.

KEY #2:

- The next step is to make sure inlets are opening properly. The size of the inlet openings must be set so as to achieve both the static pressure desired and the airflow "throw" needed. See Figure 29 on facing page.
- Sidewall air inlets should open at least 2-3 inches and ceiling inlets 1 to 1.5 inches to provide good airflow.

Keys to Perimeter Inlet Management Cont.



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Keys to Perimeter Inlet Management Cont.

KEY #3:

- Use a static pressure-operated controller to operate air inlets.
- The static pressure control senses the static pressure in the house and then opens or closes the inlets to achieve the proper opening that will produce the static pressure desired and thus produce the airflow pattern desired.

KEY #4:

- The number of air inlets allowed to operate must be matched to the total fan capacity being used.

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Keys to Perimeter Inlet Management Cont.

KEY #4:

- The number of air inlets allowed to operate must be matched to the total fan capacity being used.
- A typical broiler house will have enough inlets installed to handle half the total installed fan capacity, but when only one or two fans are being used, as in brooding, we also need to cut back on the number of inlets that will open.
- The reason for this is that if too many in- lets are operating for the number of fans running, the static pressure machine will have to choke the inlet openings down too far in order to maintain static pressure, and the airflow "throw" needed will not be achieved.
- A rule of thumb is to have about 15 operating perimeter air inlets for each 48-inch fan being used.

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Keys to Perimeter Inlet Management Cont.

KEY #5:

- Avoid having any obstructions to airflow being placed directly in the airstream from the inlet.

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Keys to Managing Tunnel Ventilation

KEY #1:

- Success in managing tunnel ventilation depends on understanding effective or equivalent temperature produced by the wind-chill effect.
- Wind-chill effect de- pends most of all on bird age and air velocity.
- the effective temperature drop will be:
  - Greater for younger birds, less for older birds;
  - Greater for lower temperatures, less for higher temperatures.
- The wind chill effect decreases as we approach 95°F and completely goes away as we approach 100°F.

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Keys to Managing Tunnel Ventilation

KEY #2:

- Extreme caution should be exercised when tunnel ventilating young birds.
- Wind-chill on 4-week birds may be double thatfor 7-week birds.

KEY #3:

- To determine the wind-chill effect in a given situation, you must observe the birds' behavior to pick up any signs of their being too warm or too cool.

Keys to Managing Tunnel Ventilation

KEY #4:

- It can be very helpful to develop guidelines for using tunnel ventilation based on your situation and experience.
- If it is to cool outside, tunnel can hurt more than it helps; bird age is the critical factor.

– If the outside temperature is less than 70°F and birds are four weeks old, stay in transitional mode.

– If the outside temperature is 65°F and the birds are between 5 and 8 weeks old, stay in transitional mode.

Keys to Managing Tunnel Ventilation

– If the outside temperature is 60°F or lower and the birds are 8 weeks old, stay in transitional mode ventilation. The fact is, if it's too cold outside, tunnel ventilation hurts rather than helps.

– Under normal conditions with fully-feathered birds, don't consider running in tunnel mode with fewer than half of your tunnel fans. This has more draw- backs than benefits, especially regarding temperature uniformity. If you can do the job with fewer than half of the fans, stay in transitional ventilation mode.

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Keys to Managing Tunnel Ventilation

KEY #5:

- Monitor the temperature difference in the house from inlet end to fan end. This can indicate two different things, depending on the situation:

– During tunnel in hot weather, a temperature difference much greater than 5 degrees F (normal) can indicate insufficient airflow or air leaks letting hot air into the house. In this situation, check air velocity and look for dirty fans, shutters and/or pads, and for open doors or other leaks.

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Keys to Managing Tunnel Ventilation

– In cooler weather with smaller birds, a more than 5 degree rise in temperature from one end of the house to the other during tunnel ventilation may indicate you should be in transitional ventilation, not tunnel. Under these conditions, the temperature rise from one end of the house to the other may be telling you that the incoming air is too cold, and as it passes through the house is picking up more heat than is desirable. You don’t experience this with transitional ventilation because the air is coming in uniformly through the perimeter vents all around the house.

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Keys to Managing Tunnel Ventilation

KEY #6:

- Migration fences should be installed as soon as we move from the brooding phase to full house ventilation.
- Using migration fences keeps birds spread out, ensures conditions for growth are uniform throughout the house.

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Keys to Managing Tunnel Ventilation

KEY #7:

- If you see any sign of birds being too warm during full tunnel ventilation (and the system is operating properly), it's time to turn on evaporative cooling.
- However, on any day when the temperature is expected to go at least into the 90°F range, it may be best to turn on evaporative cooling before getting to the point where all tunnel fans are running.

Keys to Managing Tunnel Ventilation+ Evaporative Cooling

- Evaporative cooling only needs to lower thermometer reading to range where wind-chill can keep birds comfortable.
- **For example**, if it is 95°F outside and we can get 12 degrees of evaporative cooling from our system, the real air temperature coming into the house is 83°F. If the wind chill effect from the 500 feet-per-minute air velocity is another 10 degrees F, the effective temperature felt by the birds will be 73°F – very close to optimum for fully-feathered birds.

KEY #1:

Keys to Managing Tunnel Ventilation+ Evaporative Cooling Cont.

KEY #1:

- Evaporative cooling should be turned on or programmed to come on before birds begin to feel heat discomfort.
- For fully-feathered birds, this may be in the 80°-85°F air temperature range. It is easier and better to keep heat build-up from happening in a house than it is to reduce the heat load after it has progressed too far.

Keys to Managing Tunnel Ventilation+ Evaporative Cooling Cont.

KEY #2:

- Evaporative cooling does not have to be delayed until we are in full tunnel and running all fans.

KEY #3:

- A good rule of thumb is that evaporative cooling systems should not be used when the relative humidity is above 80%, which in many locations includes after dark or before 9 a.m.
- Rule of thumb: Do not run evaporative cooling after dark or before 9 a.m.

Keys to Managing Tunnel Ventilation+ Evaporative Cooling Cont.

KEY #4:

- Good maintenance is especially important for successful evaporative cooling.

Management Includes Monitoring

- Monitoring job #1: watch bird behavior.
- **Temperature:**

- Temperature is extremely important: invest in good thermometers and put them in the right places.
- An infrared thermometer helps spot a number of different kinds of problems.

- **Relative Humidity:**

- Use an inexpensive digital relative humidity meter (humidistat), ac- curate to about ±5%. A high-accuracy digital costs more but is accurate to about ±2%.

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Management Includes Monitoring Cont.

- **Air movement:**

- Airspeed meters and streamers take a lot of the guess-work out of ventilation management.

- **Static pressure:**

- A static pressure meter helps spot air leaks, shutter problems, poor fan performance, and more.

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Course type: **Developed course**

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Chapter 1:Energy Sources In Animal Feeding

Mr. Raed Dayeh-Hebron University

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Energy Sources

A- Grains:

- Yellow corn
- Wheat
- Sorghum
- Barley
- Oat
- Rye

B- Plant Oils (Vegetable Soap-stock)

C- Animal Fat

D- Molasses

E- Milling by products:

(Wheat bran & Wheat Screenings)

Yellow Corn

- Corn (*Zea mays*) also called maize
- Corn grain structure: Hull (fiber), Bran (protein, fiber), Endosperm (starch), Germ (protein, fat)
- It is the best feed grain. Why?

- *of the highest ME content*
- *highly palatable to all types of animals*
- *of no toxic factors*

- Dent corn is the type used in animal feeding

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Yellow Corn Cont.

BENEFIT

➢ **Nutrients Content of Corn:**

- High in ME. Why?
- Whole grain corn is poorly digested in cattle, fine grinding is required.
- Heat treatment of grains causes starch gelatinization (benefits ???)
- High in lipids 4% & in EFA'S. This gives corn-fed animals a sleek, shiny appearance.
- Corn has a lower content and quality of protein than most other grains (but still the feed grain of choice. Why?

Yellow Corn Cont.

- Corn-grain protein is recognized as poor quality, being deficient in lysine and tryptophan, and low in methionine.
- Yellow corn is the only cereal grain to have significant vitamin A activity (β-carotene is the precursor)
- Corn also contains carotenoids called xanthophylls

(What the importance of xanthophylls in animal feeding?)

- Corn is low in niacin, vitamin D & B-complex vitamins but fair in its content from vitamin E
- Low in Calcium but moderately high in phosphorus (0.3%). (Organic phosphorus & availability for non-ruminants----????)
- Corn does not contain toxic compounds, subjected to mold infestation (ex. Aspergillus flavus) that secrets aflatoxins.

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Yellow Corn Grains

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Rolled Corn (رصع)

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Grinded Corn (مطحونة)

Flaked Corn (مرقه)

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Extruded Corn (مبثوقة)

BENEFIT

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Wheat

- Grown primarily for human consumption
- Used as a feed mainly when the price is low

➢ **Nutrients Content of wheat:**

- Identical to corn in its DE content
- Causes digestive disturbances (lactic acidosis) in ruminants because of the rapid digestion rate of wheat starch
- Superior to corn in terms of its protein content and quality (10-11% CP)
- Lysine is the most limiting amino acid for swine and poultry, followed by threonine and methionine

Wheat Grains

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Sorghum (Milo)

- Sorghum (*Sorghum bicolor*) is a hardy, drought-resistant crop
- The foliage of sorghum is similar to that of corn in appearance, but the grains are different

➢ **Nutrients Content of wheat:**

- Lower than corn in its ME content
- Requires more vigorous processing when fed to ruminants. Why?
- Light sorghum & dark sorghum differ in tannins content
- Poor in CP content (7-10%)
- Sorghum protein is low in lysine, threonine, tryptophan, methionine & isoleucine.

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Sorghum (Milo) Cont.

What are the adverse effects of tannins?

- reduces the palatability
- Reduces the digestibility of CP

- Low in calcium but high in phytate phosphorus
- Do not contain vitamin B12
- Little vitamin A activity

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Sorghum (Milo)

Light Sorghum

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Sorghum (Milo)

Dark Sorghum

Barley

- *Hordeum vulgare*: Grown primarily for malting & for feed

➢ **Nutrients Content of wheat:**

- Low ME content for non-ruminants because it is:
- high in fiber
- of low starch content
- high in the low digestible β-glucans

- Barley is superior to corn in its protein content (11%)
- Barley protein is low in lysine & threonine.

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Barley Cont.

- What are the adverse effects of β-glucans to non-ruminants?
- reduces the intestinal flow rate
- inhibits the formation of micelles and so reduces fat absorption
- makes the excreta wet and sticky
- In young chicks, pasty vent appears and the gut is blocked.

- What is the solution?

β-glucanase enzyme is the solution

Barley

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Oat

- ***Avena sativa***: an ideal feed for horses. Why?

➢ **Nutrients Content of wheat:**

- Has the highest protein content & quality than any cereal grain
- Lysine is the first limiting amino acid in oat protein
- **Oat is of low energy content because it is of:**

- high in fiber
- of low starch content
- high in the low digestible β-glucans

- Barley protein is low in lysine & threonine
- Oat grain has a higher mineral content than other grains

(Notice: Return to NRC tables to prove that)

Oat

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Rye

- *Secale cereale:* has never given as favorable results in animal feeding as its nutrient composition suggests that it should. This is due to numerous deleterious factors in Rye.

Deleterious Factor	Effects
Alkyl resorcinols	Reduces feed intake.
Ergot alkaloids	Gangrene of extremities, reduce feed efficiency, abortion & agalactia (lack of milk prod.) & convulsions.
Pectins, Pentosans and B-glucans	Viscous & gummy materials that causes: Sticky & wet droppings, impair nutrient absorption, promote digestive disturbances, abnormal microbial growth, diarrhea.

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Rye Cont.

BENEFIT

➢ Nutrients Content of Rye:

- The protein content of rye is similar to that of barley. Rye protein has a higher lysine content than wheat and barley, giving it a higher biological value.

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Rye

BENEFIT

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Plant Oils (Vegetable Soap-stock)

- **What are the roles of oil & fat in animal feeding?**
  - Act as a *concentrated source of energy (How much??)*
  - Increase the palatability of feed
  - Improves pelleting efficiency
  - Reduces dustiness of feeds
  - Increases the efficiency of pelleting & the pelleting machine output per hour
- **Problems Associated with Use of Fats and Oils:**

  Fat rancidity & the production of peroxides & free radicles,

  (oils more susceptible to rancidity. Why?

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Plant Oils (Vegetable Soap-stock) Cont.

- **The products of rancidity bad effects & characters:**

  - toxic

  - have an objectionable odor (reduces palatability)

  - Destruction of fat-soluble vitamins

- **How rancidity can be prevented?**

  - Vitamin E is the major natural antioxidant,
  - Synthetic antioxidants such as ethoxyquin, butylated hydroxyanisole (BHA), and butylated hydroxytoluene (BHT) are also used.

- Another problem related to oil or fat use is the drop in pellet durability & quality (excessive use should be avoided, sometimes pellet binders are required.

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Plant Oils (Vegetable Soap-stock) Cont.

- Ruminants are less tolerant of dietary fat than are nonruminants
- **Excessive levels of fat in ruminants diet may cause:**

  - Digestive disturbances,
  - Diarrhea, and
  - Reduction in feed intake
  - Reduction in Ca absorption
  - Reduction in fiber digestibility
  - Reduction in fat% in milk

- Practically, it is not recommended to add oil or fat in more than 3% to ruminants diet & in more than 5-6% in poultry diet.

Vegetable Soap-stock

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Animal Fat

BENEFIT

- **Most fats are of animal origin and includes:**
  - Tallow from beef, mutton or lamb meat
  - Lard from pork
- **Sources of animal fat:**

  - Slaughterhouses fat

  - Restaurant fat
- Because saturated fatty acids are absorbed less efficiently, fats high in saturated fatty acids usually have a somewhat lower digestible energy value than oils.

(Compare the tabulated ME content of animal fat with that for soap-stock for ruminants & poultry).

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Molasses

BENEFIT

- Molasses is a product of the sugar-refining industry
- **Sources of molasses:**

  - Sugarcane molasses

  - Sugar beets molasses

  (Both are similar in composition and feeding value)

- Liquid molasses contains 15 to 25 percent water. It is a black, syrupy sweet solution, containing at least 46 percent sugars
- Molasses is often included in manufactured feeds at levels of 2 to 5 per- cent to perform the following functions:

  - to increase palatability.

  - to reduces dustiness and "fines" and

  - to act as a pellet binder to improve pellet quality.

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Molasses Cont.

- Molasses used at levels above 5 to 10 percent may cause milling problems because of its stickiness and may form large clumps in the mixer or stick to the equipment in the feed mill
- When the ruminant animal suffers from molasses toxicity?

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Molasses

Wheat Bran

- The main characteristics are high fiber, low bulk density and low ME
- Bran is however, quite high in protein, and amino acid profile is comparable to that seen in whole wheat.
- The energy value of bran may be improved by up to 10% by simple steam pelleting, while the availability of phosphorus is increased by up to 20% under similar conditions.
- Bran would only be considered where limits to growth rate are required, and where physical feed intake is not a problem.
- High bran diets promote excessive manure wetness, and transportation costs of bran diets are increased in proportion to the reduced bulk density of the diet.

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Milling by-product (Wheat Bran)

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Wheat Screenings

BENEFIT

- Wheat screenings are a by-product of the cleaning and grading of wheat that itself is usually destined for human consumption.

- In addition to broken and cracked wheat kernels, screenings will also contain wild oats and as well as weed seeds and other contaminants.

- The higher grades (#1 or #2) contain significant proportions of wheat, and so their nutrient profile is very similar to that of wheat.

- The fiber content will directly influence energy value. With wheat screenings there will likely be some weed seeds present, and these may cause feed refusal.

Milling by-products
(Wheat Screenings)

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Chapter 2: Protein Sources In Animal Feeding

Mr. Raed Dayeh-Hebron University

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Protein Sources

A- Oil seed meals:

- Soybean meal
- Cottonseed meal
- Sunflower meal
- Rape seed meal (Canola meal)
- Linseed meal
- Peanut meal
- Safflower meal
- Coconut meal
- Palm Kernel meal
- Sesame meal

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Protein Sources

B- Corn Milling by-products

- Corn Gluten Meal
- Corn Gluten Feed

C- Animal Protein Sources.

- Meat Meal & Meat & Bone Meal
- Blood Meal
- Fish Meal
- Feather Meal

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Oil-seed Meals

- By-products of vegetable-oil production
- Oils are extracted by either of two main processes:

  - mechanical expression (expeller process)

  - solvent extraction
- Hexane is the main solvent used in oil extraction
- The protein-rich by-product meals remaining after oil extraction are the main plant protein supplements now used in animal feeding.

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Soybean Meal

- Soybeans (Glycine max) are annual legumes
- Raw soybean is toxic to most animal due to presence of many deleterious factors

➢ Deleterious factors in soybean:

- Protease inhibitors
- Lectins
- Phytoestrogens
- Saponins
- Goitrogens & several others

- Fortunately, the nutritionally significant toxins are readily destroyed by heat treatment.

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Soybean Meal Cont.

BENEFIT

- What are the adverse effects of feeding raw soybean to farm animals?
- Heat treatment of soybean meal:
- Proper & adequate heating is required
- Avoid overheating (over cooking). Why?
- Avoid insufficient heating (under cooking). Why?
- Urease test is used to assess the adequacy of heat treatment. *What is the principle of this test?*

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Soybean Meal Cont.

BENEFIT

- Soybeans meal (SBM) is the major protein supplement for non-ruminants (protein source in corn soy diets)
- Soybean meal is the standard to which other protein supplements are compared

➢ SBM is the standard protein supplement because it is:

- highly palatable,
- of high digestibility,
- of high protein content of 44 to 50 percent,
- of a good amino acid balance,
- of a low fiber content,
- and of a high digestible energy content.

- SBM is totally satisfactory as a protein supplement for ruminants (A good source of bypass protein).

Soybean Meal Cont.

- Causes diarrhea & wet litter when fed to turkey pullets in high level due to high K content
- Methionine is the first-limiting amino acid for nonruminants
- SBM has a fairly high phytic acid content, which reduces the availability of phosphorus and zinc.

Soybean Meal (48%CP)

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Cottonseed Meal (CSM)

- CSM is the remained material after the extraction of cotton oil
- Deleterious factors in cottonseed meal:
- Gossypol: toxic, causes olive-green yolks in stored eggs, heart attack, pulmonary edema, internal organs damage
- Cyclopropene fatty acids: causes pink egg albumen
- *Why cottonseed meal is more suitable for ruminants than for nonruminants?*

Cottonseed Meal Cont.

- Nutrient Content:

- High in protein, energy & fiber so it has excellent nutrient balance for dairy cows
- Because of the possibility of gossypol toxicity, whole cottonseed and cottonseed meal should be fed to dairy cows at levels no higher than 4kg per head per day
- CSM is lower in lysine and sulfur amino acids than soybean meal.

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Cottonseed Meal

Rapeseed & Canola Meal

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BENEFIT

- Rape is a member of the Brassica genus of the Cruciferae (Brassicaea) or cabbage family
- Rapeseed contains toxic compounds called glucosinolates
- **Glucosinolates:**

- Inhibit the metabolism of the thyroid gland and may induce goiter (enlargement of the thyroid gland). Hence, they are called goitrogens or goitrogenic agents.
- Have hot taste as a result they reduce palatability of meal

- *The* ***low glucosinolate*** *rapeseed meal is called* **Canola meal**

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Rapeseed & Canola Meal

BENEFIT

- Characters of canola meal:
- Contains 38-46% CP
- Contains 10-13% CF
- Contains a high level of Sinapine which is converted in the chicken cecum to trimethylamine & then to trimethylamine oxide that is secreted in feces
- Rhode Island Red lack the enzyme that converts the amine to the oxide and a fishy odor released in eggs.

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Rapeseed Meal (Canola meal)(37%CP)

Sunflower Meal (SFM)

- Sunflower is grown mainly for production of sunflower oil, widely used for edible purposes

- **SFM** has quite a high fiber content (11 to 13 % crude fiber) which, along with a very low lysine content, limits its use for nonruminants

- The combination of high protein (40 to 45 percent) and high fiber makes it quite suitable for ruminants, particularly for dairy cattle and goats, which have a high protein requirement

- **SFM** contains phenolic compounds, which have an adverse effect on palatability and may reduce protein digestibility

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Sunflower Meal (SFM)

- Decorticated sunflower meal is prepared by removing as much of the hull as possible using screens. The decorticated meal is higher in protein (45 to 47 %) and lower in fiber (10 to 12 %) than regular sunflower meal.

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Sunflower Meal (36%CP)

BENEFIT

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Linseed Meal

- Linseed meal is the residue remaining after extraction of linseed oil from flax seed.
- Linseed meal has a fairly low protein content about (35%), and is severely deficient in lysine. For this reason, it is more suitable for ruminants and horses than for swine and poultry
- **Linseed meal contains two types of toxic factors:**

- **Linatine:** an antagonist of pyridoxine. Thus, in swine and poultry, linseed meal may induce a pyridoxine deficiency
- **cyanogenic glycosides:** causes goiter in fetuses of sheep

Linseed Meal

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Peanut Meal

- Peanut meal is the residue remaining after oil extraction of Peanut seeds
- Peanut meal contains from 45-50% CP but it is deficient in lysine
- Aspergillus flavus is easily grown in this meal, producing aflatoxins that cause high morality of poultry & animals
- The fungus grows under warm, humid conditions, typical of the areas where peanuts are produced and stored

Peanut Meal

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Safflower Meal

- Safflower meal contains approximately 40% crude fiber and only 18 to 22% crude protein. The protein is deficient in sulfur amino acids and lysine. Thus, safflower meal is useful primarily for ruminants
- Decorticated safflower meal, with a lower fiber content, can be used at modest (10 to 15%) levels of the diet for swine and poultry
- Safflower meal contains two phenolic glycosides that are bitter and cathartic (laxative properties), which limits its use for nonruminants

Safflower Meal

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Coconut Meal

- Coconut meal or copra is the meal remaining after extraction of oil from the dried endosperm of the coconut
- It contains 20 to 26% crude protein and approximately 10 % crude fiber
- The lysine content is lower than for soybean meal, but the methionine content is higher
- *For the feeding of what types of animals its more suitable?*

Coconut Meal

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Palm Kernel Meal

- Contains 18-19% CP & 13% CF
- High in fiber thus, It is more suitable for the feeding of ruminants

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Palm Kernel Meal

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Sesame Meal

BENEFIT

- Sesame meal is very deficient in available lysine, and this is sometimes used to advantage in formulating lysine-deficient diets for experimental reasons
- Sesame also contains high levels of phytic acid which can cause problems with calcium metabolism leading to skeletal disorders or poor eggshell quality
- If diets contain >10% sesame, then the diet should be formulated to contain an extra 0.2% calcium.

Sesame Meal

Corn-Milling By Products

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Corn Gluten Meal & Corn Gluten Feed

- These are manufactured during wet milling of corn
- Corn gluten meal contains around 60% CP while, corn gluten feed contains only 20% CP
- Being high in protein, corn gluten meal is often compared to animal protein ingredients during formulation
- In certain regions of the world, the two products are merely called 'corn gluten' and so this must be differentiated based on protein content
- Corn gluten meal is very deficient in lysine, although with appropriate use of synthetic lysine sources, the product is very attractive where high nutrient density is required
- Gluten meal is also very high in xanthophylls pigments (up to 300 mg/g) and is a very common ingredient where there is a need to pigment poultry products (egg yolk & broilers skin)

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Corn Gluten Meal & Corn Gluten Feed

- Potential Problems:

- Using much more than 10% corn gluten meal will produce a visible increase in pigmentation of broilers and egg yolks.

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Corn Gluten Meal (60%CP)

BENEFIT

Corn Gluten Feed (20%CP)

Pelleted

Animal Protein Sources

- Meat Meal & Meat & Bone Meal
- Blood Meal
- Fish Meal
- Feather Meal

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Meat Meal & Meat & Bone Meal

- These products, derived from slaughterhouse wastes and products of rendering plants, contain:

  - carcass trimmings,

  - condemned carcasses and livers,

  - inedible offal (lungs, gastrointestinal tract),

  - tendons, ligaments, hides, horns, hair, wool, and blood

- If bone is included, it is known as "meat and bone meal"

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BENEFIT

Meat Meal & Meat & Bone Meal

➢ **Potential problems:**

- Variable in composition from amino acids depending on proportions of byproducts
- Variable in calcium and phosphorus content
- Contamination of the product with Salmonella species
- A mean for the transmission of scrapie & raging cow diseases

• In general, meat and bone meal is less palatable and has a lower protein quality than soybean meal.

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BENEFIT

Meat Meal & Meat & Bone Meal

Blood Meal

- Dried blood meal contains approximately 80% CP, is high in lysine, and is severely deficient in isoleucine
- The digestibility of blood meal is often low because of heat damage occurring in the drying process
- Processing methods using low drying temperatures have improved the feeding value of blood meal
- However, it should be used at levels not exceeding 6-8% of the diet, because of amino acid imbalances induced by higher levels.

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Blood Meal

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Fish Meal

- Fishmeal is prepared either from whole fish specifically caught for this purpose or from by-products from the use of fish prepared for human consumption
- Good source of well-balanced protein
- Very Expensive
- **Common types of fishmeal include:**
  - **Herring meal** from Canada, the United States, Iceland, and Norway,
  - **Menhaden meal** from the Gulf and Atlantic coasts of the United States,
  - **Anchovy meal** from Peru, Chile, and Ecuador, and
  - **Pilchard meal** from South Africa

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Fish Meal

- **Nutritive value of fish meal:**

  - a high content and quality of protein,
  - A rich source of minerals (Ca, P and trace elements)
  - A rich source of vitamins especially B-complex vitamins (particularly B12).
  - A rich source of lysine & SAA’s (methionine & cystine)
  - It is highly palatable to swine and poultry

- **Potential problems:**

- Taint of meat or eggs (more than 2% fish meal in ration)
- Antioxidant should be added to stabilize fat in the meal
- With young chicks, gizzard erosion is a consequence of using poorly processed or stored fish meal.

Fish Meal

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Feather Meal

BENEFIT

- Feathers are almost pure protein, with a crude protein content of 85 to 90%
- However, this protein is primarily keratin, which has a very low digestibility
- Raw feathers are almost completely indigestible. If they are cooked with steam, internal bonds in the keratin molecule are broken and the product, hydrolyzed feather meal, is of high digestibility.
- Feather meal is deficient in both lysine and methionine but has a high content of cystine
- Hydrolyzed feather- meal is somewhat unpalatable and, because of this and the poor amino acid balance, should not be fed at more than 5 to 7% of the diet for swine and poultry.

Feather Meal

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BENEFIT

Chapter 3: Minerals & Vitamins Sources in Animal Feeding

Mr. Raed Dayeh-Hebron University

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Minerals & Vitamins Sources

➢ **Contents:**

- Calcium & Phosphorus Sources
- Sodium Sources

  (most of them also are chlorine sources)
- Sources of Other Minerals Usually Added to Animal Feeds
- Practicing of Calculations about Minerals
- Samples of Vitamins & Minerals Premixes Added to Feeds of Different Livestock Animals

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Minerals & Vitamins Sources

➢ Introduction:

- The major components of animal ration (grains & oilseed meals or other protein sources) provide the animal with vitamins & minerals but they do not provide enough quantities to satisfy the animal requirements from these nutrients
- This necessitates minerals & vitamins supplementation to animal feed to satisfy the requirements
- Inorganic sources of minerals & vitamins sources are usually added to the rations through vitamins & minerals premixes or directly (not in the premix) such as limestone & DCP .

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Sources of Calcium & Phosphorus

- Limestone & Oyster shell are from the most common & cheap sources
- Particle size is more important than the source
- The larger particles of calcium retained more time in upper GIT & Ca is released more slowly to be used in eggshell formation during night when the hen is stopping eating
- Thus, due to the larger size of the oyster shell particles as compared to limestone they are preferred to limestone for laying hens despite their higher price
- The proper limestone particle size for layers is 3-4mm.

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Sources of Calcium & Phosphorus Cont.

- Dolomitic limestone contains at least 10% magnesium, and this complexes with calcium or competes with calcium for absorption sites
- The consequence of feeding dolomitic limestone is induced calcium deficiency, usually manifested by poor skeletal growth or egg shell quality
- Dolomitic limestone should never be used in poultry diets
- Most of the Plant sources of phosphorus are unavailable (only about 30% of total phosphorus in grains is available)
- The phosphorus in most phosphate sources with the exception of soft phosphate, can be regarded as close to 100% available.

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BENEFIT

Sources of Calcium & Phosphorus Cont.

- The phosphorus in most phosphate sources with the exception of soft phosphate, can be regarded as close to 100% available
- Anhydrous dicalcium phosphate (Anhydrous DCP) is about 10% less available than the hydrated form
- Some rock phosphates contain various contaminants of concern for poultry. The most common of these is vanadium
- At just 7 – 10 ppm of the diet, vanadium will cause loss in internal egg quality and hatchability
- Rock phosphates can also contain as much as 1.5% fluorine (affects Ca metabolism). Only defluorinated rock phosphates are recommended for use in poultry feeds.

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Sources of Calcium & Phosphorus Cont.

Common Sources of Calcium & Phosphorus in Animal Feeds		
Ingredient (Source)	% Ca	% Available P
Limestone	**38.0**	-
Oyster shell	**38.0**	-
Calcium carbonate	40.0	-
Bone meal	26.0	13.0
Monocalcium phosphate (MCP)	**17.0**	**25.0**
Dicalcium phosphate (DCP)	**21.0**	**20.0**
Tricalcium phosphate	23.0	19.0
Defluorinated rock phosphate	34.0	19.0
Curaco phosphate	35.0	16.0
Phosphoric acid (75%)	-	25.0

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Limestone

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Oyster Shell

BENEFIT

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Di-calcium Phosphate (DCP)

BENEFIT

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Sources of Sodium

BENEFIT

- The most common sources of sodium that can be used in animal feeds are:
  - Sodium chloride: white in color
  - Iodized salt: red in color (fortified with iodine)
  - Cobalt-iodized salt: blue in color
- Because high levels of sodium chloride can lead to increased water intake, then a substitution of sodium bicarbonate for a portion of this chloride salt has been shown to be beneficial
- Under these conditions, up to 30% of the supplemental salt can be substituted with sodium bicarbonate without loss in performance, and such birds often produce drier manure
- Chloride contributed by ingredients such as choline chloride and lysine-HCl should be accommodated during formulation

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Sources of Sodium Cont.

Most Common Sources of Sodium in Animal Feeds		
Ingredient (Source)	**% Na**	**% Cl**
Plain salt (table salt)	39.0	60.0
Iodized salt	39.0	60.0 (Iodine, 70 mg/kg)
Cobalt iodized salt	39.0	60.0 (Iodine, 70 mg/kg; Cobalt, 40 mg/kg)
Sodium bicarbonate	27.0	-

Table Salt (NaCl)

Sources of Other Minerals

- Trace minerals are available in a variety of forms
- The hydrated sources of minerals are more soluble but of lower mineral concentration because the bounded water dilutes the mineral concentration
- For example, hydrated cupric sulphate (white crystal) contains about 40% copper, whereas the more common pentahydrate (blue) contains 26% copper
- In considering concentration of mineral sources, oxides appear attractive, since they invariably contain the highest mineral concentration.
- Oxides however, are potent oxidizing agents, and if stored with premixed vitamins for any length of time, can cause the destruction of vitamins that are susceptible to oxidation
- *Since oxides are generally less available than other mineral salts, they should not be used exclusively in mineral premixes.*

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Sources of Other Minerals

BENEFIT

Cobalt Sources			
Trace element	**Common Sources**	**% of Major Element**	**Notice**
Cobalt	**Oxide**	**71.0**	- **Cobalt sulphate more available than cobalt carbonate.** - **Cobalt oxide is of very low availability & should not be considered during formulation**
	Chloride	**24.0**	
	Sulphate	**21.0**	
	Carbonate	**46.0**	

Sources of Other Minerals

Cobalt Sulphate

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Sources of Other Minerals

BENEFIT

Copper Sources			
Trace element	**Common Sources**	**% of Major Element**	**Notice**
Copper	**Oxide**	**79.0**	- Copper oxide is of very low availability - Copper sulfate is of higher - availability - Degree of hydration of Cu-sulphate should be specified
	Chloride	**37.0**	
	Sulphate	**25.5**	
	Carbonate	**55.0**	

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Sources of Other Minerals

Copper Sulphate

Sources of Other Minerals

Magnesium Sources			
Trace element	Common Sources	% of Major Element	Notice
Magnesium	Oxide	56.0	- Mg-oxide can take up water & CO_2 when stored, this reduces potency of Mg
	Carbonate	30.0	

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Sources of Other Minerals

Magnesium Carbonate

Sources of Other Minerals

Manganese Sources			
Trace element	Common Sources	% of Major Element	Notice
Manganese	Oxide	77.0	- Mn-oxide is the major source in feeds because its use is more economical than other sources. - Mn-oxide availability ranges 50-70%
	Chloride	27.5	
	Sulphate	32.5	
	Carbonate	47.0	

Sources of Other Minerals

Manganese Sulphate

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Sources of Other Minerals

Zinc Sources			
Trace element	Common Sources	% of Major Element	Notice
Zinc	Oxide	78.0	- Zinc-oxide & Zinc sulphate are commonly used in feed industry & they are of comparable availability
	Chloride	48.0	
	Sulphate	36.0	
	Carbonate	52.0	

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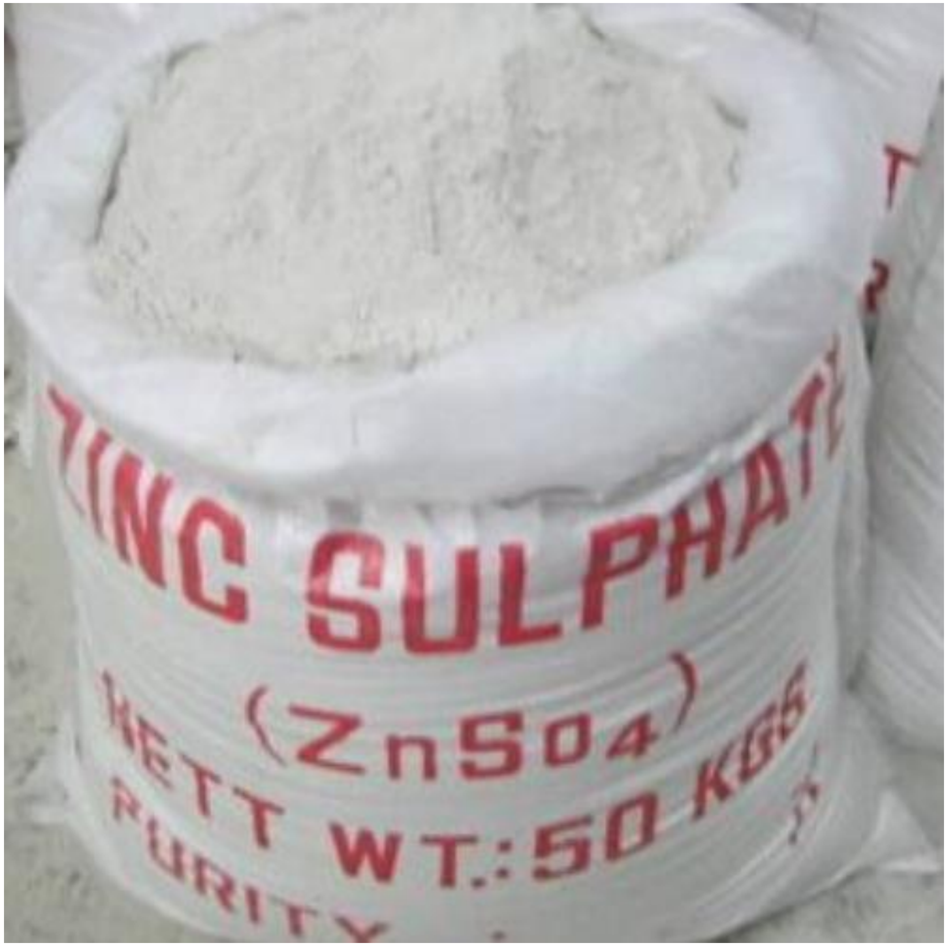
Sources of Other Minerals

Zinc Sulphate



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Sources of Other Minerals

Selenium Sources			
Trace element	Common Sources	% of Major Element	Notice
Selenium	Sodium selenite	46.0	- Sodium selenate is more available than sodium selenite - Selenium availability from whatever source, is improved when diets contain antioxidants
	Sodium selenate	42.0	

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Sources of Other Minerals

Sodium selenate

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Sources of Other Minerals

Iodine Sources			
Trace element	**Common Sources**	**% of Major Element**	**Notice**
Iodine	**Potassium iodine**	**77.0**	**- Calcium iodate is preferred to potassium iodine because it is more stable & do not deteriorate due to exposure to light, heat & moisture as potassium iodine**
	Calcium Iodate	**65.0**	

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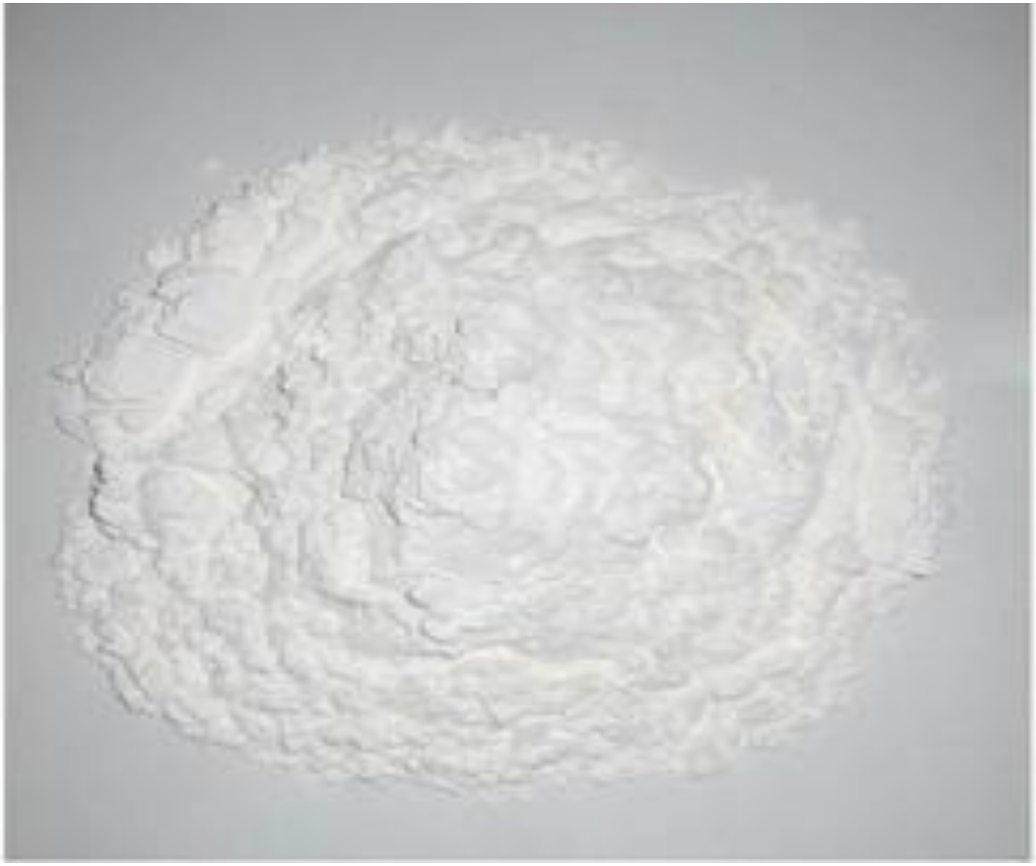
Sources of Other Minerals

Calcium Iodate Anhydrous



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- Trace minerals are available in a variety of forms
- The hydrated sources of minerals are more soluble but of lower mineral concentration because the bounded water dilutes the mineral concentration
- For example, hydrated cupric sulphate (white crystal) contains about 40% copper, whereas the more common pentahydrate (blue) contains 26% copper
- In considering concentration of mineral sources, oxides appear attractive, since they invariably contain the highest mineral concentration.
- Oxides however, are potent oxidizing agents, and if stored with premixed vitamins for any length of time, can cause the destruction of vitamins that are susceptible to oxidation
- *Since oxides are generally less available than other mineral salts, they should not be used exclusively in mineral premixes.*

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Practicing of Calculations

BENEFIT

Example 1: How do we know that sodium chloride (NaCl) contains **about 39% Na** & **60% Cl**?

- From the periodic table we find that:

- Atomic weight of Na= 23 g/mole
- Atomic weight of Cl= 35.45 g/mole
- Then the atomic weight of NaCl= 1x23 +1x35.45= 58.45 g/mole
- The level of Na in NaCl= 23/58.45 x 100%= 39.3% (around 39%)
- The level of Cl in NaCl= 35.45/58.45x 100%= 60.6% (around 60%).

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Practicing of Calculations

BENEFIT

Example 2: Calculate the level of **Na & S** in sodium sulphate (**Na_2SO_4**).

- Atomic weight of Na= 23 g/mole
- Atomic weight of S= 32 g/mole
- Atomic weight of O= 16 g/mole
- Then the atomic weight of **Na_2SO_4**= 2x23 +1x32+4x16= 142 g/mole
- The level of **Na** in **Na_2SO_4**= 46/142 x 100%= 32.4%
- The level of **S** in **Na_2SO_4** = 32/142x 100%= 22.5%

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Example 3: A feed mill is using the following formula to make broilers starter ration.

Ingredients	Level (Kg/ton)	Na% in Ingredients
Corn	359	0.03
Wheat	150	0.05
Sunflower meal (37% CP)	50	0.1
Soybean meal (48% CP)	340	0.04
Soup-stock oil	50.5	-
Limestone	16	-
DCP	14	-
Lysine	4.5	-
Methionine	4.5	-
Valine	0.5	-
AB-20	2	-
Pellet binder	3	-
Vitamins & Minerals premix (contains): - 2.471 Kg NaCl - 1.0 Kg Na_2SO_4	6	- 39% in NaCl - 32.4% in Na_2SO_4

- Now, Calculate the level of sodium in this ration.
- If the requirements of sodium in broilers starter is 0.20% (2kg Na/tone) then does this ration satisfy the requirements of birds from sodium? What are your suggestions to meet the requirements if you have sodium bicarbonate in the feed mill?

(37%)			
Soybean meal (48% CP)	340	0.04	340 kg x 0.04%= 0.136
Soup-stock oil	50.5	-	-
Limestone	16	-	-
DCP	14	-	-
Lysine	4.5	-	-
Methionine	4.5	-	-
Valine	0.5	-	-
AB-20	2	-	-
Pellet binder	3	-	-
Vitamins & Minerals premix (contains): - 2.471 Kg NaCl - 1.0 Kg Na_2SO_4	6	- 39% in NaCl - 32.4% in Na_2SO_4	2.471 kg x 39%= 0.964 1.0 kg x 32.4%= 0.324
		Total= 1.6567Kg/ton =1.6567kg/1000kg x100% = about 0.17%	

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- Thus, the level of Na in this ration do not meet the requirements & there is a deficit equals to = 0.20% - 0.17% = 0.03% = (0.03kg /100 kg of feed = 0.3 kg/ton = 300g/ton).
- This deficit can be met by adding of sodium bicarbonate (27% Na) to the ration with quantity that equals to =

Each 100 g of Na-bicarbonate contains 27 g sodium

?? 300 g sodium

= (300 X 100)/27 = 1111 g sodium bicarbonate = 1.1 kg sodium bicarbonate should be added to one ton of ration to fulfill the required level of Na in the ration = (0.20%)

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BENEFIT

Samples of Locally Available Vitamins & Minerals Premixes Added to Feeds of Livestock Animals

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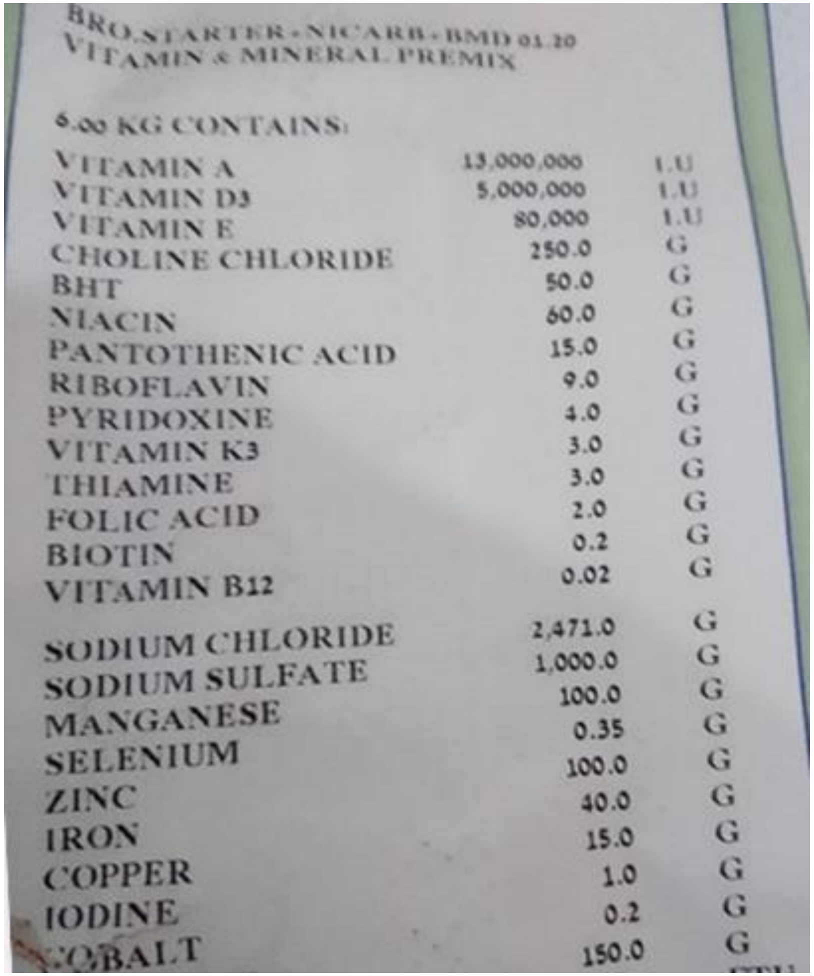
Broilers Starter Premix

BENEFIT


BRO.STARTER+NICARB+BMD 01.20
VITAMIN & MINERAL PREMIX

6.00 KG CONTAINS:

VITAMIN A	13,000,000	I.U
VITAMIN D3	5,000,000	I.U
VITAMIN E	80,000	I.U
CHOLINE CHLORIDE	250.0	G
BHT	50.0	G
NIACIN	60.0	G
PANTOTHENIC ACID	15.0	G
RIBOFLAVIN	9.0	G
PYRIDOXINE	4.0	G
VITAMIN K3	3.0	G
THIAMINE	3.0	G
FOLIC ACID	2.0	G
BIOTIN	0.2	G
VITAMIN B12	0.02	G
SODIUM CHLORIDE	2,471.0	G
SODIUM SULFATE	1,000.0	G
MANGANESE	100.0	G
SELENIUM	0.35	G
ZINC	100.0	G
IRON	40.0	G
COPPER	15.0	G
IODINE	1.0	G
COBALT	0.2	G
[illegible]	150.0	G

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BENEFIT

Broilers Grower & Finisher Premix

BROILER/GROWER+MADURA
+BMD01.20
VITAMIN & MINERAL PREMIX

6.00 KG CONTAINS:

VITAMIN A	10,000,000	I.U
VITAMIN D3	5,000,000	I.U
VITAMIN E	50,000	I.U
VITAMIN K3	3.0	G
THIAMINE	2.0	G
RIBOFLAVIN	8.0	G
NIACIN	50.0	G
PANTOTHENIC ACID	12.0	G
PYRIDOXINE	3.0	G
FOLIC ACID	2.0	G
VITAMIN B12	0.015	G
BIOTIN	0.18	G
BHT	50.0	G
CHOLINE CHLORIDE	200.0	G
MANGANESE	100.0	G
ZINC	100.0	G
IRON	40.0	G
COPPER	15.0	G
COBALT	0.2	G
IODINE	1.0	G
SELENIUM	0.35	G
SODIUM CHLORIDE	2,500.0	G
SODIUM SULFATE	1,000.0	G
AXTRA XAP	150.0	G

Components	Unit / tone	Broilers Starter Premix	Broilers grower & Finisher Premix
Vitamin A	IU	13000000	10000000
Vitamin D3	IU	5000000	5000000
Vitamin E	IU	80000	50000
Vitamin K3	G	3	3
Thiamine	G	3	2
Riboflavin	G	9	8
Niacin	G	60	50
Pantothenic acid	G	15	12
Pyridoxine	G	4	3
Folic acid	G	2	2
Vitamin B12	G	0.02	0.015
Biotin	G	0.2	0.18
BHT	G	50	50
Choline chloride	G	250	200
Manganese	G	100	100
Zinc	G	100	100
Iron	G	40	40
Copper	G	15	15
Cobalt	G	0.2	0.2
Iodine	G	1	1
Selenium	G	0.35	0.35
Sodium chloride	G	2500	2500
Sodium sulfate	G	1000	1000
Axtra Xap	G	150	150
Phytase	FTU	750	750
BMD	G	55	55
Nicarb	G	90	Maduramycin (5.0 G)

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Recommended Premixes for Cobb Broilers

Supplementary levels of Vitamins and Trace elements (per tonne)				
		Starter	Grower	Finisher 1/2
Vitamin A (Maize diets)	(MIU)	13	11	10
Vitamin A (Wheat diets)		14	12	11
Vitamin D3	(MIU)	5	5	5
Vitamin E	(KIU)	80	60	50
Vitamin K	(g)	4	3	3
Vitamin B1 (thiamine)	(g)	4	2	2
Vitamin B2 (riboflavin)	(g)	9	8	8
Vitamin B6 (pyridoxine)	(g)	4	4	3
Vitamin B12	(mg)	20	15	15
Biotin (Maize Diets)	(mg)	150	120	120
Biotin (Wheat Diets)		200	200	180
Choline	(g)	400	400	350
Folic Acid	(g)	2	2	1.5
Nicotinic Acid	(g)	60	50	50
Pantothenic Acid	(g)	15	12	12
Manganese	(g)	100	100	100
Zinc	(g)	100	100	100
Iron	(g)	40	40	40
Copper	(g)	15	15	15
Iodine	(g)	1	1	1
Selenium	(g)	0.3	0.3	0.3

MIU = million international units
KIU = thousand international units
g = grams
mg = miligrams

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BENEFIT

Chapter 4: Feed Additives in Animal Feeding

Mr. Raed Dayeh-Hebron University

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Non Nutritive Feed Additives

BENEFIT

➢ Contents:

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Non Nutritive Feed Additives

➢ Introduction:

- Feed additives are non-nutritive substances added to feed to improve the efficiency of feed utilization & feed acceptance, or to be beneficial to health or metabolism of the animal in some way. In other words, they are substances other than the known nutrients.
- The food & drug administration (FDA) must approve the feed additive before it can be used commercially.

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1- Antifungals

BENEFIT

- The molds have the following bad effects:

- Reduce palatability
- Produce mycotoxins

- Mold growth can be prevented by:

- Adequate drying: H_2O in feed s or feed ingredients not more than 12%
- Using of antifungals when H_2O is more than 13%

- Examples of antifungals are:

- Propionic acid
- Sodium diacetate
- Sorbic acid
- Gentian violet
- Ammonia treatment.

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2- Antioxidants

- Antioxidants are used to:
- prevent the destruction of fat (rancidity) & destruction of fat-soluble vitamins.
- To overcome toxic effects of peroxides
- Examples of antioxidants are:
- Vitamin E & vitamin C (natural antioxidants)
- Ethoxyquin, BHT & BHA (synthetic antioxidants).

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3- Pellet Binders

- *Advantages of pelleting are:*

- Increase density of feed & this will:
  - ✓ Increase feed intake
  - ✓ Increase growth rate
  - ✓ Increase feed efficiency
- Reduce feed wastage due to fines
- Eliminate sorting of ingredients by animal
- Reduce dust & increase the ease of handling.

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3- Pellet Binders Cont.

- ***Disadvantages of pelleting:***
- Increase the cost of ration
- Destruction of some vitamins due to high temp. of steam
- Examples of pellet binders are:
- Bentonites: added at levels 2-3% of diet, improve the utilization of ammonia in rumen by microbes (binds ammonia) & absorbs mycotoxins.
- Hemicellulose extracts
- Lignin sulfonates

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4-Feed flavors (sweeteners)

- Used to increase the acceptance of diets low palatability & to increase feed intake during periods of stress (diseases, heat stress, weaning etc.)
- Examples are:

• Sucrose
• Saccharin
• Glucose

5- Enzymes: (Digestion modifiers)

- Used to enhance the digestibility of certain feed nutrients & so improves growth rate of birds & prevent some bad effects such as wet litter & sticky droppings.
- Some examples are:

- B-glucanase: improves digestibility of B-glucan in oat & barley
- Arabinoxylanase: improve the digestibility of arabinoxylan in wheat & rye
- Phytase: to increase the bioavailability of phosphorus
- Cellulase, proteases, α-amylase & lipases are other examples.

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6- Buffers

- Are salts of weak acid or base that resist changes in PH.
- Buffers are used extensively for ruminants fed high concentrate diets due to high production of acids in rumen due to fermentation & the low production of saliva that is rich in buffers.
- Examples of buffers are:

• Sodium bicarbonate
• Potassium bicarbonate
• Magnesium bicarbonate
• Calcium carbonate
• Bentonites

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6- Buffers Cont.

- *Sodium bicarbonate* is probably the most frequently used buffer & it's use in a level of 1.5% in diet keeps the ruminal pH more than 6 & so increases the digestibility of cellulose, protein & DM of feed.
- *Ground limestone* as a buffer enhances post-ruminal starch digestion.

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7-Ion Exchange Compounds

BENEFIT

- Zeolites (hydrated aluminosilicates from clay) are the principle ion exchange compounds.
- Zeolites have beneficial effects on growth, feed efficiency & incidence of enteric disease.
- Zeolites might improve the utilization of NPN compounds by ruminants by complexing with ammonium ions & releasing them gradually over a period of time.
- The above property of zeolite is used to remove ammonia from poultry houses.
- Aluminosilicates are effective absorbents or binders of aflatoxins.

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8-Ionophores & Methane Inhibitors

BENEFIT

- Ionophores are a class of antibiotics that are extensively used as feed additives for cattle.
- The major ionophores used are:

• Monensin (rumensin): called monensin when used in poultry feeds & rumensin when used in ruminant feeds.
• Lasalocid
• Salinomycin
• Lysocellin
• Narasin

- All of these ionophores are used as coccidiostats in poultry feeding.

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8-Ionophores & Methane Inhibitors Cont.

- Feeding ionophores has the following desired effects especially in cattle:

- Improves feed efficiency
- Improves daily weight gain
- Increases the proportion of propionic acid in the end products of fermentation & so reduces the production of CO2 & methane in rumen, this increases the net energy value of feeds. Thus, the Ionophores are also named methane inhibitors that helps in reducing methane emissions that linked to global warming.
- Stimulates hepatic gluconeogenesis in liver.

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8-Ionophores & Methane Inhibitors Cont.

- Reduce lactic acidosis
- Aid in control of coccidiosis
- Toxic to larva of flies in feces
- Reduce time to estrus following parturition because it enhances gluconeogenesis & so the energy status of the animal is improved.

- Monensin is toxic to horses & donkeys.

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9- Isoacids

- These acids could improve the microbial metabolism in rumen & was found to improve milk production in dairy cattle.
- Examples of isoacids are:

• Isobutyric acid, Methylbutyric acid & Isovaleric acid

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10- Probiotics

- Probiotics are live microbes used to improve GIT microbial balance.
- Probiotics are natural alternatives to antibiotics.
- Probiotics must be:

• Viable & capable of growing in the intestinal tract
• Able to survive during passing the acidic environment of stomach
• Resistant to bile if they are to survive in the intestine
• Capable of competing the existing gut microflora
• Capable of producing the desired effect in host

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10- Probiotics Cont.

- Examples of probiotics are:
- Lactobacilli:
  - ✓ Attaches to intestinal mucosa & so prevents the enteric pathogens such as E. Coli to attach & cause their disease effects (improves host resistance).
- Yeast cultures:
  - ✓ Improves performance of calves during stress
  - ✓ Increases feed intake through increasing palatability or stimulation of rumen fermentation
  - ✓ Stimulates cellulolytic bacteria growth, thus increasing cellulose digestion.

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10- Probiotics Cont.

- Lysine secreting lactobacilli
- Probiotics that improve lactate utilization & reduce lactic acidosis.

11- Acidifiers (Acidifying Agents)

- These additives lower the pH in the stomach to create acidic environment.
- Examples of acidifiers are:
  - Citric acid
  - Fumaric acid
- Acidifiers are provided to animals at weaning time because the stomach does not become highly acidic until after weaning. This gives some pathogenic bacteria to develop & cause post-weaning diarrhea.
- Benefits of using acidifiers includes the following:
  - Prevention of post-weaning diarrhea
  - Improves growth rate & feed efficiency in pigs & broilers
  - Acidified milk replacer reduces survival of E. Coli in gut.

12- Anti-Bloating Agents

- Effective in preventing frothy bloat.
- Frothy bloat is associated with the consumption of lush, legume pasture.
- Anti-bloat agents are usually provided as components of blocks.
- Example of anti-bloating agents is:

• Poloxalene.

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13-Salivation Inducers

- These additives induce saliva secretion
- Example:
  - *Slaframine* (a mycotoxin produced by fungi that grow on red clover)
- This additive is used when low fiber high concentrate diets are fed to ruminants.
- Slaframine increases saliva production & secretion, increases the rumen PH & so increases the efficiency of feed utilization & microbial protein synthesis.

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14- Defaunation Agents

BENEFIT

- Defaunation is a process of treating a ruminant to eliminate its rumen protozoa.
- Examples are:
  - Copper sulfate
  - Nonionic & ionic detergents
- The role of protozoa in rumen:
  - Protozoa feed on bacteria, fungi & on small particles of feed in rumen.
  - Prevents excessive growth of bacteria in rumen when high concentrate diets are fed.
- Defaunation increases the population of rumen fungi.

14- Defaunation Agents Cont.

- Defaunation improves animal performance when high-energy low-protein diets are fed to cattle & sheep because the retention of a large population of protozoa in rumen due to feeding of these diets reduces the availability of microbial protein to the host animal & limits its performance or production.
- Defaunated sheep may be susceptible to copper toxicity.

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15-Hormones (metabolism modifiers)

- They increase the muscle mass & reduce the fat mass in carcass.
- Examples are:
  - Estrogen (zearalenone or Ralgro)
  - Melengestrol acetate (MGA): a synthetic progesterone.
  - Noradrinalin analogs such as clenbuterol & cimaterol (named B-agonists or repartitioning agents).
- FDA approval for the use of these additives has been withdrawn, thus they are not available for use in feeds in all of the world countries.

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16-Antibiotics (Growth promoters)

- Antibiotics are natural metabolites of fungi that inhibit the growth of bacteria.
- Antibiotics used as growth promotants are fed at lower levels than when they are used for the treatment or prevention of disease.
- Antibiotics mode of action:

• Microbes responsible for mild but unrecognized infections are suppressed

• Microbes production of growth depressing toxins is reduced

• Reduce microbial destruction of essential nutrients in the gut & improves the synthesis of vitamins & growth factors by microflora

16-Antibiotics (Growth promoters) Cont.

- There is enhanced efficiency of nutrients absorption because the intestinal wall is thinner
- Subtherapeutic levels of antibiotics increase an animal's ability to withstand stress & aid in control of postweaning diarrhea
- Examples for the most commonly used growth-promoting antibiotics are:
- Bacitracin
- Chlortetracycline (commercial products is Aurofac)
- Erythromycin
- Neomycin
- Virginiamycin

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16-Antibiotics (Growth promoters) Cont.

- The wide-spread of antibiotics may lead to the development of antibiotic-resistant strains of bacteria which could make the treatment of human disease more difficult. Thus, many countries in the world prohibited the addition of antibiotics in feeds.

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17- Worming Agents & Coccidiostat

- Examples are:

- Worming agents such as phenothiazine & piperizine
- Coccidiostates such as monensin, amprolium & sulfaquinoxaline

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BENEFIT

Chapter 5: Feed Formulation

(Algebraic & Pearson Square Methods)

Mr. Raed Dayeh-Hebron University

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Introduction

BENEFIT

Ration: Certain amount of feed provided to an animal in a 24-hour period.

A balanced Ration: is the amount of feed that will supply the proper amount and proportions of nutrients needed for an animal to perform a specific purpose such as growth, maintenance, gestation, lactation or laying.

University College of Applied Sciences

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Ration Formulation Methods

1. Algebraic Method:

- Allow formulation of simple mixtures (rations) on the basis of a single nutrient (ex. protein).

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Ration Formulation By Algebraic Method

- **Example 1:**

Formulate 100 Kg of a complete lamb diet containing 16% crude protein (CP). The feeds to be used are corn (8.9% CP) and Sunflower meal (SFM) containing 36% CP.

- **Solution:**

- X = Kgs of corn
- Y = Kgs of Sunflower meal
- **Equation 1:** $X + Y = 100$ **Kgs**
- **Equation 2:** $0.089\,X + 0.36\,Y = 16$ **Kg protein**

Ration Formulation By Algebraic Method Cont.

- A third equation is developed to subtract from equation (2) in order to cancel either X or Y; equation (3) is developed by multiplying everything in equation (1) by a factor of 0.089, thus,
- Equation 3 = 0.089 X +0.089 Y = 0.089 X 100
- **Equation 3 = 0.089 X +0.089 Y = 8.9**
- Now, subtract equation 3 from equation 2 as follow:

Equation 2: **0.089 X + 0.36 Y = 16 Kg protein**

Equation 3: **- 0.089 X - 0.089 Y = - 8.9**

----

0 **0.271Y = 7.1kg**

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Ration Formulation By Algebraic Method Cont.

Then, Y= 7.1/0.271 = 26.2 **Kg SFM**

X + Y = 100 (equation 1)

So, X = 100 -Y

X = 100 – 26.2 = 73.8 **Kg Corn**

- **Check:**

73.8 Kgs. corn X 8.9% CP= 6.57 Kgs. CP

26.2 Kgs. SFM X 36.0% CP= 9.43 Kgs. CP

--

100 Kgs **16.0 Kgs CP**

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Ration Formulation Methods

2. Pearson Square Method:

- This method can be used to formulate rations under the following Five Scenarios:

- Scenario 1: When only two feeds are involved
- Scenario 2: When three or more feeds are involved
- Scenario 3: When definite amounts of two nutrients are required
- Scenario 4: With a fixed percentage of one or more ration components
- Scenario 5: Formulating a ration by the use of many ingredients & by considering the level of many nutrients or components in the ration.

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Precautions About Using the Pearson Square:

1- It can only be used for two feed materials; however, either or both of these can be mixtures as long as the percentage of the nutrient of interest has been determined for the mix.

2- The number in the center of the square must be intermediate to the two numbers at the left corners.

3. The requirement must be expressed as a percent or proportion and can be used for any nutrient or expression of energy, e.g., percent protein, percent Ca, percent TDN, Mcal/lb., etc.

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Pearson Square Method

- **Scenario 1: When only two feeds are involved.**
- Sometimes it might be necessary to determine what combination of feeds will give a mixture with the desired content of a particular nutrient.

- **Example on Scenario 1:**

A sheep producer wants to formulate a Concentrate supplement that provides 16% Crude protein. He has shelled corn (9% CP) and Cottonseed cake (40% CP). What combination of the shelled corn and cottonseed cake will provide a mix of 16% CP the producer wants?

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Pearson Square Method

- **Solution:**

a. Draw a square at the left side of the page;

b. Insert the % CP desired in the final mixture (16) in the middle of the square;

c. Place corn with its percent CP (9) on the upper left corner & the cottonseed cake with its CP (40) on the lower left corner;

d. Subtract the % CP desired (16) from the % CP in corn (9) and place the difference (7) without the negative sign at the corner of the square diagonally opposite the corn (on the lower right side of the square);

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Pearson Square Method

- **Solution Cont.:**

e- Subtract the % CP desired in the final mix (16) from the % CP in the cottonseed cake (40) and place the difference (24) at the corner of the square diagonally opposite from the Cottonseed cake (at the upper right corner of the square). The above remainders represent proportions of the two feeds that will provide a mix containing the desired % CP.

f. The amounts can then be converted to a percentage basis and then to any other weight basis (e.g. quintal / ton) as desired for mixing purposes.

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Pearson Square Method

➢ **Solution Cont.:**

INGREDIENT			PROPORTIONS	ON % BASIS	ON A QUINTAL BASIS
Corn	9		24	(24/31)*100=77.4	77.4%*100= 77.4Kg corn
		16			
CS Cake	40		7	(7/31)*100=22.6	22.6%*100=22.6Kg CS Cake
TOTAL			31 parts	100	100 Kg (Quintal)

Thus, mixing 77.4% corn (9%CP) and 22.6% Cottonseed cake (40%CP) will provide a mix of 16% CP.

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Pearson Square Method

➢ Check:

- One can check whether the final mix really contains the desired Crude Protein (CP) level by calculating the contributions of the ingredients constituting the mixture (corn and CS cake) and summing up.

- Contribution of corn = (9*77.4)/100=7

- Contribution of CS Cake = (40*22.6)/100=9

Total CP in mix = 7+9 = 16%

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Pearson Square Method

- **Scenario 2: When three or more feeds are involved .**

- It is common practice to use more than just two feeds in formulating a feed mixture to attain a specific nutrient level.

- **Example on Scenario 2:**

What combination of corn (10% CP), Wheat bran (13%CP) and cottonseed Meal (CSM-40%CP) will provide a mix (a ration) of 16% CP?

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Pearson Square Method

- **Solution:**

Construct the Pearson Square and do the following:

a. Categorize the feeds into two groups since the square can handle only two categories at a time;

b. Specify the proportion of each feed in each group;

c. Calculate the weighted average % protein in each group.

For this example, let us assume that corn and wheat bran are grouped together in the proportion of **2:1** with cottonseed meal being used alone.

Pearson Square Method

➢ Solution Cont.:

- The weighted average % CP in the corn/bran must then be calculated as follows:

2 parts corn contributes 2*10(%CP) = 20

1 part wheat bran contributes 1*13 (%CP) = 13

TOTAL 33

- A mixture of 2 parts corn and 1 part bran (total of 3 parts) will, therefore, contain 33/3 = 11% CP. This %CP will be used for the "2 parts corn + 1 part bran" designated as CB to occupy one corner of the square and the cottonseed meal the other corner.

Proceed with the calculations as in the previous example.

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Pearson Square Method

BENEFIT

➢ Solution Cont.:

- Divide the final figure for "corn + bran" into 2/3 corn and 1/3 bran (the proportion of each feed in each group must always be indicated initially and complied with in the final mixture).

INGREDIENT	PROPORTIONS	ON % BASIS	ON A TON BASIS
CB 11	24	(24/29)*100=82.76	82.76%*1000=827.6Kg CB
16			
CSM 40	5	5/29*100=17.24%	17.24%*1000=172.4Kg CSM
TOTAL	29 parts	100	1000

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Pearson Square Method

- **Solution Cont.:**

- Ration composition will, therefore, be as follows:

Corn (2/3*82.76) = 55.17%
Wheat bran (1/3*82.76) = 27.59%
Cotton seed meal = 17.24%
TOTAL 100.0%

- **Check:**

- To check your calculations, multiply the last ration composition by the CP of each feed source as follows:

Corn contributes (55.2/100)*10 = 5.52

Wheat bran contributes (27.6/100)*13 = 3.59

CSM contributes (17.2/100)*40 = 6.89

TOTAL CP IN MIX = 16.00%

Pearson Square Method

- **Scenario 3: When definite amounts of two nutrients are required.**

- Under normal circumstances, rations are formulated to meet animal requirements for many nutrients at the same time.
- A modification of the Pearson's Square Method known as the **"Double Pearson's Square" method** can be used to formulate a ration mixture that has exact amounts of two nutrients.
- Consideration of more than two nutrients using this method becomes too complicated.
- The use of alternative methods like the trial-and-error method illustrated later in this bulletin may be more convenient.
- The use of the Double Pearson Square method to formulate a ration that meets two nutrients is demonstrated by the following example.

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Pearson Square Method

- **Example on Scenario 3:**

Suppose we want to formulate a mix with 16% CP and 2.8 Megacalories/Kg (Mcal/Kg) Metabolizable Energy (ME) by using the following feeds:

a. Corn: 9% CP and 3.4 Mcal/Kg ME;

b. Cottonseed meal: 42% CP and 2.86 Mcal/Kg ME;

c. Alfalfa hay: 18% CP and 2.49 Mcal/Kg ME

Pearson Square Method

- **Solution:**

- To solve this problem, one has to go through two squares and get a mix exact for one of the nutrients. Any one of the nutrients can be taken first. Let us take CP. **The first step is to formulate two different mixes:**

- one having exactly 16% CP and ME greater than the desired (>2.8Mcal/Kg); &
- another mix with 16% CP and ME less than the desired level (<2.8 Mcal/Kg ME).
- At least three feedstuffs are needed to do this.

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Pearson Square Method

BENEFIT

➢ Solution Cont.:

- **Step 1. Mix 1 (*16% CP; >2.8 Mcal/kg ME*)**

INGREDIENT			PROPORTIONS	ON % BASIS	CALCULATE ME
Corn	9		26	(26/33)*100=78.7%	78.7%*3.4=2.68
		16			
Cotton SM	42		7	7/33*100=21.3%	21.3%*2.86=0.61
TOTAL			33 parts	100	3.29

- **This mix supplies 16% CP and 3.29 Mcal/kg ME (greater than the desired 2.8 Mcal/Kg ME level).**

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Pearson Square Method

BENEFIT

- **Solution Cont.:**

- **Step 2. Mix 2 (16% CP;<2.8 Mcal/kg ME)**

INGREDIENT		PROPORTIONS	ON % BASIS	COMPUTE ME
Corn	9	2	(2/9)*100=22.2%	22.2%*3.4=0.75
	16			
Alfalfa	18	7	7/9*100=77.8%	77.8%*2.49=1.94
TOTAL		9 parts	100	2.69

- **This Mix supplies 16% CP and 2.69 Mcal/kg ME (less than the desired ME level).**

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Pearson Square Method

- **Solution Cont.:**

- **Step 3. Then solve for ME.**

- Mixing the two mixes formulated in steps 1 and 2 above in any proportion will not change the CP composition of the final mix since both contain 16% CP. The nutrient that will vary would be the ME. The last step is, therefore, to find the proportions of the two mixes that should be combined to give 2.8 Mcal / kg ME. Thus a third Pearson square should be made to do mix 3 (final mix).

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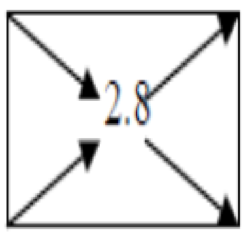
Pearson Square Method

➢ **Solution Cont.:**

- **Mix 3 (final mix) 16% CP and 2.8 Mcal / kg ME.**

INGREDIENT		PARTS	ON % BASIS
Mix 1 3.29		0.11	(0.11/0.60)*100=18.3%
Mix 2 2.69		0.49	0.49/0.6*100=81.7%
TOTAL		0.60 parts	100

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Pearson Square Method

- **Solution Cont.:**

- **Step4. Calculate ingredient composition in final mix.**

*** Corn:**

- In mix 1, 78.7 (18.3% of mix 1 in mix 3) = (78.7*18.3/100) =14.40

- In mix 2, 22.2 (81.7% of mix 2 in mix 3) = (22.2*81.7/100) =18.14

Total Corn = 14.4+18.14=**32.54%**

*** Cotton Seed Meal:**

- Only in mix 1, 21.3 (18.3% of mix 1 in mix 3)= (21.3*18.3/100)) **=3.90%**

*** Alfalfa**

- only in mix 2, 77.8 (81.7% of mix 2 in mix 3) = (77.8*81.7/100)

=63.56%

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Pearson Square Method

➢ **Solution Cont.:**

- Therefore, the ingredient composition of final ration will be:

Corn: 32.54%

CSM: 3.90%

Alfalfa 63.56%

Total 100.00%

- One can check whether the final mixture meets the desired levels of the nutrients by summing up the contributions of nutrients by each ingredient in the final mix.

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Pearson Square Method

- **Solution Cont.:**
- **Check:**

ME:

From Corn = 32.54% of 3.4(ME content of corn) = 1.11

From CSM = 3.90% of 2.86(ME content of CSM) = 0.11

From Alfalfa = 63.56% of 2.49(ME content of Alfalfa) = 1.58

Total ME in mix = 2.8Mcal/Kg (*Correct!*)

CP:

From Corn = 32.34% of 9 (CP content of corn) = 2.93

From CSM = 3.9% of 42 (CP content of CSM) = 1.63

From Alfalfa = 63.56% of 18(CP content of Alfalfa) = 11.44

Total CP in mix = 16% (*Correct!*)

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Pearson Square Method

- **Scenario 4:With a fixed percentage of one or more ration components.**

- It may sometimes be desirable to formulate a mixture using more than two different ingredients containing a particular percentage of a nutrient such as protein but with a fixed percentage of one or more ration components.

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Pearson Square Method

- **Example on Scenario 4:**

Let us assume that a sheep/goat producer wishes to formulate a 14% CP mixture using corn (9%CP), oats (12%CP), Sunflower meal (SFM-35%CP) and a mineral/vitamin supplement (0%CP). **If he decides** to include exactly 20% oats and **3% mineral/vitamin supplement** in the mixture, what combination of Corn and Sunflower meal can be used to make up the remaining 77% of the final mixture?

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Pearson Square Method

- **Solution:**

- A CP level of 14% is desired for the overall mixture. This means 14 kg of protein per 100 kg of mixture.
- Since 20 kg of each 100 kg of mix is oats (20%) it would supply = 2.4% (12% of 20 kg).
- The 3% mineral/vitamin supplement provides no protein (0%).
- Thus, the 23 Kgs of oats and mineral/vitamin premix per 100 kg of mix would provide

= 2.4 kg CP (2.4+0).

- The remainder of the 14 kg of CP needed i.e.

= 11.6 (14-2.4) must come from

the 77 (100-23) kg of corn and SFM seed meal.

Pearson Square Method

- **Solution Cont.:**

- In order to determine what combination of 77 kg of corn and SFM meal will provide the needed 11.6 kg of protein, an adaptation of the square method can be used.
- To do this, it is first necessary to calculate what % Crude Protein will be needed in the corn and SFM combination to provide 11.6 kg of crude protein per 77 Kgs as follows:

77 Kg should contain 11.6 kg

100 Kg should contain ???

=> (11.6/77)*100= 15.1 (the needed CP% of the corn and SFM mix)

Pearson Square Method

➢ Solution Cont.:

- This figure is then used in conjunction with the square method as follows: Per 77 parts (calculated by ratio)

Corn	9	19.9	19.9/26= x/77;	x= 58.93 parts corn
	15.1			
NSM	35	6.1	6.1/26= x/77;	x= 18.07parts NSM
TOTAL		26 parts		77.00

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Pearson Square Method

- **Solution Cont.:**

- Therefore, the constitution of the final ration will be:

Oats	**20.00%**
Mineral/Vitamin supplement	**3.00%**
Corn	**58.93%**
SFM	**18.0%**
	Total 100.00%

Pearson Square Method

- **Solution Cont.:**
- **Check:**

One can check whether the final mix provides the desired level of protein by summing up the contributions of protein by each of the constituent feed ingredients.

Contribution of Oats=	20*(12/100) =2.4%
Contribution of Mineral/Vitamin supplement=	3*(0/100) =0.0%
Contribution of Corn=	58.93*(9/100) =5.3%
Contribution of SFM=	18.07*(35/100) =6.3%
Total % Crude Protein in final (100%) Mix	**= 14.0%**

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Pearson Square Method

- **Scenario 5:Formulating a ration by the use of many ingredients & by considering the level of many nutrients or components in the ration.**

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Pearson Square Method

- **Example on Scenario 5:**

Formulate a ration for pregnant ewes in the last trimester of pregnancy that contains 15% CP, 2.7 Mcal/kg, 1.0% Ca, 0.5 P, 0.5% Salt, 0.1% vitamins & trace minerals premix by the using of the following ingredients:

Ingredient	CP%	ME (Mcal/Kg)	Ca%	P%
Corn	8	2.9	0.02	0.3
Soybean meal 48%	48	2.8	0.25	0.62
Wheat screenings	13	2.5	0.1	0.5
Limestone	---	---	38	---
DCP	---	---	22	19
Salt	---	---	---	---
Vitamins & minerals premix	---	---	---	---

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Pearson Square Method

➢ **Solution:**

- Suppose that the major ingredients (corn + SBM + WS) will compose about 97% of the ration & the level of the remained components (limestone + Premix + DCP+ Salt) will be about 3%.
- Then, the 150kg proteins in the 1000 kg of ration should be provided by 97% of the 1000 kg (ton) of ration. Thus, the ration should be formulated with a level of CP that equals to = 150kg CP / 970kg of ration * 100% = 15.46% around 15.5%.
- Moreover, the level of ME also should be adjusted to be 2.7 Mcal in 97% of the ration components, thus it should equal to = 2.7/0.97 = 2.78Mcal/kg.

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Pearson Square Method

➢ **Solution Cont.:**

- ***Mix 1: (15.5% CP)***

INGREDIENT		PROPORTIONS	ON % BASIS	CALCULATE ME
corn	8	32.5	(32.5/40) *100=81.25%	81.25%*2.9= 2.356
	15.5			
SBM	48	7.5	(7.5/40) *100=18.75%	18.75%*2.8 = 0.525
TOTAL		40 parts	100	2.88

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Pearson Square Method

- **Solution Cont.:**

- ***Mix 2: (15.5% CP).***

INGREDIENT	PROPORTIONS	ON % BASIS	CALCULATE ME
SBM 48	2.5	(2.5/35)*100 = 7.14%	7.14 %*2.8 = 0.20
15.5			
WS 13	32.5	(32.5/35)*100= 92.86%	92.86 %*2.5 = 2.32
TOTAL	35 parts	100	2.52

Pearson Square Method

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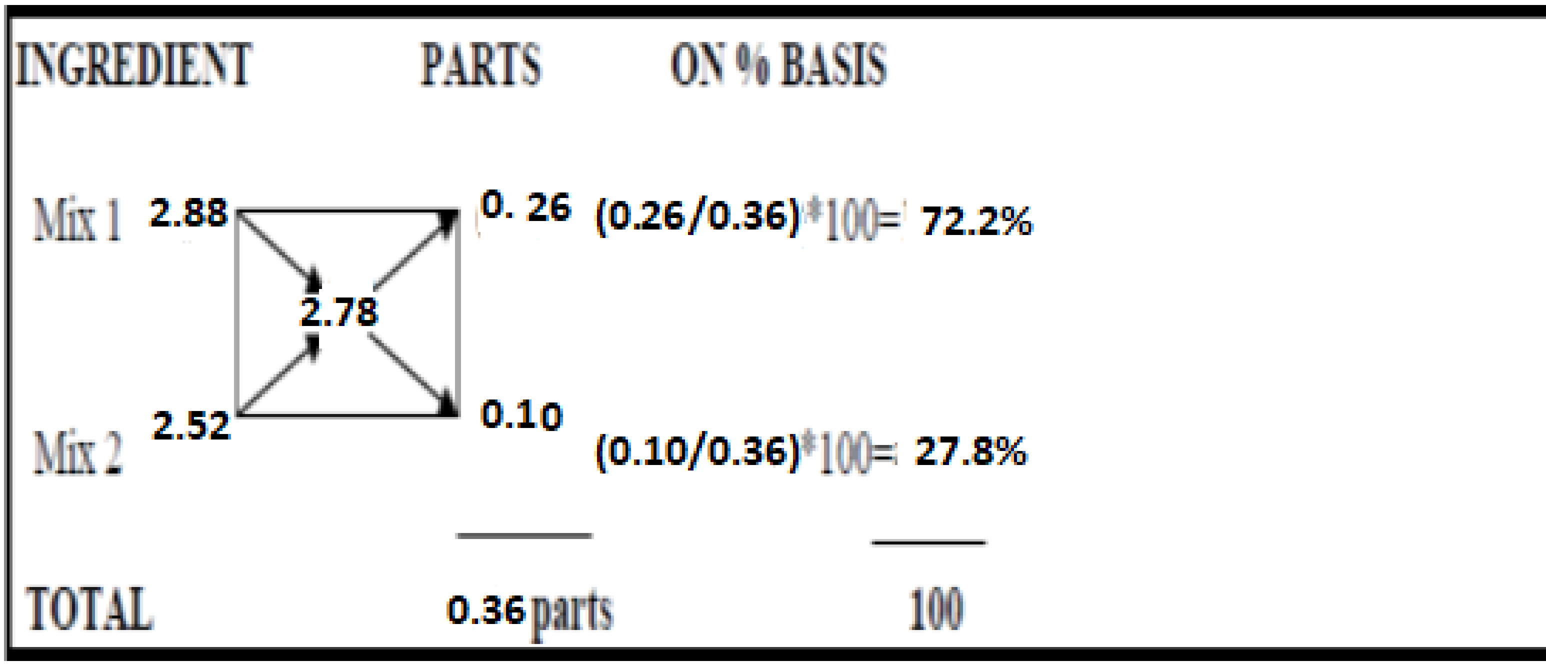
➢ Solution Cont.:

- ***Mix 3: (Final Mix). (15.5% CP & 2.78 Mcal ME).***



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Pearson Square Method

- **Solution Cont.:**

- ***Step 4. Calculate ingredient composition in final mix.***

*** SBM:**

- In mix 1= 18.75*(72.2% of mix 1 in mix 3)=(18.75*72.2/100)= 13.54%

- In mix 2= 7.14*(27.8% of mix 2 in mix 3)=(7.14*27.8/100)=1.98%

Total SBM = 13.54 +1.99= **15.53%**

*** Corn:**

- Only in mix 1= 81.25*(72.2% of mix 1 in mix 3)= (81.25*72.2/100)) =**58.66 %**

*** WS:**

- only in mix 2= 92.86*(27.8% of mix 2 in mix 3)= (92.86*27.8/100)

= **25.81%**

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Pearson Square Method

➢ Solution Cont.:

- *Therefore, the ingredient composition of the ration till now will be:*

Ingredient	%	CP%	ME (Mcal/kg)	Ca%	P%
Corn	58.66	4.69	1.70	58.66*0.02% = 0.012	58.66*0.30% = 0.176
SBM	15.53	7.45	0.435	15.53*0.25% = 0.039	15.53*0.62% = 0.096
WS	25.81	3.36	0.645	25.81* 0.1%= 0.026	25.81* 0.5%= 0.129
TOTAL	100	15.5	2.78	0.077	0.401
Requirement	100	15.5	2.78	1.0	0.5
Deficit	0	0	0	0.923	0.099

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Pearson Square Method

- **Solution Cont.:**

- Now, the deficiency of phosphorus should be covered first by the using of DCP (which will provide calcium beside phosphorus to the ration), as follow:

Each 1% DCP	Provides	0.19 P
??	Provides	0.099 P

= (0.099 * 1%)/0.19 = **0.52% DCP**

- But the 0.52% of DCP will provide calcium also by = 0.52% * 22% (0r 0.22) = **0.114%** Calcium, **thus the previous table will become as follow:**

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Pearson Square Method

➢ Solution Cont.:

Ingredient	%	CP%	ME (Mcal/kg)	Ca%	P%
Corn	58.66	4.69	1.70	58.66*0.02% = 0.012	58.66*0.30% = 0.182
SBM	15.53	7.45	0.435	15.53*0.25% = 0.039	15.53*0.62% = 0.096
WS	25.81	3.36	0.645	25.81* 0.1%= 0.026	25.81* 0.5%= 0.129
Previous total	100	15.5	2.78	0.077	0.401
DCP	0.52	---	---	0.114	0.099
New total	100.52	15.5	2.78	0.191	0.5
Requirement	100	15.5	2.78	1.0	0.5
Deficit or Excess	0. 52 excess	0	0	0.809 Deficit	0

Now the deficiency of calcium should be covered by the using of limestone, as follow:

1% limestone Provides 0.38 Calcium

?? Provides 0.809 Calcium

= (0.809 * 1%)/0.38 = 2.13% Limestone.

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Pearson Square Method

- **Solution Cont.:**
- **Therefore, the final ingredient composition of the ration will be:**

Ingredient	%	Kg/1032.5 kg	Kg/1000 kg (ton)	As %
Corn	58.66	586.6	568	56.8
SBM	15.53	155.3	150	15
WS	25.81	258.1	249.9	25
DCP	0.52	5.2	5.2	0.5
Limestone	2.13	21.3	21.3	2.1
Salt	0.5	5.0	5.0	0.5
VTM Premix	0.1	1.0	1.0	0.1
Total	103.25	1032.5	1000.4 Kg around (1 ton)	100%

In the third column we make adjustment for the large ingredients only & the levels of small ingredients remain as in column no.2.

CHECK THE COMPOSITION OF THE ABOVE RATION.

You can check the composition of the above ration by the using of the Excel sheets.

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Chapter 6: Trial & Error Method for Ration Formulation

Mr. Raed Dayeh-Hebron University

الكلية الجامعية للعلوم التطبيقية
University College of Applied Sciences

Introduction:

By the using of this method the requirements of the animal can be fully met.

When using this method, the trials lead to different diets with different contents but these diets should be manipulated until the required one is obtained.

This method of ration formulation is time consuming & stressful. However, the use of technology & the computer-based programs make such as Excel spreadsheet makes it easier & more interesting.

Requirements of Application:

- Nutrient composition of ingredients to be used as that shown in table 1 (Nutrient composition of some ingredients used in ration formulation for sheep).
- Determination of the ration specification which will help to achieve the animal nutrients requirements
- Guess a level for each ingredient included in the ration. Recommendations built on experience as that shown in table 2 can be followed to make the resulted formula close to the required one.

Requirements of Application:

- Design a ration formulation table in which the ration specifications are listed in the top raw, the available ingredients in the first Column, the proposed percentages for ingredients in the second column & the calculated total content of the proposed ration & requirements in the bottom rows as shown in table 3.
- Calculate the content of ration from energy & nutrients & compare that with the specifications of the required ration.
- Make adjustments for the levels of ingredients until the whole ration specifications are met.

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Table (1): Nutrient composition of some ingredients used in ration formulation for sheep (on as fed basis).

Ingredient	ME (Mcal/Kg)	CP%	Ca%	P%
Soybean meal (48%)	2.78	48.0	0.25	0.11
Corn	2.78	7.0	0.01	0.31
Barley	2.74	11.9	0.04	0.34
Limestone	0	0	38.0	0
Di-calcium phosphate (DCP)	0	0	22.0	19.0
Soap-stock oil	7.0	0	0	0
Salt	0	0	0	0
Vitamins & Minerals premix	0	0	0	0

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Table (2): Recommendations about the levels of ingredients used informulating concentrate sheep rations with different CP levels.

Ration CP%	Cereals %	Protein Sources % (SBM 48%)	Salt%	Limestone %	DCP %	Soup -stock oil%	Vitamins & Minerals premix %
10	85.0-90.0	5.5-7.0	0.5	1.0-2.5	0-1.0	1.0-3.0	0.1
12	70.0-85.0	10.0-12.0	0.5	1.0-2.5	0-1.0	1.0-3.0	0.1
14	75.0-80.0	16.0-18.0	0.5	1.0-2.5	0-1.0	1.0-3.0	0.1
16	70.0-75.0	20.0-22.0	0.5	1.0-2.5	0-1.0	1.0-3.0	0.1
18	65.0-70.0	24.0-26.0	0.5	1.0-2.5	0-1.0	1.0-3.0	0.1
20	60.0-65.0	28.0-30.0	0.5	1.0-2.5	0-1.0	1.0-3.0	0.1
22	56.0-62.0	32.0-35.0	0.5	1.0-2.5	0-1.0	1.0-3.0	0.1

Notice:

- The recommended level of cereals mentioned in the above table will be helpful when corn & barley are used & some adjustments are required when other cereals are used.
- The recommended level of protein source mentioned in the above table will be helpful when soybean meal (48% CP) is used & some adjustments are required when other protein sources are used.
- The Guideline levels in the above table will make your trialed formula close to the required one & minor adjustments will be still required.

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Table (3): Ration formulation table.

Ingredient	%	ME (Mcal/Kg)	CP%	Ca%	P%
Soybean meal (48%)					
Corn					
Barley					
Limestone					
Di-calcium phosphate (DCP)					
Soap-stock oil					
Salt					
Vitamins & Minerals Premix					
Total	100				
Requirements (Ration specifications)					
Remarks					

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Example:

Formulate a ration for the fattening of lambs containing: 18% CP, 2.7 Mcal of ME, 0.75% Ca, 0.45% P, 0.5% salt & 0.1 Vitamins & minerals premix by the using of the following available ingredients:

Soybean meal (48%), Corn, Barley, limestone, DCP & Soap-stock oil, Salt & Vitamins & Minerals Premix.

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Solution:

1. Design a ration formulation table in which the ration nutrients specifications are listed in the top raw, the available ingredients in the first Column, the proposed percentages for ingredients in the second column & the calculated total content of the proposed ration & requirements in the bottom rows as follow:

Ingredient	%	ME (Mcal/Kg)	CP%	Ca%	P%	Salt %	Premix %
Soybean meal (48%)							
Corn							
Barley							
Limestone							
Di-calcium phosphate							
Soap-stock oil							
Salt							
Vitamins & Minerals Premix							
Total	100						
Requirements (Ration specifications)	100	2.7	18	0.75	0.45	0.5	0.1
Remarks							

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From Table 2

2. Propose the inclusion rate in front of each ingredient using recommendations mentioned in table 2 (recommended level for formulating a ration of 18% CP).

Ration CP%	Cereals %	Protein Sources (SBM 48%) %	Salt %	Limestone %	DCP %	Soup -stock oil %	Vitamins & Minerals premix %
18	65.0-70.0	24.0-26.0	0.5	1.0-2.5	0-1.0	1.0-3.0	0.1

Now, the ration formulation table can be filled as follow by the help of the above recommendations:

Ingredient	%	ME (Mcal/Kg)	CP%	Ca%	P%	Salt %	Premix %
Soybean meal (48%)	26						
Corn	40						
Barley	30						
Limestone	1.7						
Di-calcium phosphate	0.7						
Soap-stock oil	1.0						
Salt	0.5						
Vitamins & Minerals Premix	0.1						
Total	100						
Requirements (Ration specifications)	100	2.7	18	0.75	0.45	0.5	0.1
Remarks							

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3. Now, the content of the proposed ration can be calculated as follow:

Ingredient	%	ME (Mcal/Kg)	CP%	Ca%	P%	Salt %	Premix %
Soybean meal (48%)	26	0.26*2.78=0.7228	0.26*48=12.48	0.26*0.25=0.065	0.26*0.11=0.0286		
Corn	40	0.40*2.78=1.112	0.40*7.0=2.8	0.40*0.01=0.004	0.40*0.31=0.124		
Barley	30	0.30*2.74=0.822	0.30*11.9=3.57	0.30*0.04=0.012	0.30*0.34=0.102		
Limestone	1.7	0	0	0.017*38=0.646	0		
(DCP)	0.7	0	0	0.007*22=0.152	0.007*19=0.133		
Soap-stock oil	1.0	0.01*7.0=0.07	0	0	0	0	0
Salt	0.5	0	0		0	0.5	
Premix	0.1	0	0		0		0.1
Total	100	2.73	18.85	0.88	0.388	0.5	0.1
Requirements (Ration specifications)	100	2.7	18	0.75	0.4	0.5	0.1
Remarks	Ok	0.03 Excess	0.85 Excess	0.13 Excess	0.012 Deficit	Ok	Ok

4. Thus, the ingredients levels should be manipulated to cancel the excesses & avoid the deficits. This can be achieved through the following:

- Reducing the level of SBM, soap-stock oil & limestone & increasing the level of DCP a little pet as following.

5- When doing that the formulation table will be as follow:

Ingredient	%	ME (Mcal/Kg)	CP%	Ca%	P%	Salt %	Premix %
Soybean meal (48%)	23.7	0.237*2.78=0.658	0.237*48=11.37	0.237*0.25=0.059	0.237*0.11=0.026		
Corn	42	0.42*2.78=1.167	0.42*7.0=2.94	0.42*0.01=0.0042	0.42*0.31=0.1302		
Barley	30.9	0.309*2.74=0.847	0.309*11.9=3.67	0.309*0.04=0.0123	0.309*0.34=0.1050		
Limestone	1.3	0	0	0.013*38=0.494	0		
DCP	0.8	0	0	0.008*22=0.176	0.008*19=0.152		
Soap-stock oil	0.7	0.007*7.0=0.049	0	0	0	0	0
Salt	0.5	0	0		0	0.5	
Premix	0.1	0	0		0		0.1
Total	100	2.72	18.0	0.75	0.41	0.5	0.1
Requirements (Ration specifications)	100	2.7	18	0.75	0.4	0.5	0.1
Remarks	Ok	Very Close (OK)	OK	Ok	Ver Close Ok	Ok	Ok

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Trial & Error Method for Ration Formulation by Using of Excel Spread-Sheet

الكلية الجامعية للعلوم التطبيقية
University College of Applied Sciences

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Advantages of Using Excel Spreadsheet:

Makes the formulation of ration easier, accurate calculations than hand calculations & saving time.

Requirements of Application:

1. Designing of an Excel spreadsheet that contains the available ingredients, their content from feed nutrients, a column for the proposed inclusion rate for each ingredient, a row for the calculated sum of percentage of each nutrient & a row for the requirements or ration specifications, a model for an excel spreadsheet is shown in figure 1.
2. The only thing that you have to do is to propose an inclusion rate (Kg/ton) in front of each ingredient depending on your experience & on the Guidelines summarized in table 1.
3. The Excel sheet will automatically calculate the nutrients participation from each ingredient in the whole ration & the total nutrients participation of the whole ingredients to compare it with requirements.

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Figure (1): An Excel Spreadsheet Model.

Ration Formulation for sheep

Ingredients	Ingredient Inclusion rate (kg/ton)	CP %	ME Mcal/Kg	Ca %	P %	Sodium %	Chlorine %
Sunflower meal 37%		36	1.86	0.25	1	0.1	0.1
SBM-48-		48	2.78	0.25	0.11	0.03	0.05
CORN		7	2.78	0.01	0.31	0.02	0.04
Wheat		10	2.87	0.01	0.34	0.02	0.05
Sorghum		10	2.82	0.04	0.3	0.02	0.09
Barley		11.9	2.74	0.04	0.34	0.02	0.15
Wheat bran		15.2	2.28	0.1	1.22	0.02	0.06
Remulage		16	2.7	0.13	0.83	0.05	0.03
Salt		0	0	0	0	39	60
Limestone		0	0	38	0	0	0
DCP		0	0	22	19	0	0
Vitamin & Min. Premix		0	0	0	0	0	0
Ammonium chloride		165	0	0	0	0	66
Sodium sulphate		0	0	0	0	32	0
Sodium bicarbonate		0	0	0	0	27	0
Oil		0	7	0	0	0	0
Total content		0	0	0	0	0	0
Requirements (Specifications)							
Difference (content - requirements)		0.000	0.000	0.000	0.000	0.000	0.000

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Table (1): Recommendations about the levels of ingredients used in formulating concentrate sheep rations with different CP levels.

Ration CP%	Cereals%	Protein Sources % SBM only	Protein Sources% SBM + SFM	Salt%	Limestone%	DCP%	Fat%	Na-sulphate %	Ammonium chloride %	Na-bicarbonate %
14	75-80	16-18	9-10 SBM + 8-9 SFM	0.3-0.5	1-2.5	0-0.6	1-3.5	0.1-0.2	0.3-0.5	0.3-0.5
16	70-75	20-22	11-12 SBM + 11-12 SFM	0.3-0.5	1-2.5	0-0.6	1-3.5	0.1-0.2	0.3-0.5	0.3-0.5
18	65-70	24-26	17-18 SBM + 10-11 SFM	0.3-0.5	1-2.5	0-0.6	1-3.5	0.1-0.2	0.3-0.5	0.3-0.5
20	60-65	28-30	22-24 SBM + 11-12 SFM	0.3-0.5	1-2.5	0-0.6	1-3.5	0.1-0.2	0.3-0.5	0.3-0.5

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Notice about table 1:

1. The Guideline levels in the above table will make your trialed formula close to the required one & minor adjustments will be still required.
2. SBM (Soybean meal 48%), SFM (Sunflower meal 36%).

Example:

Formulate a ration for ewes in the first 8 weeks of lactation containing: 14% CP, 2.6 Mcal of ME, 0.9% Ca, 0.45% P, 0.3% Na & 0.3% Cl by the using of the following available ingredients:
Sunflower meal, SBM, corn, barley, wheat bran, limestone, premix, salt, sodium carbonate & oil.

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Solution

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Ration Formulation for sheep

Ingredients	Ingredient Inclusion rate (kg/ton)	CP %	ME Mcal/Kg	Ca %	P %	Sodium %	Chlorine %
Sunflower meal 37%	85	36	1.86	0.25	1	0.1	0.1
SBM-48-	80	48	2.78	0.25	0.11	0.03	0.05
CORN	523	7	2.78	0.01	0.31	0.02	0.04
Wheat		10	2.87	0.01	0.34	0.02	0.05
Sorghum		10	2.82	0.04	0.3	0.02	0.09
Barley	165	11.9	2.74	0.04	0.34	0.02	0.15
Wheat bran	100	15.2	2.28	0.1	1.22	0.02	0.06
Remulage		16	2.7	0.13	0.83	0.05	0.03
Salt	4	0	0	0	0	39	60
Limestone	21.5	0	0	38	0	0	0
DCP	1	0	0	22	19	0	0
Vitamin & Min. Premix	1	0	0	0	0	0	0
Ammonium chloride		165	0	0	0	0	66
Sodium sulphate		0	0	0	0	32	0
Sodium bicarbonate	4.5	0	0	0	0	27	0
Oil	15	0	7	0	0	0	0
Total content	1000	14.04	2.62	0.902	0.45	0.304	0.304
Requirements (Specifications)		14	2.6	0.9	0.45	0.3	0.3
Difference (content-requirements)		0.044	0.020	0.002	0.003	0.004	0.004

Organisation: **Hebron University**

Course title: Protected Agriculture (51411)

Course type: **Developed course**

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BENEFIT

Smart Greenhouse

Introduction;

Crop management depends on having the right information to make necessary decisions.

Real-time monitoring of the greenhouse environment with sensors and advanced software can greatly improve yields and economic performance by optimizing plant growth.

The system can collect the information related to greenhouse environment and crop status and control the greenhouse automatically based on the collected information to predict and act on situations for perfectly controlled climatic conditions. By densely monitoring climatic conditions.

A greenhouse environment is an incredibly complex and dynamic environment and strongly influences crop cultivation.

The efficiency of plant production in greenhouses depends significantly on the adjustment of optimum climate growth conditions to achieve high yield at low expense, good quality and low environmental load.

To achieve these goals several parameters such as air temperature, humidity, light intensity, and carbon dioxide concentration must be controlled optimally given certain criteria through heating, lighting, ventilation and carbon dioxide injection.

Continuous monitoring and controlling of these environmental factors gives relevant information pertaining to the individual effects of the various factors towards obtaining maximum crop production.

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Greenhouse environments present unique challenges to good control.

Temperature changes occur rapidly and vary widely depending on solar radiation levels, outside temperatures and humidity levels, wind speed and direction and the amount of plant material in the greenhouse.

Poor light intensity and high humidity often result in poor fruit set and quality.

Proper control of plant disease is critical in greenhouse environments, where high temperatures and high humidity are ideal for diseases to develop. Insect and nematode infections, too, can become rampant under the confined greenhouse conditions.

More accurate control can reduce heating fuel and electrical costs, increase the productivity of workers by enabling them to attend to more valuable tasks, enabling managers and growers to make better management decisions and spend more time managing the process.

More precise control of temperatures and humidity helps reduce plant stress and diseases and consequently the need for fungicides and other chemicals, helps produce healthier plants less susceptible to disease and insect infestation, improved grower information and management all combine to increase the health and uniformity of plants

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Today, computerized control systems are the standard for modern greenhouses, with continued improvements as the technology advances. Environment conditions can be maintained by these computerized control systems, where the system can be operated manually and/or automatically.

The main components of any control system are measurement controller, data processing, data acquisition, data presentation and recording.

In the environment control system, each parameter must be maintained continuously within a certain range.

Greenhous Technology;

1- **Protection from**

- Extreme temperature
- High wind velocity
- Insect-pests and diseases
- Torrential rain fall
- Snowfall

2- **It augments**

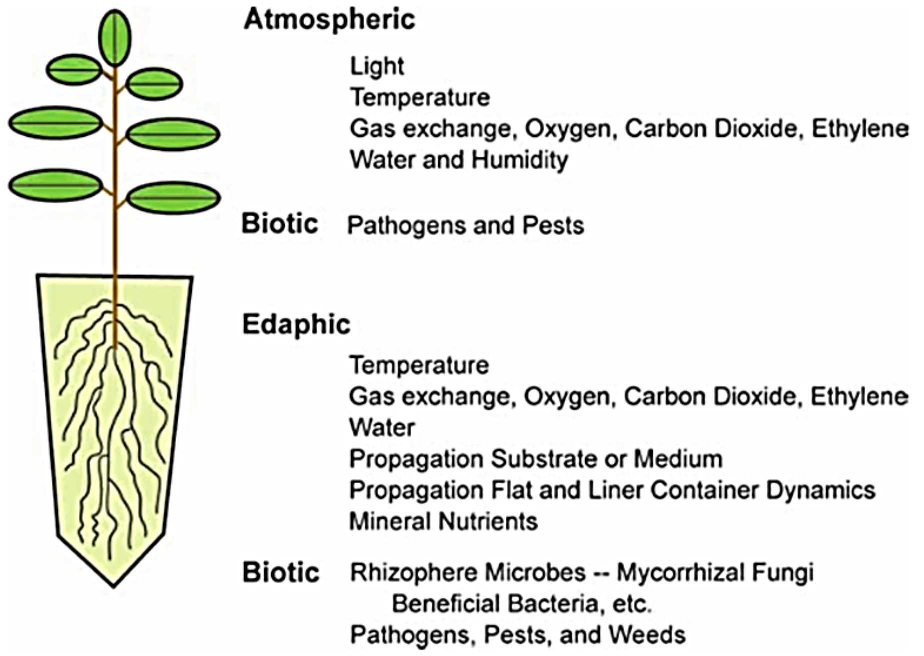
- CO2 concentration
- Humidity
- Nutrient uptake
- Soil health
- Photosynthesis

3- **Result in**

- Increased productivity
- Improved quality

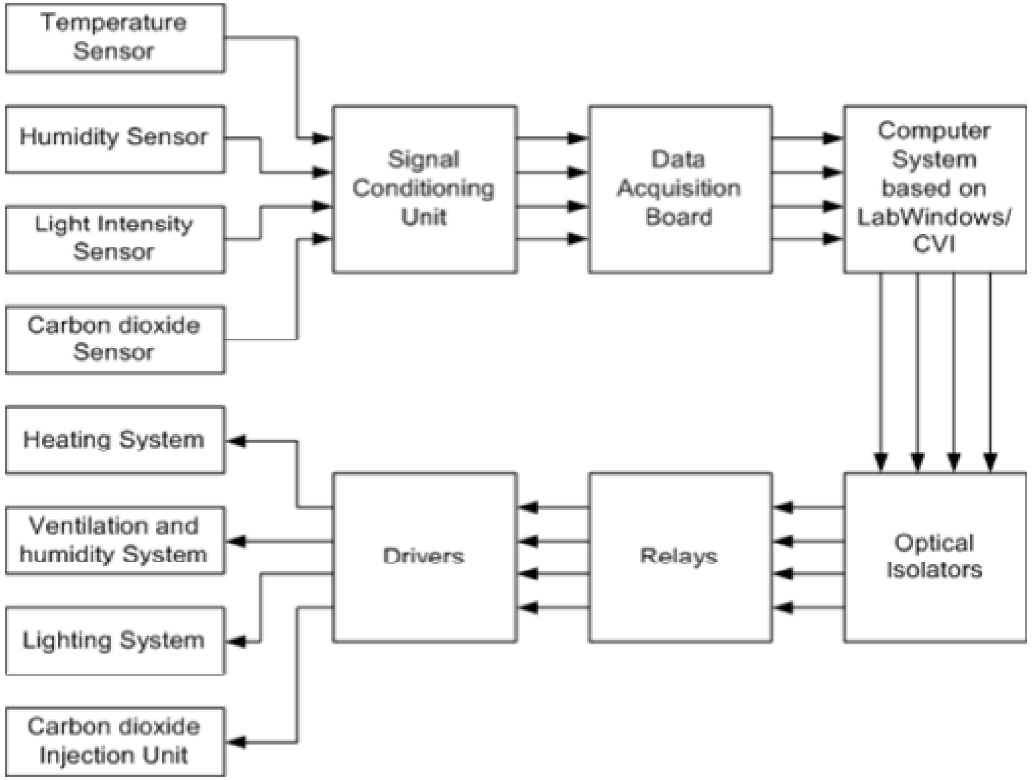
To enhance plants growth and production commercial producer manipulate the environment affecting plant by managing:

A. **Microclimatic conditions**: (light, water-relative humidity, temperature and gases).
B. **Edaphic factors:** (soil or media, mineral nutrition and water).
C. **Biotic factors:** interaction of plant with other organisms (such as beneficial bacteria , mycorrhiza fungi, pathogens , insect pests , etc.)



The plant environment: manipulation of microclimate, edaphic , and biotic factors.

The computerized greenhouse environmental monitoring system



Scheduling model of the computerized greenhouse environmental monitoring system.

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Selecting the Sensors;

The computerized greenhouse environmental monitoring system depending on different **sensors** to make the correct decision as (temperature and relative humidity sensors, barometer, precipitation, light, wind speed, leaf wetness, leaf temperature, electrical conductivity, pH sensor, soil moisture sensor, soil temperature, insect pests traps with sensors, diseases monitoring system or (module for each crop) and other sensors) all these signals from sensors go t **software on a computer** then give the orders to the **drivers** (heating system, ventilation and humidity systems, lightning system, and carbon dioxide injection unit).

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Sensors → **Computer Software** → **Drivers**

There is many companies in the world making those sensors and software.

For an example metos company which work on Palestine.

all sensors listed are from metos company production. There is sensors and software's from others company.

Temperature And Relative Humidity;

Pessl instruments air temperature and relative humidity sensor

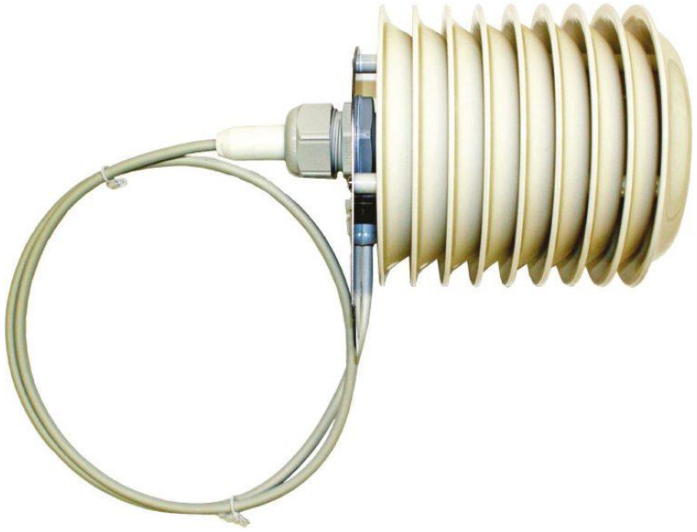
Sensor HYT221

Operating temperature range: -40°C to +125°C

Humidity range 0% to 100% RH

Accuracy ±0.2°C (0°C to +60°C)

±2 % RH at +23 °C (0% to 90% RH)



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BENEFIT

Barometer;

Pessl Instruments **Barometer;**

The Pessl Instruments barometric sensor measures the “absolute air pressure” of the atmosphere on site. It is designed for application in the field of environmental protection, where high accuracy, quick response, long-term stability and reliability are required. The instrument is suited for indoor and outdoor use. A tempered piezoceramic sensor for absolute pressure is used, characterized by its thermal and mechanical stability.

Working range 0-1150 mbar

Precipitation;

Pessl Instruments **Rain Gauge**

Technical Specifications

Sensor Type	Double tipping bucket rain gauge
Sensitivity	1 tip per 0.2 mm or 1 tip per 0.5 mm
Collector Surface	200 cm2
Maximum Rain	12 mm/minute
Dimensions	185 mm diameter x 250 mm H
Accuracy	±5%

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BENEFIT

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BENEFIT

Light;

Pessl Instruments Par Quantum;

Photosynthetically Active Radiation (PAR) is typically measured as Photosynthetic Photon Flux Density (PPFD), which has units of quanta (photons) per unit of time per unit of surface. The units most commonly used are micromoles of quanta per second per square meter (µmol s-1 m-2). Plant scientists, horticulturists, ecologists, and other environmental scientists use MD507D Quantum Sensors to accurately measure this variable.

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Technical Specifications

Sensor	EG&G VACTEC VTB1012B
Calibration	Calibration against LI-190SZ under daylight. Absolute difference max. 5%, typical 3%.
Linearity	Maximum deviation of 1% up to 3000 W/m².
Stability	2% change over a 1 year period
Response Time	150 ms

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Wind;

Pessl Instruments **Wind Speed** IM512CD is a cup type anemometer for low cost and long term, accurate wind measurements for all kinds of use. It calculates average wind speed in the specific time period.

Sensor Pessl Instruments Wind Speed

Technical Specifications

Range	0 to 50 m/s, gust survival 60m/s
Sensor	12 cm diameter cup wheel assembly, 40 mm diameter hemispherical cups
Turning Factor	75 cm
Distance Constant (63% recovery)	2.3 m
Threshold	1.1 m/s

Leaf;

Pessl Instruments Leaf Wetness

The leaf wetness sensor works by measuring the conductivity on a filter paper, which is held between two stainless steel electrodes in a transparent holder. The use of transparent Lucite plastic as a holder reduces the warming up of the sensor when it is exposed to direct sunlight.

PESSL INSTRUMENTS LEAF WETNESS SENSOR

Con…

Pessl Instruments Leaf Temperature

IM522CD is a highly accurate leaf temperature sensor. It measures the radiated temperature around the surface of a leaf or a canopy.

PESSL INSTRUMENTS LEAF TEMPERATURE SENSOR

Water;

Pessl Instruments Electrical Conductivity;

The conductivity sensor provides a complete self contained measurement. The sensor utilizes a reliable and robust sensor for conductivity measurement and a thermistor for temperature measurement. The sensor is ideal for hydrographical and environmental water monitoring, in agriculture and industrial applications. The durable design ensures suitability for the harshest environment applications.

Con…

Technical Specifications

Range	0.1 µS/m – 1000 mS/cm
Resolution	0.1 µS/cm

PESSL INSTRUMENTS ELECTRICAL CONDUCTIVITY SENSOR

Necessary Interface to connect this sensor with iMETOS: 600025 / 900029 Interface box with display.

Con…

Pessl Instruments pH Sensor

The pH sensor is a reliable and cost-effective sensor for measuring the pH value of various aqueous solutions. The pH scale covers values between 0 and 14.

Acids have pH values between 0 and 6; caustic solutions have pH values between 8 and 14. Value 7 is neutral.

PESSL INSTRUMENTS pH SENSOR SENSOR

Technical Specifications

Range	pH 0.00 to 14.00
Resolution	0.01 pH
Accuracy	±2% F.S.

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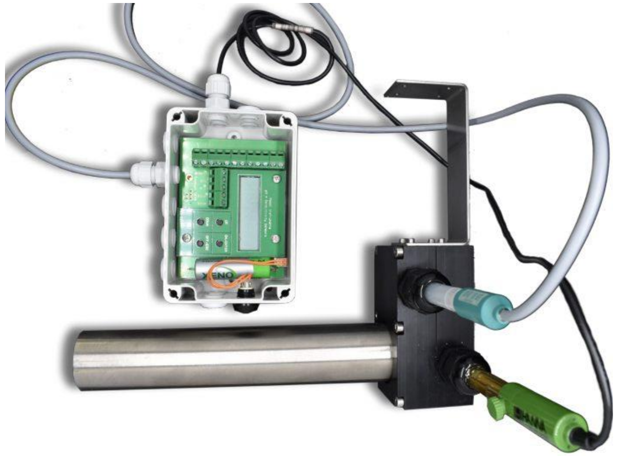
Con…

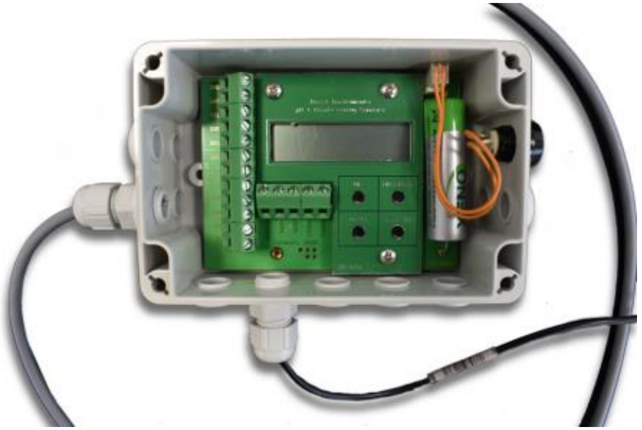
EC & pH Interface Box With Display In Ip65 Box

The EC500PH EC & pH Interface box is a measuring device with display in IP65 Box to be integrated into any iMETOS sensor chain interface for continuous EC & pH measurements in water. It is compatible with the majority of industry standard EC & pH sensors. The actual reading can be seen on the display. With the built in calibration mode, all sensor readings can be calibrated and checked from time to time.

Connection Possibilities

- 1 EC Sensor (Part.no. EC501)
- 1 pH Sensor (Part.no. PH501)





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BENEFIT

Con…

Pessl Instruments Pressure Switch

Simple and robust design makes pressure switch suitable for use with compressed air, hydraulic oil, oil emulsions and water. Detection threshold is 1 bar and switch off is at 0.5 bar (other values on demand). The main purpose of this sensor is to control/check the performance of the irrigation system.

Con…

Technical Specifications

Material	Zinc-plated steel (G 1/4″)
Switching function	Open contact, closed contact, changeover
Media	Water, compressed air, hydraulic oil, oil emulsion
Maximum medium temperature	+85 °C

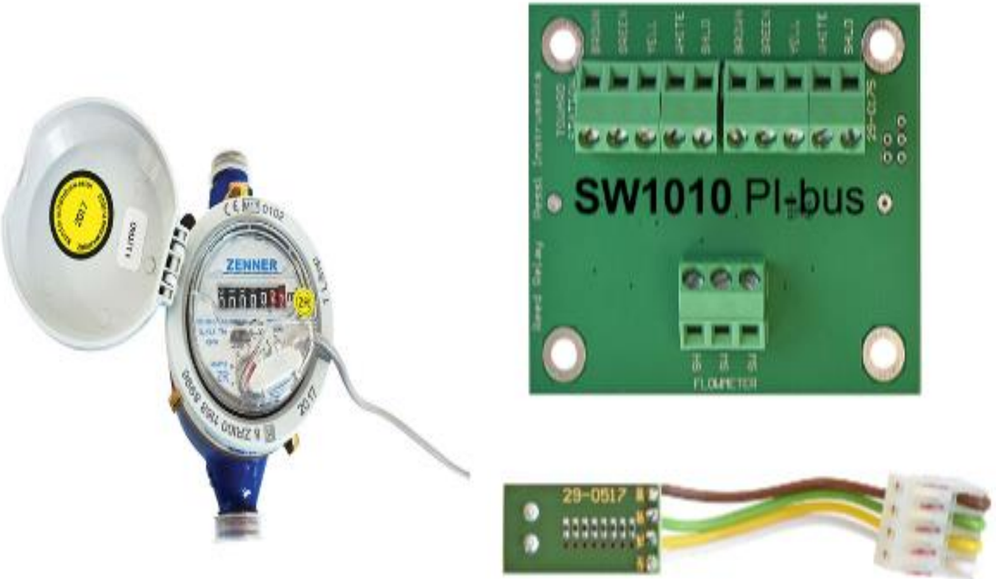
PESSL INSTRUMENTS PRESSURE SWITCH SENSOR

Con…

Pessl Instruments Water Counter Interfaces

These interfaces support most of the water meters used in irrigation with a pulse output.

Applications: Irrigation management, irrigation consulting, smart irrigation, irrigation tractability and book keeping, alarms and supervision. Used widely in open field crops, hydroponics and greenhouse.



SW1000 pulse counter (Reed/Rain input)

Soil Moisture;

PESSL INSTRUMENTS Soil Moisture & Soil Temperature Sensor PI54-D

The PI54-D soil moisture sensor has a larger volume of influence. It determines volumetric water content (VWC) by measuring the dielectric constant of the soil using capacitance technology and soil temperature. It is 10 cm long and thus measures 1 liter of soil, while high frequency minimizes salinity and textural effects which makes PI54-D accurate in most soils.

Pessl Instruments **Soil Moisture Sensor** Pi54-d

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BENEFIT

Soil Temperature;

Pessl Instruments Soil Temperature

The Soil Temperature Sensor is a PT1000 in a waterproof stainless steel housing. The sensor output is a duty-cycle signal.

Pessl Instruments **Soil Temperature Sensor**

Technical Specifications

Sensor SMT172	Operating temperature range: -30 °C to +75 °C Accuracy: ±0.5 °C (-30 °C to +75 °C)
Sensor PT1000	Operating temperature range: -30 °C to +75 °C Accuracy: ±0.1 °C (-30 °C to +75 °C)

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iMETOS iSCOUT;

is a combination of hardware and software solutions for remote monitoring of different agricultural and industrial insects.

With the inspiration of helping the farmer to grow his crop in the optimal and most healthy way, Pessl Instruments GmbH, developed an optical high-resolution camera system, together with a computer vision software which is able to recognize insects from the photo.

Con…

Optical high-resolution camera system is embedded inside insect trap, to remotely monitor insect pressure at fields.

provide different types of traps, to cover a broad spectrum of insect species. All of the photos and data from computer vision software is displayed online, on a Field Climate web portal.

Heating Subsystem;

Temperature control is necessary for attaining high crop growth, yield and quality. Extreme temperatures may induce stress and associated damage to the plasmatic structures or the photosynthetic apparatus of the plant.

Less extreme suboptimal temperatures may delay plant development and affect other plant characteristics such as dry matter distribution .

There are two main factors affecting greenhouse temperature:

1. The impact of greenhouse structure and regions which includes greenhouse volume, wall thickness, transparent area, the heat capacity, temperature and infiltration of outdoor environment, etc;

2. The effect of the adjustment of other environmental parameters on the temperature, these parameters include humidity, light illumination, carbon dioxide etc.

The aim of every producer is to reduce the energy input per unit of production, and maintain and increase the quality of final product.

Uniform crop growth is very important for most production systems and the heating and ventilation systems have a major impact on producing uniform crops.

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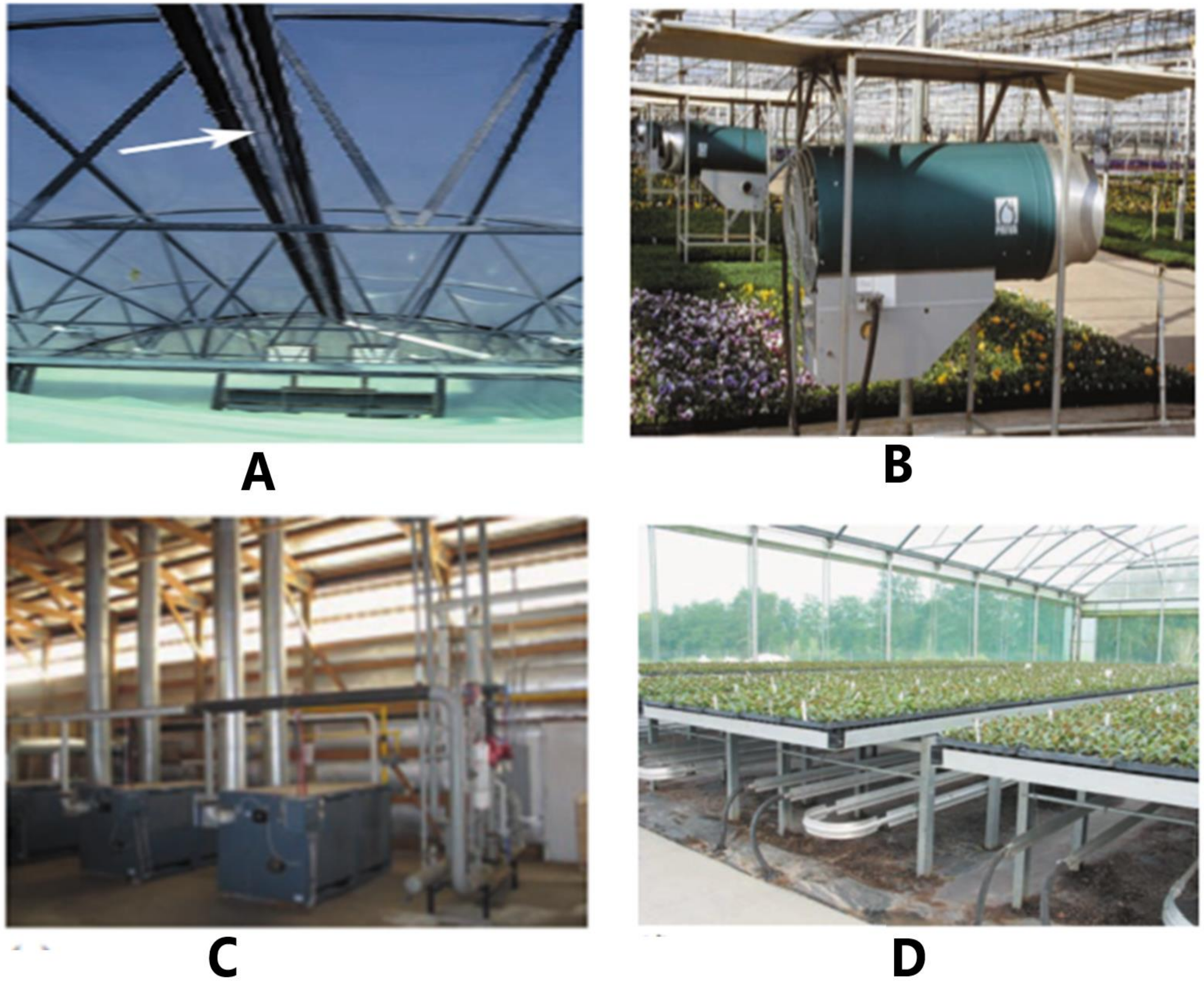
Propagation house heating systems;

A) Gas-fired infrared or vacuum-operated radiant heaters (arrow).

B) Forced hot air heating system.

C) Greenhouse, hot water boilers.

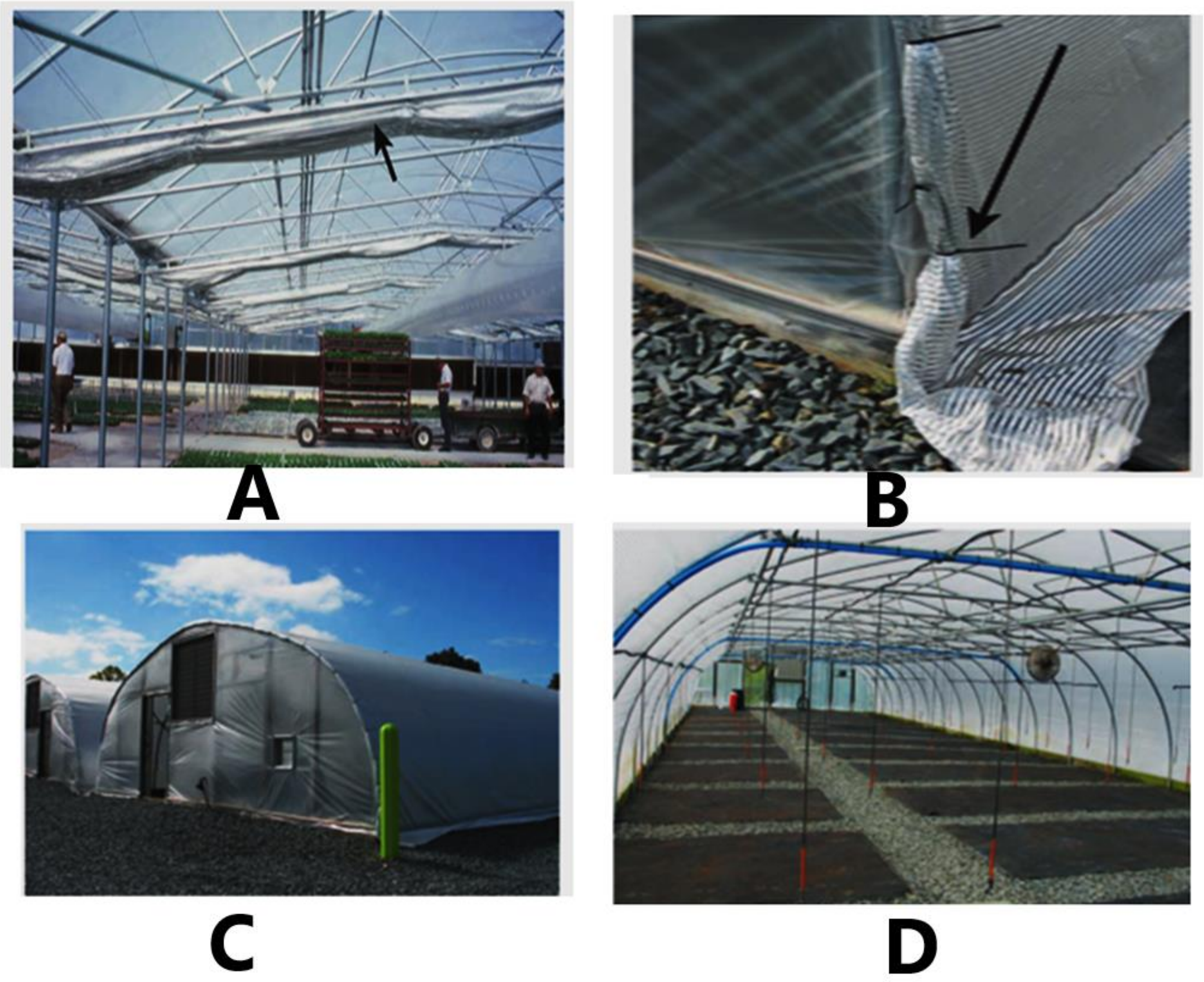
D) Heating below the bench for better control of root zone temperature.



A) Prop house with thermal and shade curtains (arrow) to reduce winter heating costs and reduce light irradiance and greenhouse cooling expenses during summer months.

B) Thermal screen for energy conservation, made of woven aluminized polyester fabric, covering for propagation house with 46% light transmission.

C and D)The fabric is placed on top of polyethylene propagation house the covered house.



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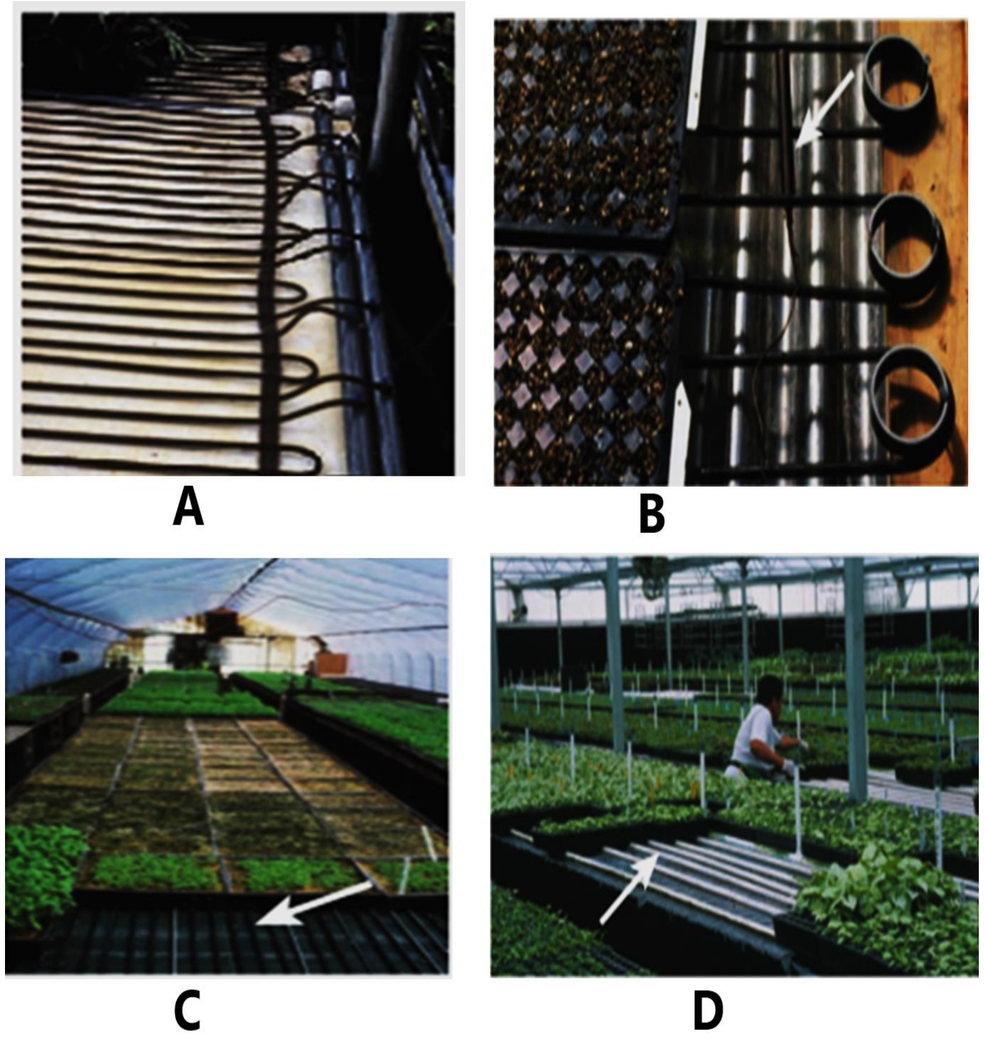
Hot water, root zone heating of propagation flats;

A) Biotherm tubing heating root zone of the plug tray.

B) Notice the probe (arrow)for regulating temperature.

C) The flexible hot water tubing is hooked into larger PVC pipes at set distances to assure more uniform heating.

D) Cuttings in propagation flats placed over white PVC hot water tubing; in milder climates, the ground hot water tubing may be all that is used to control root zone temperature of the propagation house.



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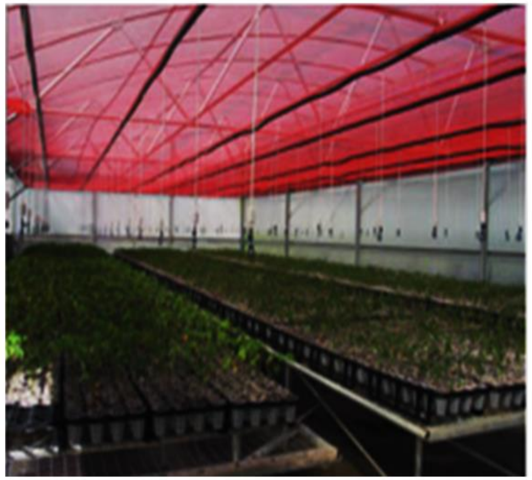
A and B) Propagation houses covered with red shade cloth for enhanced root initiation and development.

The red netting increases the red, while reducing the blue and green spectra.

C) Shading seed propagation flats to reduce light irradiance and heat load.

A



B

C

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Ventilation and Humidity Subsystem;

It is important to maintain the proper humidity since the humidity inside the greenhouse has a close relation to crops growth, volume and insect damages.

In particular, ventilation plays an important role in controlling relative humidity inside facilities, and ventilation equipment should be installed with a consideration of the physiological need of a crop. Too much ventilation in the afternoon changes the size of flower buds near the growing point of flowers and it lowers quality of flowers, and this in turn, is the cause of fallen fruit and blossom.

Whenever the natural ventilation is insufficient it is necessary to use ventilators.
The cooling efficiency can be increased by combining the natural and mechanical ventilation systems with air humidifiers.

Con…

A general type of cooling system uses a porous pad installed in one top side of the greenhouse, which is maintained wet. On the opposite side, an exhaust fan is installed. The air admitted through the pad becomes cooler by evaporation effect.

The fog system is formed by suspended pipes on the greenhouse structure, spraying tiny drops of water into the greenhouse, contributing to increase air humidity and decrease the air temperature. Dehumidifier system is used for decreasing the air humidity

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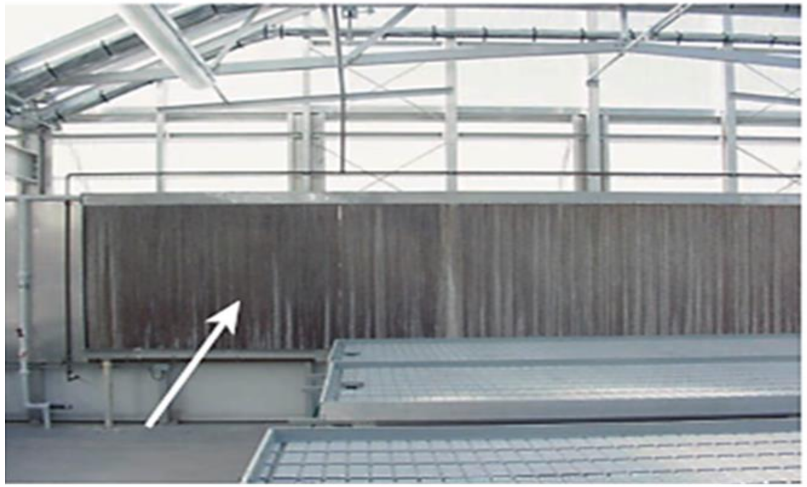
Pad and Fan system;

A system commonly used in greenhouse cooling to reduce the air temperature by raising the relative humidity and circulating air.

A



B

Fully automated polycarbonate-covered greenhouse.

A) Air is pulled by exhaust fans (black arrows) to vent and cool. Components of both heating and cooling systems are electronically controlled via a weather monitoring station (white arrow) that feeds environmental inputs to computerized controls.

B) Cool cells (wettable pads) through which cooler, moist air pulled across the propagation house by exhaust fans.

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Lighting Subsystem;

During winter time, the light level is not adequate for optimal plant production, and because light is the energy source promoting photosynthesis and growth, under low light conditions other environmental factors cannot be utilized efficiently. The irradiance level is therefore the growth limiting-factor during winter.

Under low irradiance conditions, energy use can be reduced because increased temperature cannot be used efficiently for growth. In contrast, when irradiance is higher, the plants are able to utilize both a higher temperature and carbon dioxide concentration.

Con…

Greenhouse lighting systems allows us to extend the growing season by providing plants with an indoor equivalent to sunlight.

Using the supplemental lighting system is a common way for greenhouse lighting. However, it can be done either with photoperiod lighting system or through walkway and security lighting.

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Con…

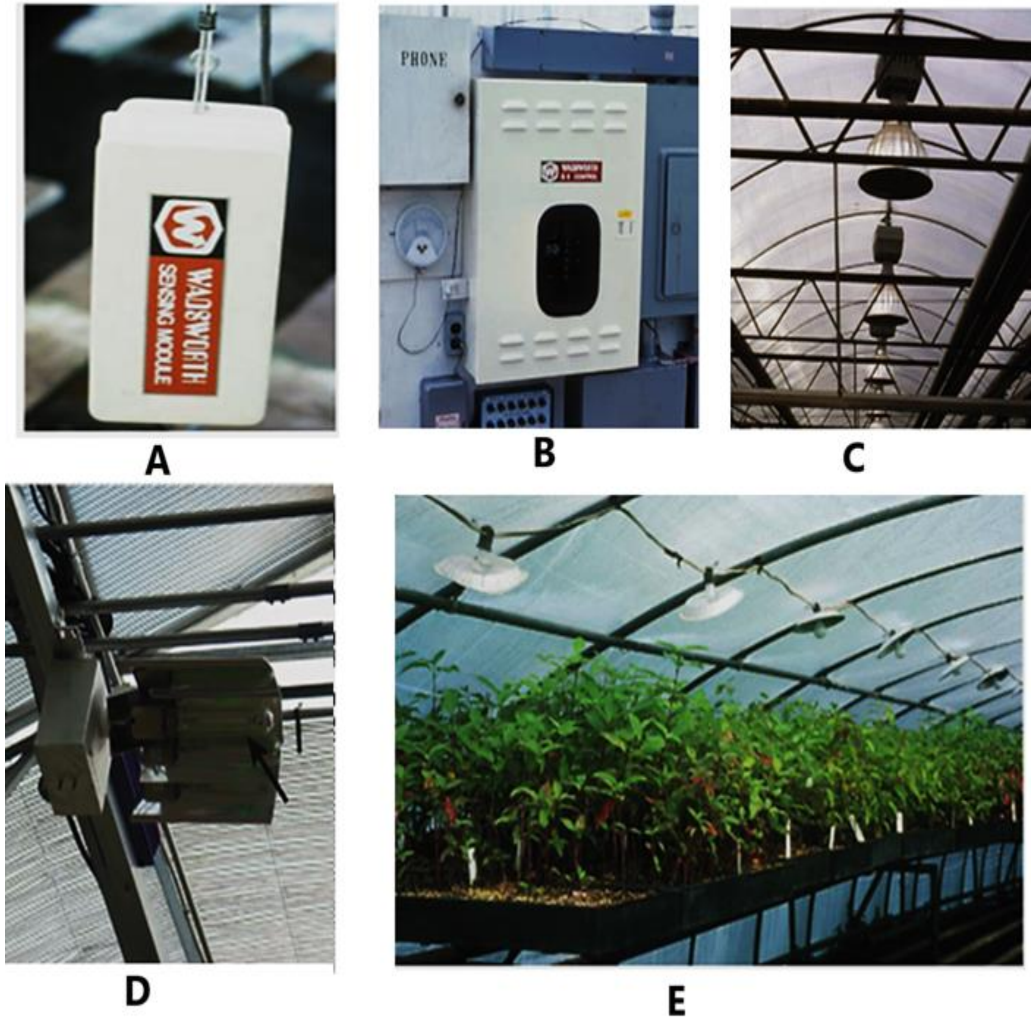
Manipulating the propagation environment;

A) Greenhouse sensor that are connected to an analog or computer-controlled environmental system.

B) Analog-type controller.

C) High vapor pressure sodium lighting for propagating plants during low light conditions.

D and E) Lighting to extend photoperiod, which encourages Japanese maple cuttings to avoid dormancy.



Carbon dioxide Injection Unit;

Carbon dioxide concentration plays a very important role in the photosynthesis process.
The average carbon dioxide concentration in the atmosphere is approximately 313 ppm, which is enough for effective photosynthesis.

A problem arises when a greenhouse is kept closed in autumn or/and winter in order to retain the heat, when not enough air is circulated to have the appropriate carbon dioxide concentration .

Con…

Air movement in greenhouse is needed for acceptable carbon dioxide distribution and to maintain uniform temperature within the crop zone.

In order to improve the growing of herbs inside the greenhouse, it is necessary to increase carbon dioxide concentration in company with favorable conditions of temperature and light.

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BENEFIT

CO_2 Gas Generator

Organisation: Hebron University

Course title: Soil Fertility and Fertilizers (55212)

Course type: New course

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BENEFIT

The Role of Sensor Techniques in Smart Farming

Introduction:

Rapid growth in society, weather change, decreased rainfall, and demand for excess food to sustain billions of people globally are placing a lot of influence on farming. That provides negative impacts on traditional farming practices. We are hear come with smart sensors in agriculture.

The current situation wants farming to become more “smart” by using modern and intelligent technologies. To find the solutions for the best utilization of resources, meeting the global population’s ever-increasing consumption needs.

Smart sensors in agriculture provide data that helps farmers monitor and optimize their crops and keep updated with changing environmental and ecosystem factors.

Smart sensors in agriculture, farmers can understand their crops and their productivity, sustain resources, and can prevent or control the crops from environmental impact or disaster.

The concept of smart farming:

The concept of smart farming is a new concept that refers to the use of the technology of the industrial revolution and modern information and communication technologies in farm management with the aim of improving the quality and quantity of production, raising the efficiency of agricultural resource management and rationalizing their use.

Therefore, smart agriculture is known as the green revolution. The smart farming system relies on the use of modern technologies such as remote sensors, geographic information systems, the Internet of things, drones, artificial intelligence, and data analysis and processing systems in order to raise the efficiency of farm management, starting from land leveling, through seed setting, irrigation, fertilization, pest and disease control, and even the final product.

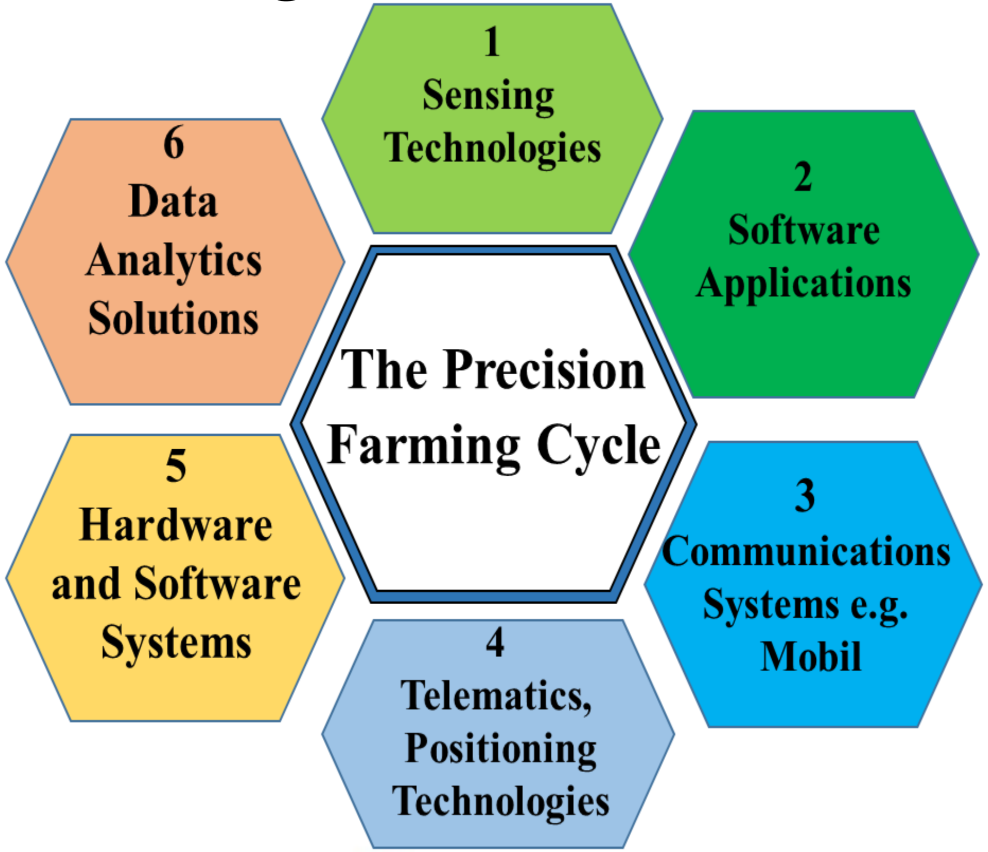
As smart farming techniques allow monitoring the growth of crops, identifying pests and diseases before their spread, determining the amount of fertilizers and pesticides required, and the appropriate time to apply them to the crop, as well as the appropriate dates for irrigation and the quantities of water required for each plant.

This undoubtedly achieves the concept of high efficiency in farm management from by making the right decision at the right time, which in turn positively affects production and quality, maintains soil fertility, and reduces costs.

The precision farming cycle:

The precision farming cycle starts by identifying variability. The fertilizer application and drilling rate can then be adjusted and regulated on the basis of this information.

Yield mapping allows effective monitoring of the success of site specific management systems. Soil maps also make site specific tillage a reality.



All these systems are supported by processes such as soil mapping, soil sampling and yield potential mapping. This increases yields and saves on inputs while also protecting the environment and conserving scarce resources.

What are the first steps for precision farming?

- **Traditional**: Without data support, decisions come primarily from visual inspection, weather information, and agricultural knowledge. With this approach, there is room for improvement. If you take all possible reductions of costs into account, there might be an even bigger gap between the average efficiency and potential efficiency.

With the traditional approach, a lot of time is spent on visual inspection. Detection of potential problems is delayed and the window to react is short. A lot of work is done pre-emptively or too late (e.g. protecting all your crops

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from a certain disease right at the start of the season, or acting on a disease only once you've visually detected it).

- **The evolution of precision farming:** It has evolved of agriculture from an era where the farmer had to guess what his plants needed, to an age in which he can manage the field remotely, relying solely on data. We divided the evolution of crop advice into three stages:-

- The first stage; is the traditional way the farmer relies on visual inspection, weather information, and agricultural knowledge.

- ❖ The second stage; falls in the category of generic decision supporting systems. With this, knowledge and insights are supplemented by measurement data from weather stations.
- ❖ The third and most efficient stage is personalized crop advice; fine-grained and frequent data collection from multiple sources, all linked together on one platform that is translated to automated personalized crop advice. This stage brings the most benefits for growers.

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BENEFIT

Note: The comparison between the three stages shows the need for fine-tuned data gathering and combining multiple data sources. Only when agricultural data is merged into one platform it becomes truly relevant.

- **Generic Decision Supporting System**: Knowledge and insights are supplemented by measurement data from weather stations. To draw conclusions, Generic Decision Supporting System (DSS) models are used. These are algorithms which describe conditions causing events to occur that need the farmer's attention.

For example: if you have relative air humidity at 90% or higher, and a temperature between 12 and 18°C for a period of 5 days, you have an increased chance of phytophthora infections in potatoes. It improves the timing and prioritization of cultivation actions. The downside is that the model is static.

- **Personalized crop advice**: This describes the ultimate vision; fine-grained and frequent data collection from multiple sources, all linked together on one platform. The large amounts of data are backed up by Decision Making Support models, which are further enhanced by machine learning.

Automated tailor-made cultivation advice is extremely detailed and targeted. It gives the chance to perform each action at the right time, place and quantity to optimize efficiency in yield and the use of resources.

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There are four benefits for the precision farming process:

1. **Economic**: when using precision farming platforms and machinery, the farmer can save expensive resources such as water, fertilizer, electricity, and a lot of time. The more precise data the farmer has of his field; the better decisions he can make. As a result, he can achieve higher yields, spend less on expensive farming resources.

2. **Environmental**: precision farming helps the farmer take care of his land, use less fertilizers, water only when needed, and prevent diseases. When the land is healthier, the water around it is cleaner, the plants are more nutritious, and the earth can live for longer.

3. **Traceability**: It's becoming for farmers to receive help from crop advisors/agronomists. The crop advisor can give the farmer the best advice based on actual data, not according to the farmer's memory or knowledge.

4. **Communication across the value chain**: the farmer has three primary connections he needs to nurture. These are with his farming team, his customers, and his crop adviser/agronomist. The team can easily access the field information to add notes and follow changes. The crop advisor or agronomist can better see and learn about the farmer's fields and track their advice.

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BENEFIT

Smart farming has a set of goals, the most important of which are:

1. Promote agricultural innovation.
2. Creating green jobs.
3. Preserving and protecting the environment through better management of natural resources.
4. Adaptation to climate change.
5. Reducing greenhouse gas emissions.

6. Reducing the phenomenon of hunger and poverty.
7. Increasing production and improving the quality of agricultural crops.
8. Implementing sustainable management of natural resources.
9. Improving soil management and fertility.

How are they used of agriculture sensors in smart farming?

Precision farming is a widely practiced form of smart agriculture using Internet of Things (IoT). This method of farming relies on data and analytics extracted from IoT sensors and devices that are placed on farm equipment and surveillance devices used in the process.

There are different types of sensors used in agriculture and the most salient ones are air and soil sensors. The other forms of sensors that one often comes across in precision farming and smart agriculture are GPS based sensors, GIS-based sensors, electrochemical sensors, mechanical sensors, soil moisture sensors, airflow sensors, yield monitoring sensors, and more.

What is the Role of Sensors in smart farming?

Sensors used in agriculture for smart farming are known agriculture sensors. They provide data that helps farmers to monitor and optimize crops with environmental conditions and challenges.

These sensors in agriculture installed and fixed in weather stations, drones, and robots used in the agriculture industry. They can be controlled by mobile apps precisely, which develops for this purpose.

Agriculture sensors based on wireless connectivity; they can be controlled directly using wi-fi or through cellular towers with the help of mobile phone applications.

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Types of The Sensors in Agriculture:

A sensor is an easy and small tool that measures or detects natural world conditions such as motion, heat, or light and converts this condition into an analogue or digital representation.

There are many types of sensors used in agriculture for smart agriculture incorporates:

1. Location Sensors.
2. Optical Sensors.
3. Electro-chemical sensors.

4. Mechanical Sensors.

5. Dielectric soil moisture sensors.

6. Airflow sensors.

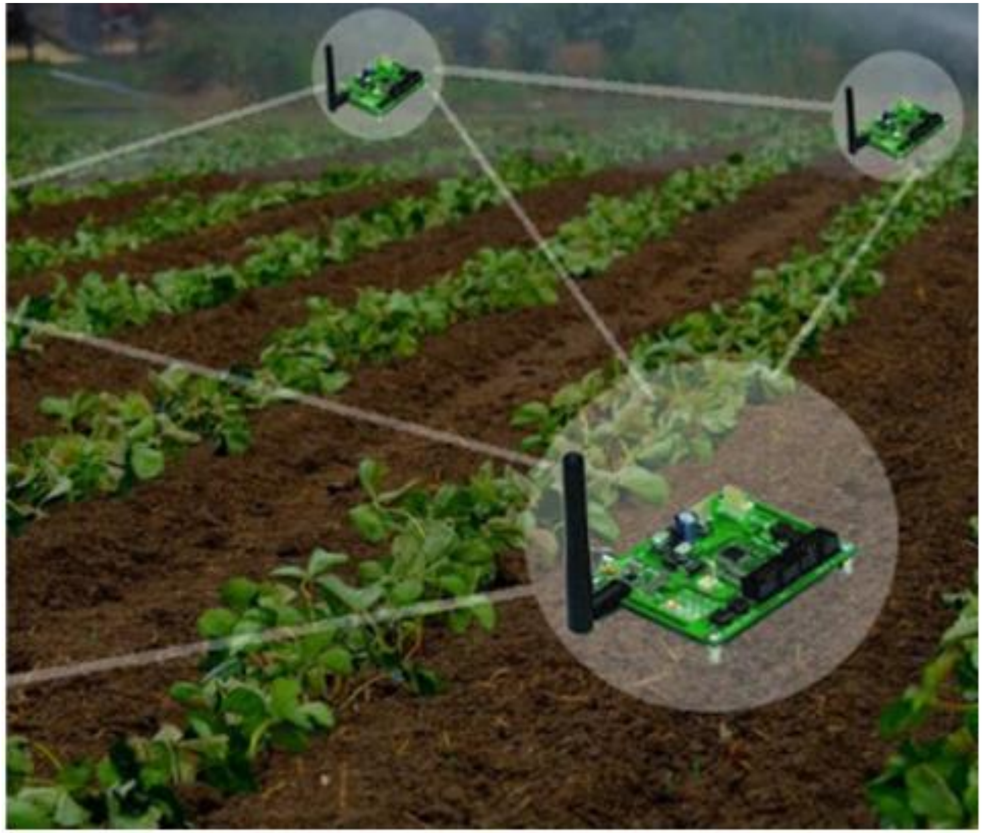
7. Electronic Sensors in Agriculture.

8. Agriculture Sensors IoT.

1. Location Sensors in Agriculture

Location-based sensors help farmers get greater insights on the cultivable land by increasing angles of examination of specific sections of the plot and unlock greater value.

GPS based sensors, GIS-based sensors, and manned and unmanned aerial devices like drones and satellite imagery help get a 3-dimensional analysis of the land and the composition of soil in the cultivated region.



Location Sensors In Agriculture

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2. Optical Sensors in Agriculture

Optical sensors are used in agriculture to understand the properties of the soil and crop by the analysis of the amount of reflected light on the growing parts of the crop in real-time.

Optical sensors tell the analysis tools to increase the dosage of nitrogen for weaker and unhealthy plants and regulate the dosage of nitrogen for the healthy ones. Optical sensors are also used to study the crop vigor by including the biomass of the soil and Nitrogen to other gases ratio in the soil as variables.

This helps farmers regulate the moisture levels in the air and soil and prevent damp conditions. (Damp conditions accelerate the rate of growth for bacteria and moss).

Optical Sensors in Agriculture

How Do Optical Crop Sensors Function?

It employs light to measure soil properties, various frequencies of light. These sensors placed on vehicles or drones, allowing soil reflectance and plant color data to be gathered and processed. Optical sensors can determine clay, organic matter, and soil moisture content.

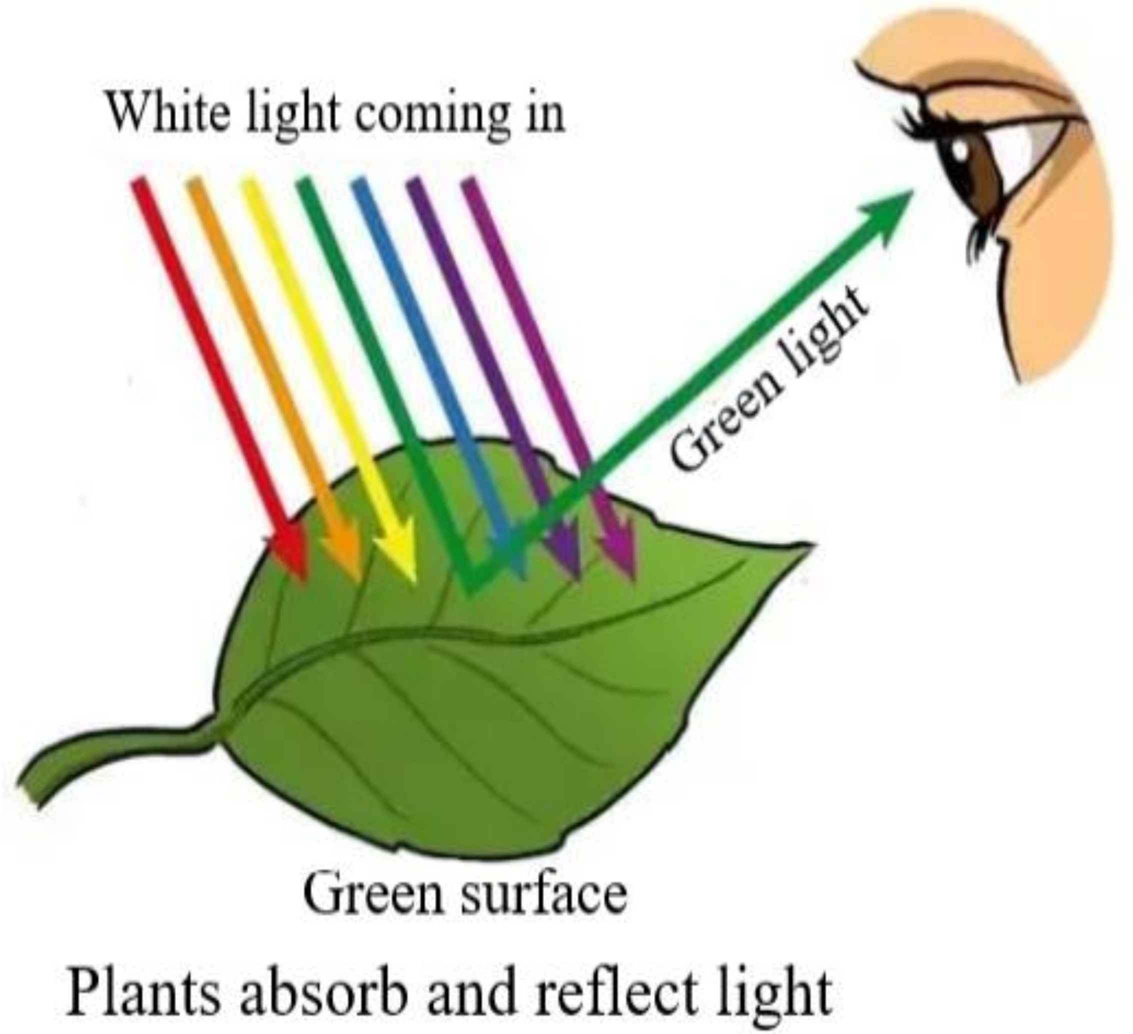
Optical crop sensors evaluate crop conditions by shining light of specific wavelengths at crop leaves, and measuring the type and intensity of the light wavelengths reflected back to the sensors. Not all optical sensors use the same light wavelengths.

Different color light waves can be used to measure different plant properties. Commercially available crop sensors use two or more of red, green, blue or near infrared (NIR) color light waves.

Green plants absorb much of the visible light wavelengths, particularly the blue and red light waves, and reflect much of the green light waves. This is why plant leaves appear green to us.

Sensing the reflectance of green light wavelengths from plants can provide a relative measure of chlorophyll in the leaves.

Green reflectance can be used to evaluate crop nitrogen status, the degree of iron deficiency chlorosis, sulfur deficiency, or any other condition causing reduction in green color.



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How Crop Sensors Determine In-season Nitrogen Fertilizer Rates:

Crop sensors can be mounted on nitrogen fertilizer applicators equipped with computer processing and variable rate controllers to apply fertilizer during the growing season. Each commercial sensor manufacturer recommends specific operating procedures to calculate a fertilizer rate based on a vegetative index.

The sensor software uses a step-by-step mathematical procedure, called an algorithm, to estimate a fertilizer rate.

Typical procedures for using crop optical sensors take place in four steps:

Step 1: Nitrogen-rich Strips Plant a nitrogen-rich strip in each field within each variety with an abundance of nitrogen fertilizer applied prior to planting the crop. This strip must have enough nitrogen to make sure the crop plants will not show any nitrogen deficiency symptoms.

The sensor is operated over the nitrogen-rich strip to establish a nitrogen-sufficient reference area in the field.

The remaining areas of the field are compared to the nitrogen-rich strip to make nitrogen rate recommendations.

Step 2: Scan nitrogen reference Strip with Sensors; The user takes sensor readings from the nitrogen-rich reference strip.

Reference values are stored in the computer for on the go calculations.

Use of sensors green seeker under field conditions

Step 3: Select the Appropriate Crop Algorithm; The sensor manufacturer incorporates algorithms for each crop. The algorithms are generally based on in-season estimated yield (INSEY).

INSEY is determined by dividing the sensor NDVI readings by the growing degree days. Generally, the sensors operator must enter the growing degree days for the field area into the sensor computer.

Step 4: Sensing the Field. The operator then drives over the rest of the field, automatically sensing, calculating, and applying a variable rate of nitrogen fertilizer to the crop. Sensor values may be different if the crop leaves are wet or dry.

Temperature changes throughout the day may also cause changes in sensor values. The nitrogen-rich or virtual strip should be re-sensed if the field conditions change during fertilizer application.

Potential Uses for Crop Sensors:

1. In-season nitrogen fertilizer.
2. Increase nitrogen use efficiency.
3. In-season crop yield estimate.

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3. Electro-chemical Sensors for Soil Nutrient Detection in Agriculture

Electrochemical sensors could provide the most important type of information needed for precision agriculture (soil nutrient levels and pH). Monitoring the pH level of the soil is essential for sustainable and eco-friendly farming while maximizing revenue.

Electrochemical sensors are used to monitor and analyses the soil quality and take measures to alter the pH level or continue practices to maintain the current level for the next phases in the lifecycle of a crop.

Electrochemical sensors are used in both outdoor farms and greenhouse based farming establishments.

Electrochemical sensors are mainly used to monitor the levels of Phosphorous, Nitrogen, Potassium, Calcium, Sodium, Magnesium, Copper, Iron, Boron, Zinc, Boron, Manganese, Molybdenum.

Electrochemical Sensors for Soil Nutrient Detection

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4. Mechanical Soil Sensors for Agriculture

Mechanical sensors are used to measure the resistance offered by the soil by applying resistive forces. This is mainly carried out with load cells or strain gauges.

Mechanical Soil Sensors for Agriculture

Mechanical sensors are used to determine the amount of force that roots are exerting to optimize the tilling methodologies and optimizing the inflow of water.

This data is also used in the early stages of the life cycle of the crop to determine the right amount of pressure that is exerted by the tractor to offer maximum yield on a long duration.

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5. Dielectric Soil Moisture Sensors in Agriculture

Dielectric soil moisture sensors are used to monitor the moisture levels of the soil to help optimize methods of irrigation management.

This helps the farmer better understand the nature of the soil, its capacity to hold moisture, understand the median and mean of the evaporation rate and also get a detailed insight on the root zone of the crop.

Dielectric Soil Moisture Sensors

Water potential sensors and tensiometer sensors are the two prominently used di-electric soil moisture sensors used in precision farming.

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6. Airflow Sensors in Agriculture

Airflow sensors are used to record the number of gaseous substances present in the soil at a particular landscape after irrigation or to get an overview of the land that is to be cultivated before the seeding process.

Airflow Sensors in Agriculture

It determines the optimum pressure required to pump air to aerate the soil and make it more fertile.

It is also used to determine the properties of the soil, its compaction, moisture-holding capacity, and more.

7. Electronic Sensors in Agriculture

It installed on tractors and other field equipment to check equipment operations. Then, cellular and satellite communication systems used to convey the data immediately to computers or e-mail it to people.

The field executive can then recover the information on their office computer or cell phone.

Electronic Sensors in Agriculture

8. Agriculture Sensors IoT

Internet of Things (IoT)-enabled smart farming sensors, modules and software help inform decisions for productivity improvements. IoT-enabled smart farming leverages sensors and gateways to collect and analyze data.

This sensor provides information such as air temperature, soil temperature at various depths, rainfall, leaf wetness, chlorophyll,

Agriculture Sensors for IoT

wind speed, dew point temperature, wind direction, relative humidity, solar radiation, and atmospheric pressure is measured and recorded at scheduled intervals.

There is a big list of sensors used in agriculture IoT sensors which means (Solutions for Smart Farming).

1. Monitor climate conditions.
2. Greenhouse automation.
3. Crop management.
4. Cattle management and monitoring.
5. Smart precision based agriculture using sensors.
6. Agricultural drones.

How does the use of Sensors in Agriculture can help the farmers in a futuristic way?

1. Labour shortages and the need for food to feed an increasing global population, agricultural robots and technologies now commonly used by farmers.

2. The vision and mission of machine education now allow robots and sensors to see and train surroundings, and of the cheaper costs of smart sensors, they used for more than a year.

3. New innovative sensing technology allows farmers to monitor their fields’ pest groups remotely and take immediate action to protect their crops, using online cloud services and a dashboard.

Things to Consider Before Starting Smart Sensors in Agriculture System as we can see;

1. The uses of sensors in agriculture are endless. There are many ways smart devices can help you increase your farm's performance, productivity and revenue.

2. There are specific challenges with sensors in agriculture, which you need to be aware of before investing in sensors in agriculture and smart farming. choose sensor for your device.

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3. To create a clarification for agriculture, you need to choose the sensors for your device. your choice will depend on the types of information you want to gather and the purpose of your solution in general.

4. Maintenance of your device is a challenge that is of main importance for sensors in agriculture if your sensors used in the field and can easily damage. In this case, you need to make sure your device is durable and easy to maintain. Otherwise, you will need to replace your sensors more frequently.

5. Smart farming applications should use in the field. A farm owner should be able to access all information on-site or remotely via a smartphone or desktop computer.

6. The quality of your sensors is important to the success of your product, and it will depend on the correctness of the gathered data and its authenticity.

7. To ensure your smart farming application performs well, you need a reliable internal infrastructure.

8. Each connected device should be independent and have enough wireless range to communicate with the other devices and send data to the main server.

9. Your internal systems have to be completely secure. Failing to properly secure your system only increases the chances of stealing your data or even taking control of your sensors which connected with your field.

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10. Data analytics should be the focus of every smart sensor in agriculture solution. you need to have convincing data analytics capabilities and apply algorithms and machine learning in order to obtain actionable insights based on the obtained data.

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Advantages of Sensors in Agriculture;

1. There are many advantages of Agriculture Sensors, from which you can take many privileges.
2. Sensors in Agriculture invented to meet the increasing demand for food with minimum resources such water, fertilizers and seeds.
3. They are easy to operate and use and easy to maintain.
4. Sensors are cheaper in price and best in quality.

5. They can use for measuring pollution and global warming for their fields and crops.
6. These sensors equipped with wireless chips so that they can be controlled remotely.

Disadvantages of Sensors in Agriculture;

1. One huge disadvantage of smart farming is that it requires an unlimited or continuous internet connection to be successful. This means that in rural communities, especially in the developing countries where we have mass crop production, it is completely impossible to operate this farming method.

2. In places where internet connections are frustratingly slow, smart farming will be an impossibility.

3. Smart farming makes use of high techs that require technical skill and precision to make it a success. It requires an understanding of robotics and information and communication technology (ICT). However, many farmers do not have these skills. and advantages and Disadvantages of Smart Farming, this can be a discouraging factor hindering a lot of promising farmers from adopting it.

4. Increased unemployment.

5. Too Much Dependency on Technology.

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6. Initial capital costs may be high and so it should be seen as a long-term investment.

7. It may take several years before you have sufficient data to fully implement the system.

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Conclusion;

1. Smart sensor-based approaches are presented for precision agriculture.

2. The use of remote sensors like temperature, humidity, soil moisture, water level sensors and pH value, will provide an idea to on productive farming, which will show accuracy as well as practical agriculture to deal with challenges in the field.

3. This advancement could empower agricultural management systems to handle farm data in an orchestrated manner and increase the agribusiness by formulating effective strategies.

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4. The evolutions of machine learning and the internet of things (IoT) established methods offered to help researchers to implement these methods in agriculture to support farmers.

5. This paper presents to contribute to an overview of the modern sensor technologies deployed to precision agriculture and suggests an abstract of the present and essential applications and presents the challenges and feasible solutions and applications.

6. These will support farmers to improve throughput, effective utilization of field and manage pests.

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