ČESKÁ ZEMĚDĚLSKÁ UNIVERZITA V PRAZE

FAKULTA TROPICKÉHO ZEMĚDĚLSTVÍ

Quality, Storage and Processing of Meat Products

Ing. Klára Urbanová, Phd.

CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

CZECH REPUBLIC DEVELOPMENT COOPERATION

Czech University of Life Sciences Prague Faculty of Tropical AgriSciences

Quality, Storage and Processing of Meat Products

Author
Klára Urbanová

ISBN 978-80213-2853-2

Prague 2018

Content

1. Composition of Meat

Introduction

- For centuries, meat and its derived products represent one of the most important foods consumed in many countries around the world.
- Humans are adapted to an omnivorous diet, based on the shape of their teeth and their unspecialized gut.
- Meat play an important role part in our diet.

Source of meat

- Mammals
  - cattle, sheep, goats, pigs, buffaloes, camels, yaks, lamas, deers and rabbits
- Birds
  - especially domestic fowls and turkeys, geese and ducks
- Fish, seafood and various invertebrates
- New species for meat production
  - antelopes, the American bison and the ostrich…
- Despite this range, the main important meat-producing species are domestic cattle, sheep, pigs and poultry.

Meat production and consumption

- Over the 10 years
  - beef and sheep meat production increased by 20 %
  - pig meat production rose by 40%
  - poultry meat even by 70%

- These differences in production reflect differences in preference by consumers.
  - pig and poultry meat are becoming relatively more popular

Meat production and consumption

- Factors influencing meat consumption:
  - price (pork and poultry are cheaper to produce than beef and sheep meat)
  - healthy (poultry is generally considered by consumers to be healthier to eat)
  - growth of population in parts of the world where pork and poultry are traditionally the preferred meats (China)

Meat production and consumption

The geographical variation in the production of the different meats *

	Total meat	**Beef**	**Sheep meat**	**Pig meat**	**Poultry meat**
Asia and Far East	68.6	7.4	2.7	43.7	14.8
North America	41.6	14.4	0.2	10.4	16.6
EU	33.0	8.7	1.2	16.0	7.9
South America	18.7	9.3	0.3	2.4	6.6
Former Soviet Union	18.7	7.0	0.9	7.8	3.0
Africa and Middle East	9.6	3.4	1.8	0.5	3.9
Australia and NZ	4.4.	2.3	1.1	0.4	0.6

The nutritional value of meat

- Animal products contribute about a third of all protein consumed by humans (fish, milk and eggs are included).

- It contains all the essential amino acids.
- An essential amino acids are an amino acid that cannot be synthesized de novo (from scratch) by the organism, but must be supplied in its diet.
    - phenylalanine, valine, threonine, tryptophan, methionine, leucine, isoleucine, lysine, and histidine

The chemical composition of meat

- 55–60% is water
- 3–4% of minerals, vitamins
- 35–40% of organic substances
- Three major categories of organic compounds:
  - proteins, fats and carbohydrates

The approximate chemical composition of an animal like a pig

Substance	Percentage
Inorganic	
Water	60
Minerals	1
Organic	
Proteins	20
Fats (lipids)	15
Carbohydrates	1

Typical composition of some raw meats (g/100g)

Meat	**Separable components**	**Water (g)**	**Protein (g)**	**Fat(g)**	**Energy (kJ)**
Beef	Lean	74	20.3	4.6	515
	Fat	24	8.8	66.9	2 665
Lamb	Lean	70.1	20.8	8.8	678
	Fat	21.2	3.2	71.8	2 803
Pork	Lean	71.5	20.7	7.1	625
	Fat	21.1	6.8	71.4	2 803
Veal fillet		74.9	21.1	2.7	456
Chicken meat		74.4	20.5	4.3	506
meat and skin		64.4	17.6	17.7	962
Turkey meat		75.5	21.9	2.2	448
meat and skin		72	20.6	6.9	607

The chemical composition of meat
Proteins

- Proteins have a very wide range of functions.
  - structural (e.g. the collagen of connective tissues like tendon)
  - contractile (e.g. the actin and myosin that make up the major part of muscle)
  - enzymes - catalyse chemical reactions (creatine kinase)
  - hormones (e.g. insulin, which regulates the level of glucose in the blood)
  - antibodies - in immunological responses
  - transport functions (e.g. the haemoglobin of blood and the myoglobin of muscle, which carry oxygen)

Proteins

- are large biomoleculs, consisting of one or more long chains of amino acids
  - *non-essential*
  - *essential (cannot be synthetized)*

R
|
H — C — COOH
|
NH_2

The structure of an amino acid, R= depends on the type of amino acids

- Proteins may be combined with lipids in lipoproteins and with carbohydrates in glycoproteins.

Proteins

- Properties of proteins:
  - denatured at relatively low temperatures (<60°C) and in acidic environment
- Denaturation leads
  - to loss of solubility in aqueous solutions
  - to stop the enzymatic, immunological or hormonal processes.

The chemical composition of meat
Lipids (Fats)

- Fats are a very concentrated source of energy.
- The energy value of fat is almost double that of carbohydrate or protein.
- Animals are able to accumulate large amounts of fat can survive long periods without sufficient food (over winter).
- Hibernating animals have large fat depots.

Energy value of fats, proteins and carbohydrates

Component	**Energy kJ/g**
Fat	37
Proteins	17
Carbohydrates	17

Lipids

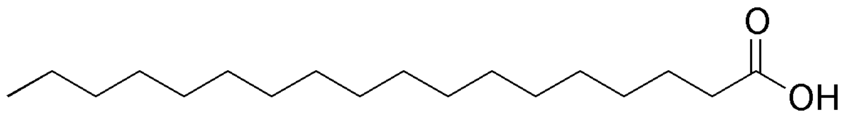
- Functions
  - energy storage
  - structure of cell membrane
  - hormones
  - insulation against body temperature losses
  - protective padding in the skin and around organs, especially kidney and heart

Lipids

- Fats, like other lipids, are generally hydrophobic, and are soluble in organic solvents and insoluble in water.
- Composition:
  - triglycerides in which three fatty acid molecules are linked to triacylglycerols
  - free fatty acids
- Wax, wax esters - wax ester is an ester of fatty acid and alcohol

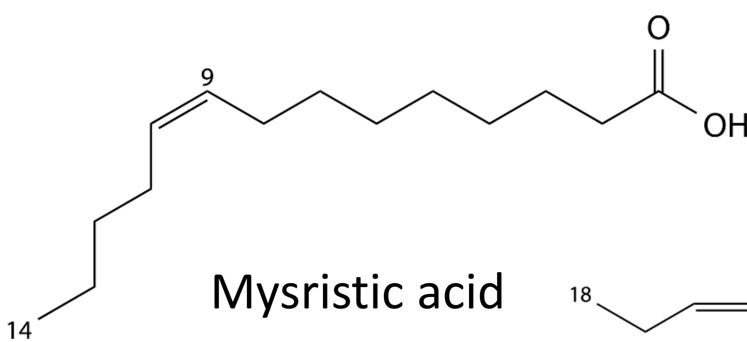
Fatty acids

- Saturated fatty acids - no double bonds (C=C)

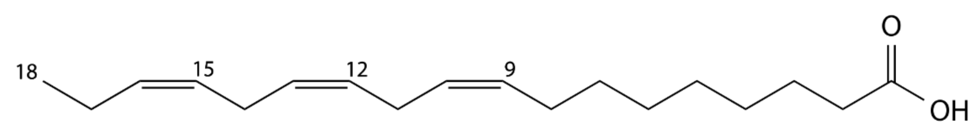


Stearic acid

- Unsaturated fatty acids - a single double bond (monounsaturated) or two or more (polyunsaturated - PUFAs).



Mysristic acid



Linolenoic acid

Fatty acids

- Fatty acids containing double bonds can exist as *cis* or *trans* isomers.
  - trans-unsaturated fatty acids
    - occur in small amounts in nature but became widely produced industrially from vegetable fats for use in margarine, snack food…
    - increase risk of coronary heart disease
- The majority of naturally occurring fatty acids in animal fats are the *cis* forms.

***cis* (*Z*)** ***trans* (*E*)**

Fatty acids

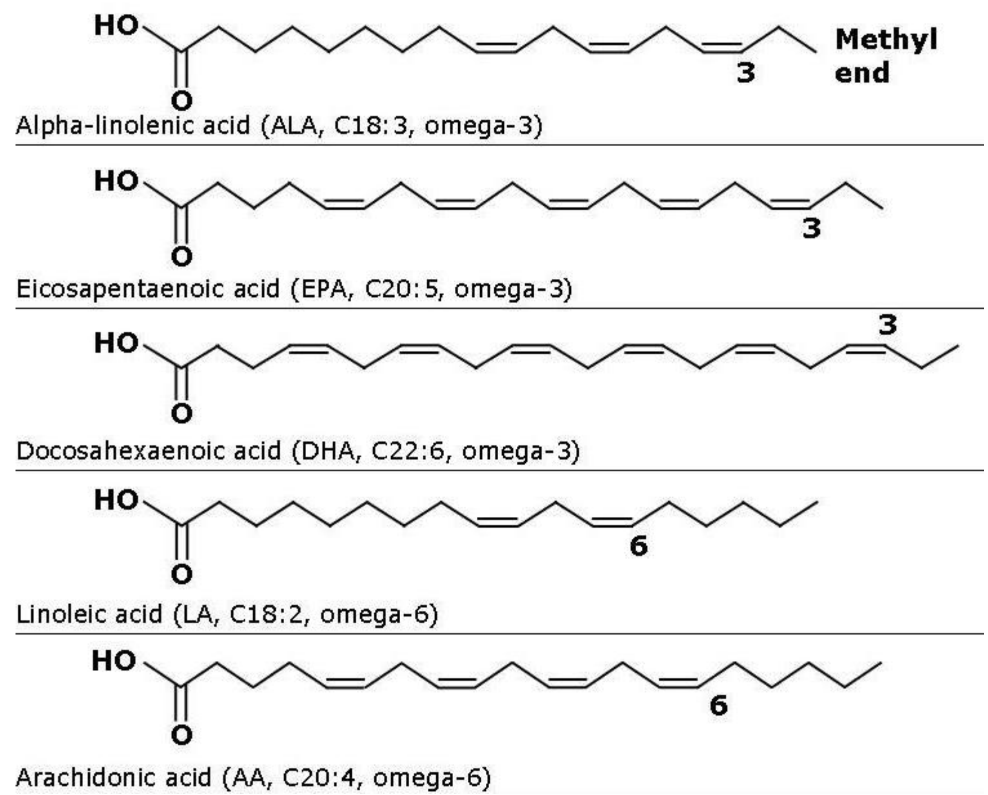
- Essential fatty acids: linoleic, linolenic and arachidonic acids, cannot be synthesized by animals and must be obtained from the diet.
- They are abundant in the oils found in plant seeds.

Examples of the unsaturated fatty acids

Common name	**Chemical structure**	**Δ^x**	**C:D**
Myristoleic acid	$CH_3(CH_2)_3CH{=}CH(CH_2)_7COOH$	cis-Δ^9	14:1
Myristic acid	$CH_3(CH_2)_{12}COOH$	14:0	
Palmitoleic acid	$CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$	cis-Δ^9	16:1
Palmitic acid	$CH_3(CH_2)_{14}COOH$	16:0	
Oleic acid	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$	cis-Δ^9	18:1
Stearic acid	$CH_3(CH_2)_{16}COOH$	18:0	
Linoleic acid	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	cis-Δ^9,Δ^{12}	18:2
Linolenic acid	$CH_3CH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	cis -Δ^9,Δ^{12},Δ^{15}	18:3
Arachidonic acid	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_3COOH$	Cis $\Delta^5\Delta^8$,Δ^{11},Δ^{14}	20:4

Fatty acids - ‘omega 3’ and ‘omega 6’

- An important characteristic of polyunsaturated fatty acids is where the first double bond occurs from the methyl (CH_3) end of the molecule.
- Both groups have important metabolic functions
- The desire a dietary ratio it
- 4 or 5:1 for *n*-6: *n*-3
- The proportion is especially important in relation to the incidence of cardiovascular disease.



Fatty acid composition of some fats and oils

- The differing proportions of the constituent saturated and unsaturated fatty acids illustrate their importance in determining the hardness or softness of the fat.

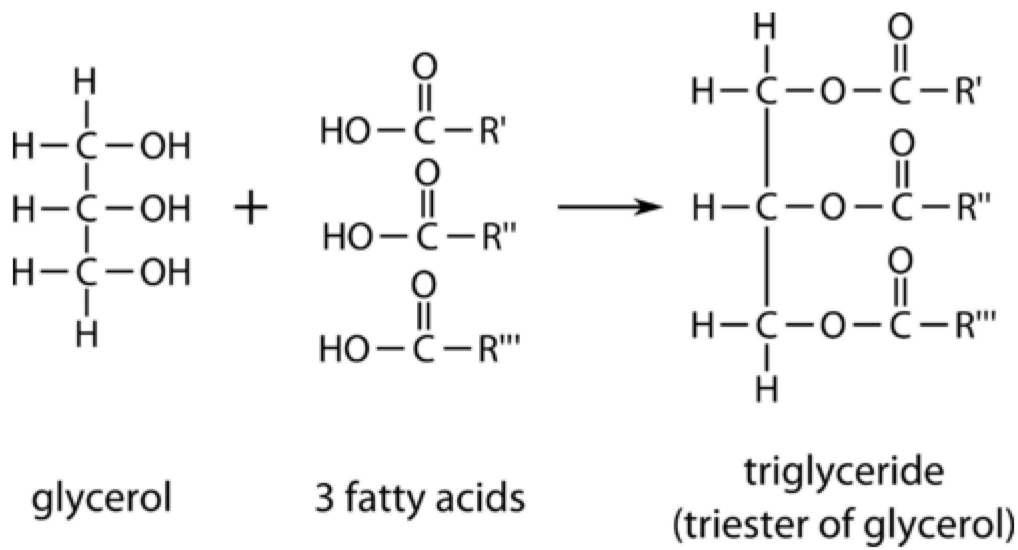
- A major problem with unsaturated fats is their sensitivity to oxidation (degradation of fats).

Fatty acid composition of some fats and oils*

	Lamb	**Beef**	**Pork**	**Chicken**	**Salmon**	**Corn oil**
Saturated fatty acids	53	45	40	35	21	13
Unsaturated fatty acids	47	55	60	65	79	87
Ratio (saturated/ unsaturated acids)	1.1	0.8	0.7	0.6	0.3	0.2
Hardness of fat	Hard →					Soft

Triglyceride

- The general formula:



Where R´, R´´,R´´´ may be the same or different fatty acids.

Triglyceride

- **Fats -** Triglycerides that contain mainly saturated fatty acids are solid at room temperature (20°C) – most animal fat
- The fats from fish and marine mammals tend to be polyunsaturated, containing up to six double bonds, and therefore are oils (cod liver oil, whale oil) at room temperature or above.

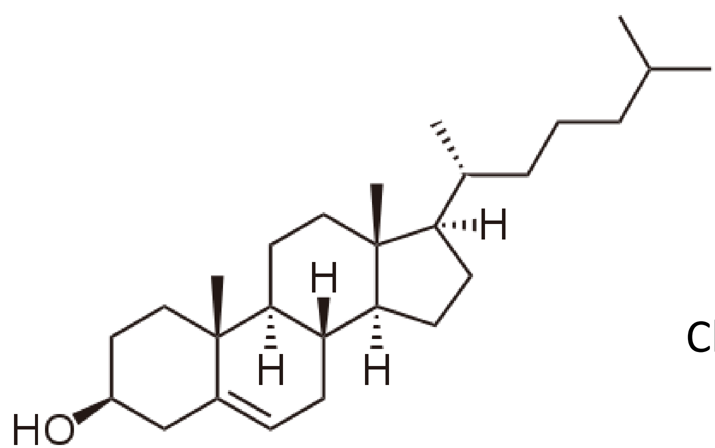
- **Oils** - a large proportion of unsaturated fatty acids are usually liquid - plant oil.

Lipid oxidation

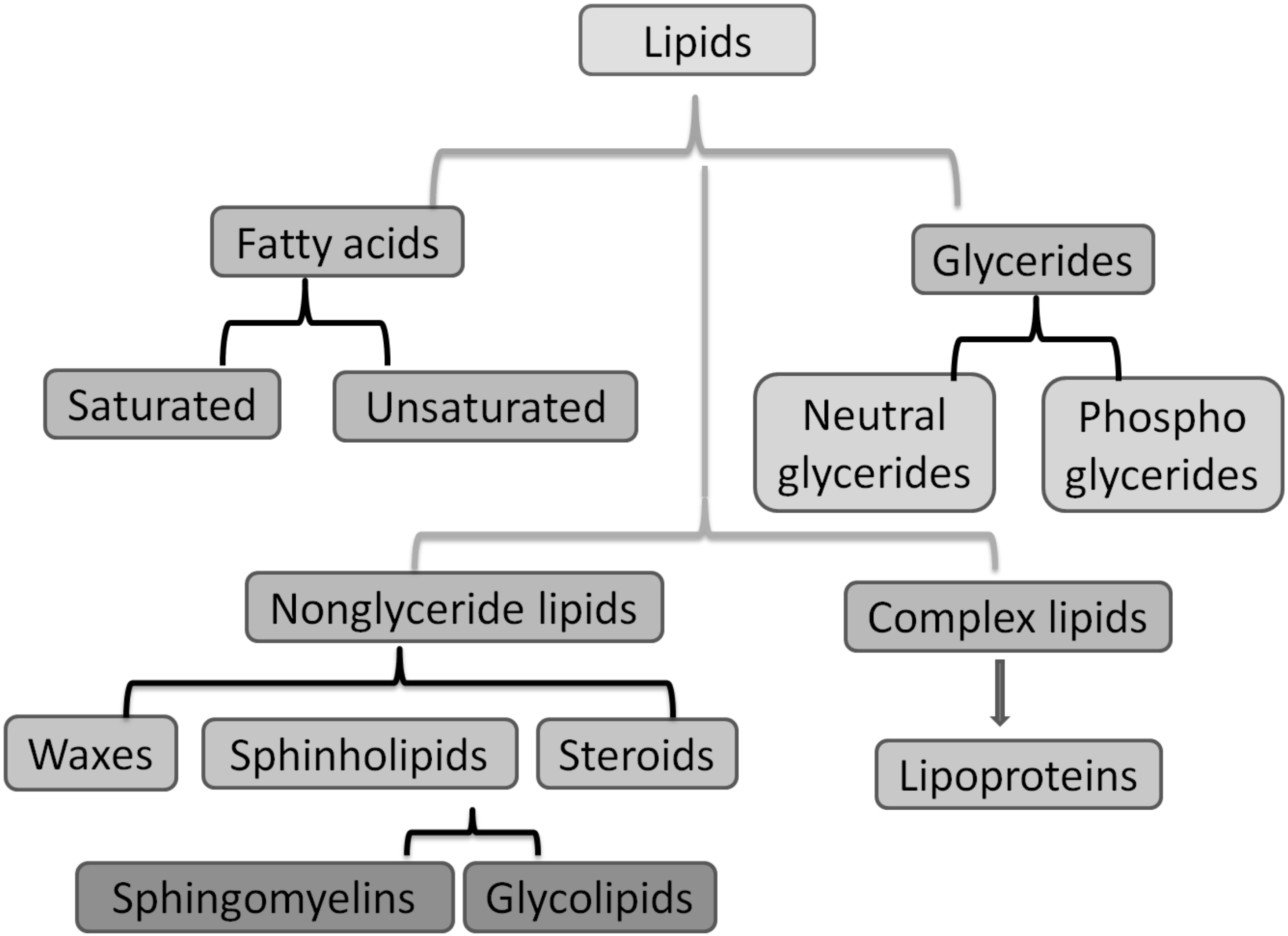
- The polyunsaturated fatty acids present in the meat can react with oxygen to form fatty acid hydroperoxides.
  - These are unstable and break down into various compounds
    - aldehydes, ketones and carboxyl compounds $\longrightarrow$ off-flavours

Other important lipids

- **Phospholipids**
  - a major structural component of cell membranes, include the lecithins also found in blood plasma.
- **Sphingomyelins**
  - are an important constituent of nerves and glycolipids are also found in cell membranes.
- **Steroids** have a characteristic ring structure.
  - The commonest is cholesterol, found in cell membranes, steroid hormones



Cholesterol

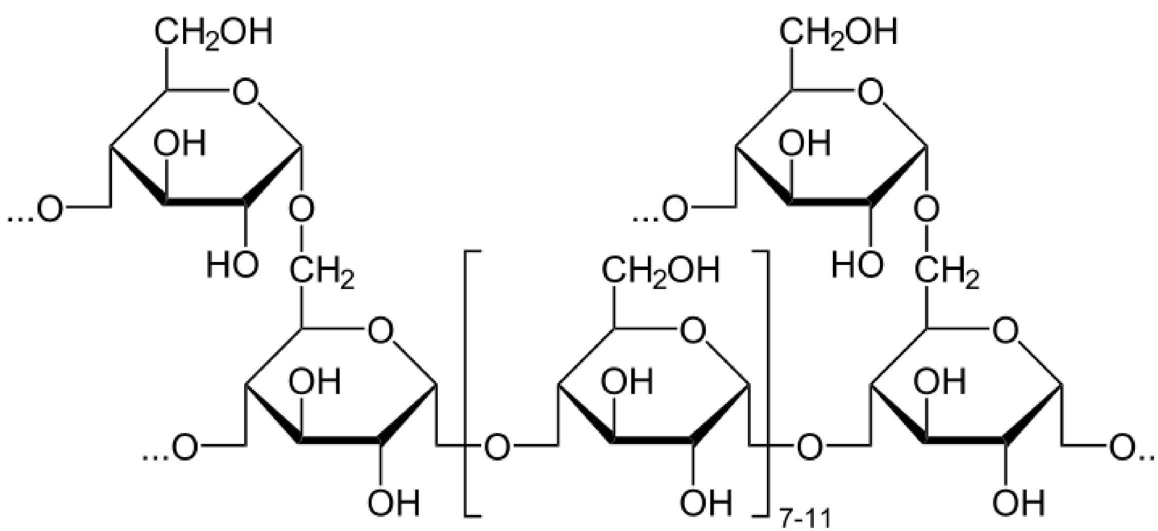

Lipids
Fatty acids
Saturated
Unsaturated
Glycerides
Neutral glycerides
Phospho glycerides
Nonglyceride lipids
Waxes
Sphinholipids
Steroids
Sphingomyelins
Glycolipids
Complex lipids
Lipoproteins

The chemical composition of meat
Carbohyrdates

- Minor component of animals, but in muscles very important
- Monosaccharides - glucose , fructose, galactose
- Disaccharides – sucrose, lactose, maltose
- Polysaccharides - composed of long chains of monosaccharides units – starch, glycogen, celluose

Glycogen

- Glycogen - a polymer of glucose (consists of up to 50,000 glucose units)
- It is comparable in function to the starch of plants
  - in that it acts as an energy store
  - especially as a readily available source of glucose
- It is found particularly in the muscles and the liver.



Structure of glycogen

The chemical composition of meat
Nucleotides

- Nucleotides are complex molecules made up of three constituent parts,
  - phosphoric acid (H_3PO_4)
  - sugar molecule containing five carbon atoms
  - purine or pyrimidine molecule
- Nucleotides form the basis of the nucleic acids, RNA and DNA.
- Nucleotides are complex molecules made up of three constituent parts,
  - cytosine (C), guanine (G), adenine (A), or thymine (T)—
  - a monosaccharide sugar deoxyribose (DNA) or ribose (RNA)
  - phosphate group

Nucleotides – purine-containing nucleotide Adenosine triphosphate (ATP)

- Nucleotides also play a central role in life-form metabolism at the fundamental, cellular level.
- ATP transports chemical energy within cells for metabolism.
- It is absolutely essential for the functioning of all known cells.
- Its significance lies in the fact that the decomposition of ATP to ADP is released considerable amounts of energy.
- This energy is used in almost all types of cellular processes, such as many biosynthetic pathways, intracellular transport, and membrane transport, the production of protein, RNA synthesis or **muscle contraction**.
- The energy in the bond becomes available to fuel other processes in the animal's body.

Nucleotides

- AMP can have one or two extra phosphate molecules added to it to produce adenosine diphosphate (ADP) and adenosine triphosphate (ATP) respectively.
- The importance of these extra phosphates is that they are joined to the AMP molecule by what are referred to as energy-rich bonds.
- These bonds, particularly that of the third phosphate in ATP, act as stores of chemical energy.
- Thus, when ATP is hydrolysed to ADP:
- ATP + H2O $\longleftrightarrow$ ADP + H_3PO_4
- The energy in the bond becomes available to fuel other processes in the animal's body.
- One of these is muscle contraction.

Minerals

- About 1% of meat mass
- Mostly soluble in water
- Important for nutrition of consumer
- High retention in human organisms if received as a component in meat

- **Calcium** - active in muscle contraction and blood precipitation and is component of bones.
- **Iron** is present in haem pigments (meat colour) and is very good utilizable for human organism.
- **Zinc -** mostly from beef
- **Selenium**

Vitamins

- Meat – important source
- Group B - B1 (thiamine), niacin, B2 (riboflavin), B6, B12
- Muscle and viscera
- Lipophilic vitamins in adipose tissue and liver: A, D and E
- Vitamin C – only in liver and fresh blood
- Vitamins in meat enter in organisms together with proteins, which is important for their utilization

2. Animals for Meat Production

Domesticated animals

- Cattle - most used in the world, expensive, different breeds and quality
- Pig - pork is most used in central Europe, USA, Asia - different preference of ratio lean/fatty
- Sheep - meaty breeds, lamb (Australia), less tasty from wool breeds
- Goat - often as secondary product to milk
- Horse (donkey) - No common, major meat in only a few countries (Central Asia), taboo food in some cultures
- Camels - North Africa, Asia
- Poultry - cheap, easy to prepare, easy breeding
- Rabbit - minor importance, preferred in some countries (France, Malta).
- Lama, alpaca - South America

Beef

- Domesticated 8000 BC
- Modern beef breeds originate from the Europe/ N. Africa and Asia
- Today 800 breeds
- Different breeds – different properties of meat
- Current cattle are bred to withstand harsh conditions
  - drought and heat
  - high humidity
  - high altitude
  - low temperatures
  - disease resistant etc

Beef

- Cattle includes all kinds of breeds.
- Some breeds are primarily used for the beef, some for the milk.

- Certain breeds of cows are bred for their ability
  - to make milk (Holsteins or Jerseys)
  - to grow muscle (Angus or Hereford).

- Meat breeds
- Dairy breeds
- Dual-purpose breeds

Meat breeds

- Selective breeding for meat yield (Angus, Hereford, Gelbvieh, Limousin, Wagu)

- Beefy rumps, back and shoulders
- Some breeds have muscle *hypetrophy* – rumps and shoulders (e.g. Piedmontese, Belgian Blue)
- Weight up to 1700 kg

Dairy breeds

- Selective breeding for milk yield
- 6 800 l of milk per lactation
- Light-built body frame
- Less muscle tissue rumps, back and shoulders

- Milk is primarily intended for calves.
- To make cows produce milk, it must be artificially inseminated (in intensive farming). Her calf is then removed.
- Cow in intensive farming is forced to produce 10 times the amount of milk than is natural for her.
- They are exhausted after 4-6 years (normally lives for about 20 years).

Dairy breeds

- Dairy breeds:
  - Holstein-Fresian
  - Brown Swiss
  - Guernsey
  - Ayrshire
  - Jersey (Red and White)

Composition and structure of milk

- Milk consists of
  - (i) an oil-in-water emulsion
    - the fat is dispersed in the milk serum known as whey
  - (ii) a colloidal suspension of proteins of various sizes in milk serum
    - casein micelles, globular proteins, and lipoprotein particles
  - (iii) a solution of lactose, soluble proteins, minerals, vitamins, and other components.

Composition and structure of milk

- The main component of milk is water.
- The remaining compounds are mainly
  - fat (3.9%)
  - protein (3.3%)
  - lactose (5%),
  - minerals (0.7%)
  - vitamins (e.g., vitamins A and C)
  - enzymes (e.g., lactoperoxidases (LP) and acid phosphatase)

Hogs - Pork

- Modern hogs – domesticated from Eurasian Wild Boar 6000-7000 B.C.
- Largest producers – China, U.S., Brazil, Canada, Russia etc.
- Omnivore – easy to feed but for commercial purposes has high requirements for feeding quality →expensive.
- Swine fertility – approx. 20 piglets/year
- Ideal market weight in approx. 6 months – 120kg

Hogs - Pork

- Modern hog breeding and selection is dependent on a number of factors:
  - average litter size
  - gain – ability to grow fast
  - disease and stress resistant
  - fat/lean ratio
  - meat quality – colour, marbling, texture

Poultry farming

- Poultry farming is the raising of domesticated birds
  - chickens, ducks, turkeys and geese
  - purpose of farming: meat or eggs for food
- Poultry are farmed in great numbers (especially chickens)
  - more than 50 billion chickens are raised annually as a source of food (meat and eggs).
    - Layers - chickens raised for eggs
    - Broilers - chickens raised for meat

Intensive and alternative poultry farming

- 74 % of the world's poultry meat, and 68 % of eggs are produced in **intensive** ways
- alternative to intensive poultry farming is free-range farming

Rabbits

- Meat, fur
- Rabbits are a food meat in Europe, China, South America, North America, some parts of the Middle East, Australia
- Compared with the meat of other species (especially pork and beef), rabbit meat is richer in proteins and certain vitamins and minerals
- Less fat

Goats

- Consume less forage than beef cattle
- Milk, meat
- Yield approx. 18 kg of meat
- The cuisines best known for their use of goat
  - African cuisine, Middle Eastern, North African, Indian, Indonesian, Nepali, Pakistani, Mexican, Caribbean and few European cuisines
- Goat has a reputation for strong, gamey flavour, but can be mild depending on how it is raised and prepared.

Sheep and Lamb

- Meat, milk, wool and skin
  - multipurpose breeds
- Texel, Suffolk, Hampshire, Dorset, etc.
- Australia, New Zealand, USA, UK, etc.

Fish

- Fish is an important source of protein.
- The economic activities associated with its harvest, handling, processing, and distribution provide a means of livelihood for millions of people.
- Fish is a highly perishable food product, requiring proper handling, processing, and distribution.

Contribution of fish to human nutrition

- Fish represents a valuable source of micronutrients, minerals, essential fatty acids, and proteins in the diet of many countries.
- The meat of fish and seafood products contains
  - 80% water
  - 8%–25% proteins
  - 1%–30% fat
  - 0.6%–1.5% mineral compounds
  - Vitamins (B, fish oil - A, D)
- Lipids contained in fish are rich in essential polyenoic fatty acids
  - valuable nutritionally are the *n*-3 polyenoic acids

Sea fish

- **Commercial fishing**
- Commercial fishermen harvest almost all aquatic species,
  - tuna, cod and salmon to shrimp, krill, lobster, clams, squid and crab
- Commercial fishing methods have become very efficient using large nets and sea-going processing factories.
- Individual fishing quotas and international treaties seek to control the species and quantities caught.
- A commercial fishing enterprise may vary from
  - one man with a small boat with hand-casting nets or
  - a few pot traps, to a huge fleet of trawlers processing tons of fish every day

Sea fish

- **Fish farms**
- It involves raising fish commercially in tanks or enclosures.
- Fish species raised by fish farms include salmon, carp, tilapia, catfish and trout.
- Increased demands on wild fisheries by commercial fishing has caused widespread overfishing.
- Fish farming offers an alternative solution to the increasing market demand for fish and fish protein.

Fresh water fish

- Commercial fish industry
- Fish farms – fish are bred in the reservoir, ponds – carp, trout
- Wild – freshwater, brooks, lakes, rivers
- Carp, catfish, eel, pike, trout etc.

Invertebrates

- Sponges (Porifera)
- Jellyfish
- Worms
- Insects, spiders, crabs
- Cuttlefish, snails, mussels
- Starfish, sea-cucumber

Jellyfish

- Delicacy in Asia – Japan, Korea, China
- Harvested mainly in southeast Asia
- Dried jellyfish – preserved for weeks

Worms

- Habitat: marine, freshwater, terrestrial
- Mostly parasites of plants and animals including humans
- Earthworms - decomposers – high risk of microbial contamination
- High water content
- Nutrients
    - proteins
    - Ca, Fe, Mg, K, P, Cu

Insects and Spiders

- Historic basis – traditional protein source – before hunting and farming
- Increased interest recently for the following reasons:
  - rising cost of animal protein
  - environmental pressures
  - population growth
    - increasing demand for protein

Insects and Spiders

- Mini-livestock – intentional cultivation of insects and edible arthropods
  - more environmentally friendly alternative to traditional animal live stocking.
- Insect farming is much cheaper than cattle farming and requires much less energy.
  - Cattle requires a huge amount of energy and money to raise and feed cattle, remove waste and to keep them healthy.
- Insects have high concentrations of amino acids, vitamin B12, riboflavin, vitamin A,…
- Good source of protein

Snails

- Heliculture (snail farming)
  - is the process of raising land snails specifically for human use,
    - either to use their flesh as edible escargot,
    - or more recently, to obtain snail slime for use in cosmetics,
    - or snail eggs for human consumption as a type of caviar.
- Major exporters – France, Indonesia, Greece, China
- Specific farming climate:
  - 15–25 °C
  - high humidity (75% to 95%)

Crabs

- Crabs make up 20% of all marine crustaceans caught,
- Consumed worldwide
  - 1,5 million tonnes annually
- Crabs are widely hunted for their meat, which is obtained mainly from the claws and body of the individual.
- The largest producer is China

Prawns and shrimps

- Farming dates to the 1970s
- Mainly Asia – China and Thailand
- Pacific white shrimp (*Litopenaeus vannamei*)
- Giant tiger prawn (*Penaeus monodon*)

Oysters

- Fishing oysters - harvested in shallow waters from their beds
- Oyster farming was practiced by the ancient Romans as early as the 1st century BC on the Italian peninsula and later in Britain for export to Rome.
- The French oyster industry has relied on aquacultured oysters since the late 18th century.

Mussels

- Humans have used mussels as food for thousands of years.
- About 17 species are edible, of which the most commonly eaten are *Blue mussel*
- In Belgium, the Netherlands, and France, mussels are consumed with French fries or bread.

Any benefits of eating meat?

- Source of nutritive valuable substances
- Valuable proteins, vitamins, minerals (Fe, Ca)
- Fat – source of unsaturated fatty acids (essential)

3. Structure of Muscle Tissue

The structure of meat

- Carcass meat consists of lean, fat and bones, together with connective tissue.
- 65% of the proteins in the animal body are skeleton muscle protein
- 30% connective tissue proteins (collagen, elastin)
- 5% blood proteins and keratin (hairs, nails)

- Basic meat tissues
  - epithelial tissue
  - nervous tissue
  - connective tissue
  - muscle tissue

Epithelial tissue

- Epithelial tissues line the cavities and surfaces of blood vessels and organs throughout the body.
- All glands are made up of epithelial cells.
- Functions of epithelial cells
  - secretion, selective absorption, protection, transcellular transport, and sensing

Epithelial tissue

- **Protection** from radiation, desiccation, toxins, invasion by pathogens, and physical trauma
- **Diffusion** - Simple epithelial tissue is ideal for the diffusion of liquids, nutrients and gases
- **Secretion** - In some glands, epithelial cells will secrete enzymes or hormones.
- **Sensation** - Specialised epithelial cells in the tissue contain sensory nerve endings that are stimulated by sensory sites such as the nose, ears, skin, tongue and eyes.

Nervous tissue

- Nervous system:
- Composed of neurons and neuroglia
- High content of lipids, proteins
- Food: brain tissue

Connective tissue

- Individual types of connective tissue from each other at first sight are very different (ligaments, bones)
- Main functions
  - mechanical support function
  - contributes to maintain a constant concentration of ions and water
  - forming fabric reserves organism and have a defensive function.
- By composition and firmness it is possible to distinguish:
  - ligaments (collagen, elastin)
  - cartilages (glycoproteins, e.g. chondroitin sulphate, joint cartilage)
  - bones
  - adipose tissues - fats

Connective tissue

- The main component of the connective tissue is collagen, together with the protein elastin.
- Collagen fibres are straight, inextensible and non-branching.
- Collagen can form very strong structures.
- Elastin fibres are branched and elastic.
- Occurs especially in the walls of blood vessels and in ligaments.
- It also contributes to the elasticity of skin.

Tendons

- A tendon
  - is a tough band of fibrous connective tissue that usually connects muscle to bone
  - contain large amounts of collagen
  - usually avoid before culinary treatment
  - is used as a food in some Asian cuisines

- Tendon is tough and fibrous prior to cooking, but becomes soft after a long period of cooking.

Adipose tissue

- Adipose tissue - simply fat is loose connective tissue composed mostly of adipocytes
- Natural occurring part of the meat carcass
- Fat content depends on breed, age and nutrition of animal
- Culinary using (sausages, salami, cracklings)

- Fatty tissues function:
- Energy deposits (store energy)
- Insulation against body temperature losses
- Protective padding in the skin and around organs

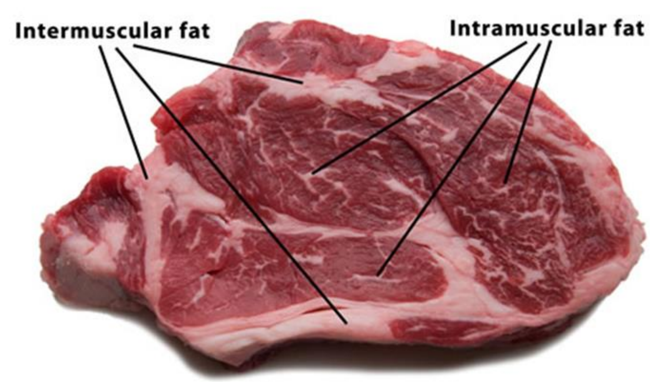
Adipose tissue

- **Subcutaneous fat deposits -** under the skin
  - from pigs are the best suited and also most widely used in meat processing, e.g. backfat, jowl fat and belly
  - fatty tissues are easily separated from other tissues and used as separate ingredients for meat products
  - easy to trim to produce leaner-looking meat

- **Surrounding organs -** kidney, heart fat deposits
  - kidney fat of pigs is not recommended for processed meat products (hardness and taint)

Adipose tissue

- **Intermuscular fat**
  - deposits between muscles occurring in certain locations in muscle tissues
  - They are either trimmed off or left connected (e.g. intermuscular fat in muscle tissue) and processed together with the muscle meat
- **Intramuscular fat**
  - deposits between the muscle fibre bundles
  - is also referred to as marbling fat because when abundant it gives a marbled appearance



Adipose tissue

- Marbling of muscle meat contributes:
  - to tenderness and flavour of meat
  - consumers prefer marbling of meat for steaks and other roasted meat dishes

- Processed meat products:
  - fat is added to make products softer and also for taste and flavour improvement.

Adipose tissue-Beef tallow

- Tallow is animal fat from ruminants.
- At ordinary temperature it is rigid.
- It can be obtained at lower temperatures than lard.
- Tallow is difficult to digest, especially at lower temperatures.
- Limited use in food industry – only high-quality beef tallow

Blood

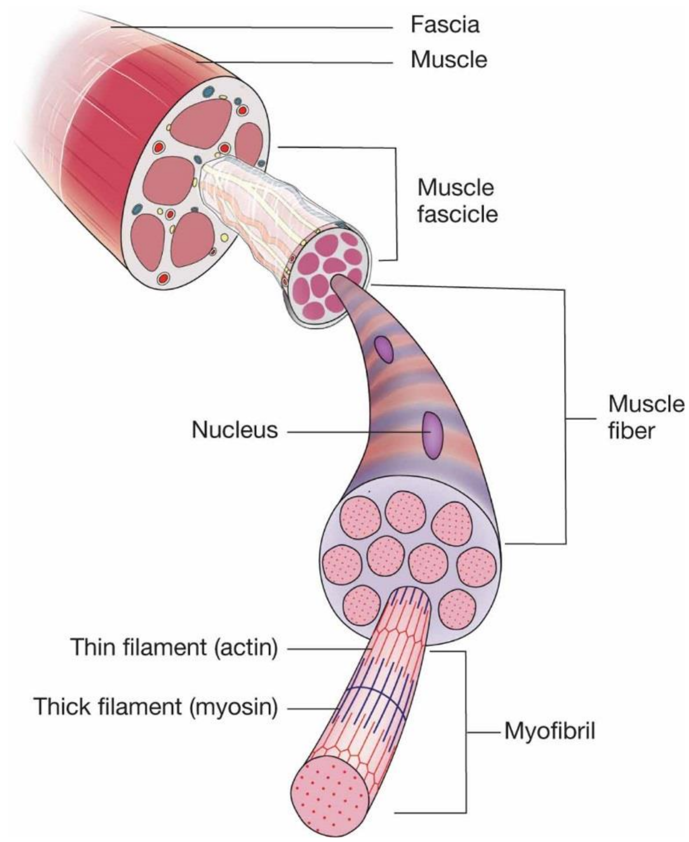
- Very short shelf-life
- Very good source of iron
- Added to several meat products – colour
- Might have a bitter/metal off-taste for some consumers

Muscle tissue

- The most important component of meat is the muscle.
- Skeletal muscle is made up of thousands of cylindrical muscle fibers.
- The fibers are bound together by connective tissue through which blood vessels and nerves run.
- An ordered arrangement of fibers creates the characteristic texture of meat.

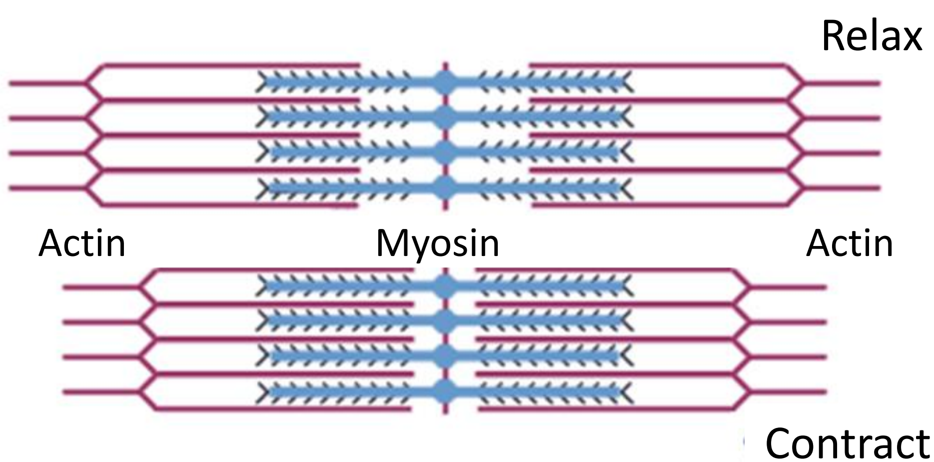
Skeletal muscle

- Skeletal muscle are organs of the muscular system
- There are more than 600 muscle in the animal body.
- Vary widely in shape, size and action.
- A muscle is composed of muscle fascicles.
- Around each fascicle are arteries, veins and nerves.
- Each fascicle contains several muscle fibres (muscle cells).
- Within each muscle fibre are myofibrils that contain thin strands of **actin** and thick strands of **myosin**.



The Contractile and Other Muscle Proteins

- Myosin and actin form the major parts of the thick and thin filaments in the muscle
- Actin filaments, usually in association with myosin, are responsible for many types of cell movements.
- During muscle contraction the thick and thin filaments of the myofibrils slide over one another.



Myoglobin

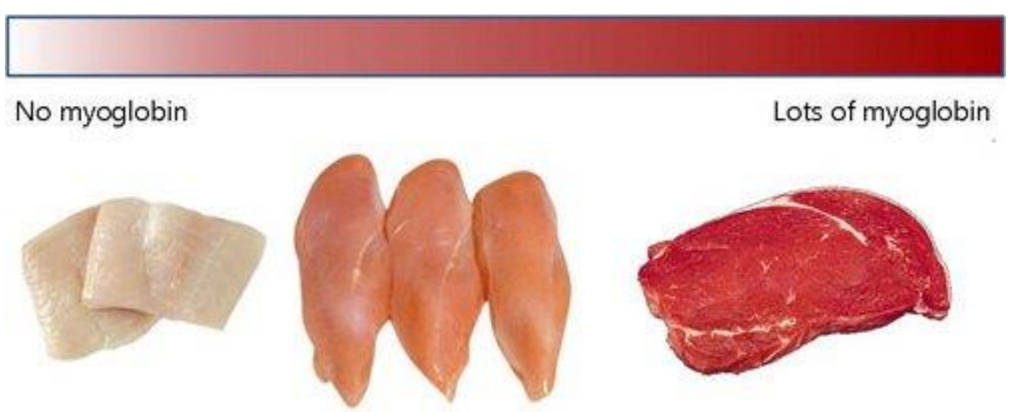
- Myoglobin is an iron- and oxygen-binding protein found in the muscle tissue of vertebrates.
- contains hems
  - pigments responsible for the colour of red meat.
- Similar to the blood pigment haemoglobin it transports oxygen in the tissues of the live animal.

Myoglobin

- Oxygen is needed for the biochemical process that causes muscle contraction in the live animal.
- The greater the myoglobin concentration, the more intense the colour of the muscle.
- This difference in myoglobin concentration is the reason why there is often one muscle group lighter or darker than another in the same carcass.

Myoglobin

- Myoglobin concentration in muscles also differs among animal species.
- Beef has considerably more myoglobin than pork, veal or lamb, thus giving beef a more intense colour.
- The maturity of the animal (with older animals having darker pigmentation).



Post-mortem changes in muscle

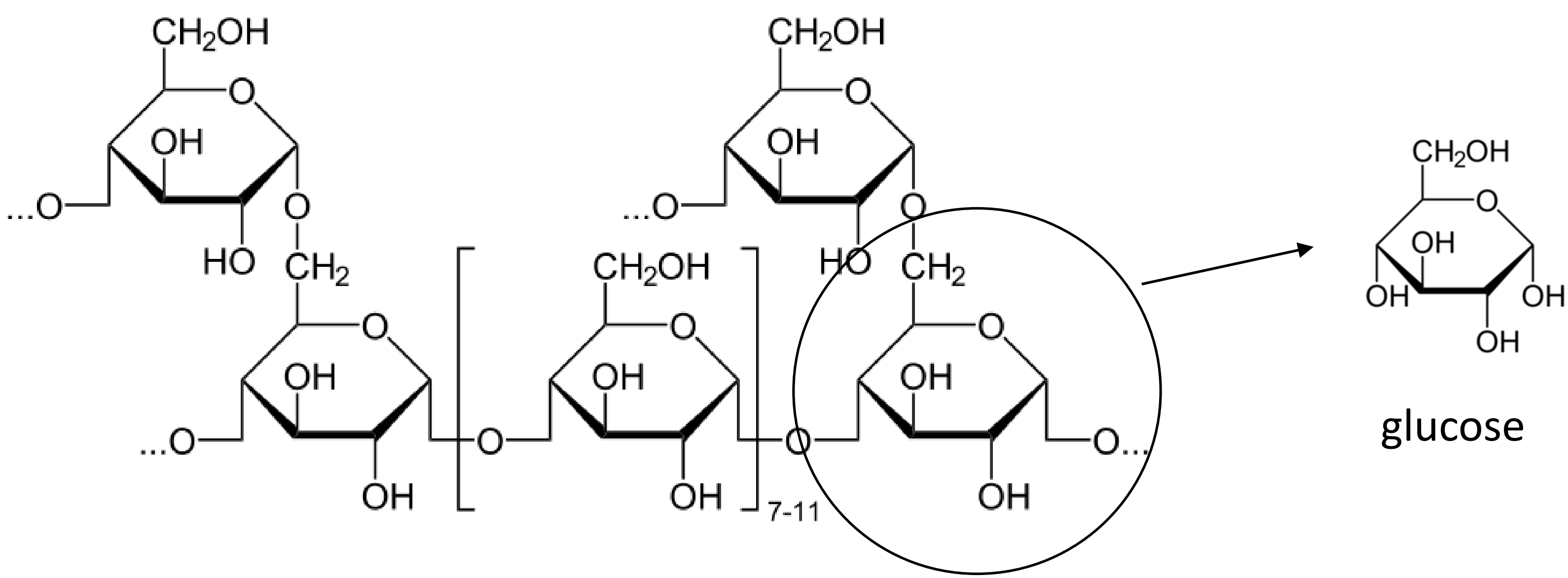
- A period of time normally elapses between
  - **the slaughter of an animal and consumption of the meat**
- the carcass cools down
- becomes stiffer the surface dries
- the fat becomes firmer
- the texture and flavour of the lean improve.
- These effects are accompanied by significant biochemical changes in the muscles:
  - acidification
  - the development of rigor mortis

Muscle metabolism in the living animal

- The major function of muscles is to contract and, the energy for contraction, comes in the form of the purine nucleotide, **adenosine triphosphate (ATP).**
- In living muscles the fuels for producing this ATP are
  - **glucose from the blood**
    - mostly used in fed animals
  - **free fatty acids (FA)**
    - level of free fatty acids is low in fed animals
    - In the fasting state FA -derived from the breakdown of triglyceride stores in the fat depots of the body- are metabolized
  - **glycogen** which is stored directly within the muscle fibres
    - is mobilized only when the rates of breakdown of fatty acids and glucose cannot provide energy at a sufficient rate meet the demands of contracting muscle

Glycolysis

- is a series of reactions that extract energy (ATP) from glucose and glycogen
    - Aerobic conditions – with oxygen
    - Anaerobic conditions – without oxygen



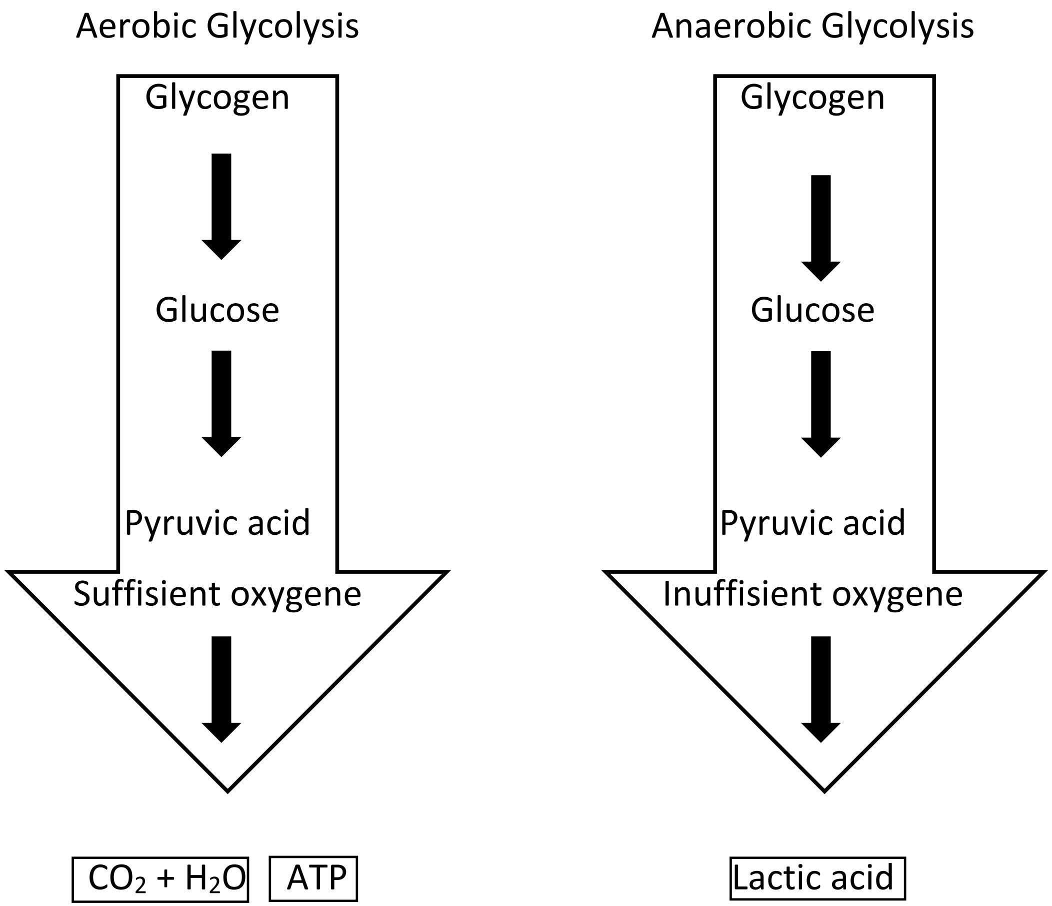
Glycolysis - aerobic conditions

- Glycogen and glucose are broken down essentially by the same process.
- Overall, the reaction can be described as:
- $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$
- Operation of the whole system requires aerobic conditions
  - six oxygen molecules are needed to oxidize each glucose molecule

Glycolysis - anaerobic conditions

- Under anaerobic conditions only the glycolytic part of the system can operate.
- Normally is only occurs during very heavy exercise.
- Under these conditions is formed lactic acid,
  - the reaction is catalysed by the enzyme lactate dehydrogenase
- Lactic acid molecules are produced:
- $(C_6H_{10}O_5)n + n\ H_2O \rightarrow 2n\ C_3H_6O_3$

  glycogen lactic acid

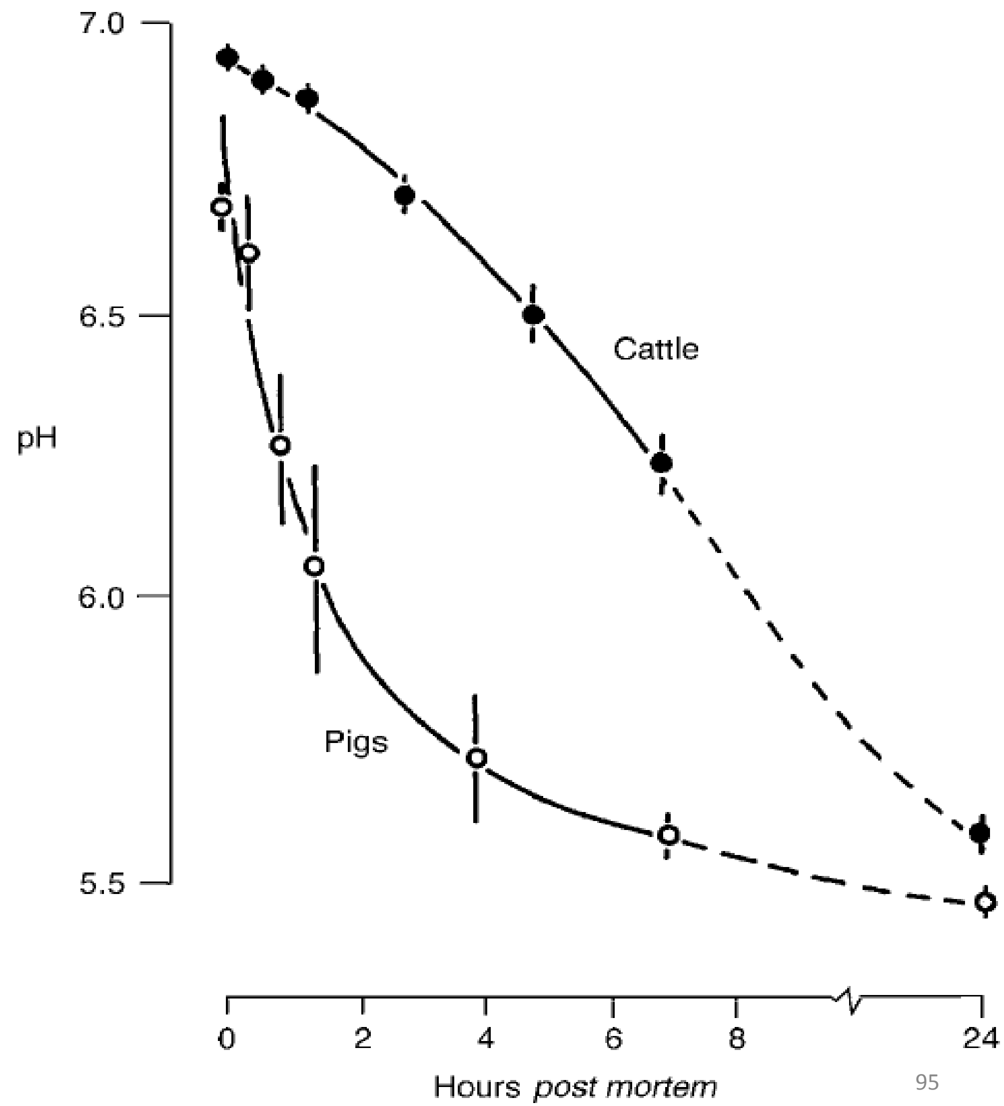

Aerobic Glycolysis
Glycogen
Glucose
Pyruvic acid
Suffisient oxygene
$CO_2 + H_2O$
ATP
Anaerobic Glycolysis
Glycogen
Glucose
Pyruvic acid
Inuffisient oxygene
Lactic acid

Post-mortem acidification

- At the death of the animal the supply of oxygen (and glucose and free fatty acids) to the muscles stops when the blood circulatory system fails.
- Any subsequent metabolism must be anaerobic and ATP can only be regenerated through breakdown of glycogen by glycolysis.
- As glycogen is broken down so lactic acid accumulates .
- Because this is not removed by the blood system the muscle gradually acidifies (decreasing pH of meat).

The patterns of acidification of the m. longissimus dorsi in pigs and cattle.

- The process of acidification normally takes
- 4–8 h in pigs,
- 12–24 h in sheep
- 15–36 h in cattle



The development of rigor mortis

- In a resting muscle
  - ATP serves to keep the muscle in a relaxed state by preventing the formation of actomyosin.
- Rigor mortis occurs when the ATP level falls below the very low level required to maintain relaxation.
- When this happens, the actin and myosin molecules of the thin and thick filaments combine irreversibly to form actomyosin and extensibility of the muscle is lost
- The time of onset of rigor relates to factors affecting the level of glycogen at death.
- Each muscle fibre goes into rigor very quickly once ATP is depleted, but the variation between individual fibres leads to a more gradual development of stiffness in the whole muscle as more and more fibres.

The resolution of rigor mortis

- Rigor mortis is very important in meat technology.
- The onset of rigor mortis and its resolution partially determines the tenderness of meat.
- After a variable period of time there is a progressive ‘resolution’ of rigor when the muscles soften.

- **Tenderization** - process of softening meat

The rate of tenderization

- The rate at which this tenderization occurs varies with temperature and in the different species.
- It is faster at higher temperatures.
- Chicken meat achieves 80% of its maximum tenderness about 8 h after death of the bird
- whereas beef takes 10 days to reach the same level of tenderness.
- These differences in the rate of tenderization lead to different recommended ‘ageing’ times prior to cooking the meat.
- Recommended conditioning times for pork, lamb and beef.
    - Pork - 4-10 days
    - Lamb - 7-14 days
    - Beef - 10-21 days

Meat ageing and tenderization

- Meat aging is a process of preparing meat for consumption, mainly by breaking down the connective tissue – softening of meat
- The tenderization could be attributable to two types of process:
- Changes in the connective tissue components of the meat
- Weakening of the myofibrils
- Aging leads to
    - production of extractive compounds - flavour
    - increase of pH value
    - increase of edibility of meat

Mechanism of tenderization

- Tenderization results from the activities of proteolytic enzymes present in the muscles.
- Their normal role is in the breakdown and recycling of proteins which occurs continuously in all living tissues.
- There are two main sorts of enzyme involved,
  - **cathepsins** and **calpains**
- **Calpains** are more important in the red meat and poultry
- **Cathepsins** is more important in the post-mortem degradation of fish muscle

Tenderizing by marinating and injection

- **Tenderizing with salts and acids**
- Meat can be tenderized by the action of salt solutions or acids.
- Traditionally, meat is marinated in vinegar (acetic acid) or wine.
- The action of the acid is
  - to break the muscle structure down
  - makes the myofibrils swell and hold water better, increasing tenderness and juiciness.
- An extension of marinating is to infuse or inject solutions into pieces of meat.

Tenderizing by marinating and injection

- **Tenderizing with enzymes**
- Naturally occurring enzymes can be added to meat.
- The enzyme was injected into the blood system in an inactivated form.
- It became activated during the acidification of the muscles *post mortem* and also when the meat was subsequently cooked.
- Plants enzymes– papain, bromelin, … (papaya, pineapple, kiwi..)
- Papain is proteolytic enzyme and results in more tender meat.

Deep autolysis

- Too long aging period leads to a deep autolysis
- Excessive proteolysis
- Break up of structure
- Soft, muddy texture
- Bitter, unpleasant flavour
- Microbial spoilage
- Taint, slime, discolorations

- It is important to follow the proper aging time

Conclusion

- The major changes occurring in muscles after the death of the animal are
  - acidification
  - the development and resolution of rigor mortis.

- The **acidification** affects colour and waterholding capacity
- The **resolution of rigor** results in tenderization.
- With time, the juiciness and flavour of the meat after cooking also often improve.

4. Live Animal Handling and Meat Quality

Why do we kill animals?

- People kill animals since ancient times
  - source of food (protein, essential fatty acids, vitamins, minerals)
  - hide, fur, horns
- Today
  - less farmers, large-scale production of meat
  - people are separated from farming and animal
  - packages of meat in supermarket

Each meat was sometimes live animal!!!

The effects of live animal handling on carcass and meat quality

- The efforts of farmers to produce animals with good carcass and meat quality may be wasted if they are handled in less than optimal ways before slaughter.

- The importance of pre-slaughter handling in affecting quality is therefore increasingly recognized.

Live animals handling

- Loading and unloading animals can be difficult and stressful
- Times spent between leaving the farm and slaughter
  - Animals can spend considerable times in transit.
- On arrival at the plant, animals are held for various lengths of time before slaughter in a lairage or stockyard.
- They need to be supplied with water and, if appropriate, bedding and food.
- Stress for animals involves
  - removal from their home environment
  - loading and unloading onto vehicles, often long journeys
  - holding in unfamiliar surroundings

Live animals handling

- Stressed animals are exposed to
  - physical stresses such as extremes of temperature
  - vibration and changes in acceleration
  - noise, confinement and crowding
  - psychological stresses such as the breakdown of social groups and mixing with unfamiliar animals

- **The effects on carcass and meat quality**
- The way the animal responds to these stresses, and the effects associated with them, can influence carcass and meat quality.

The marketing process

- **Economic losses**
  - Total loss results if an animal dies during transport.
  - Losses if the carcass is damaged through bruising, fighting or other trauma necessitating removal of the damaged tissue.
  - Losses occur if animals are subjected to a period of food or water deprivation and the stresses associated with transport.

The marketing process

- The most commonly recognized consequences of poor preslaughter handling on lean meat quality are pale, soft, exudative (PSE) meat in pigs and dark, firm, dry (DFD) meat in pigs and cattle.
- PSE and DFD meat
  - PSE (pale,soft, exudative) and DFD (dark, firm, dry)
  - PSE and DFD meat are two of the major quality problems in the meat industry.
  - PSE affects pigs and DFD occurs in all species
  - The names describe the characteristics of the muscle in comparison with normal meat.

Problems associated with PSE and DFD meat

- The colour of meat is one of the most important criteria consumers use to select meat.
- Meat which is too pale or too dark is discriminated against in preference to normal coloured meat
- The large amount of exudate (drip loss or purge) from PSE meat, especially if it collects in the packaging, also contributes to the undesirable appearance.
- DFD meat has poor processing characteristics with
  - slow or uneven formation of cured meat pigments
  - Flavour development is poor in processed products and flavour is poor in cooked fresh DFD meat.
- PSE pork tends to taste dry and have poor texture after cooking
- DFD meat has a high spoilage potential, so does not keep well and has a short shelf life

Causes of PSE and DFD meat

- Both PSE and DFD meat are caused by stress of the live animal at and before slaughter.
- Prevention of PSE and DFD meat relies on avoidance of stresses preslaughter.
- Many specific handling procedures have been put forward to reduce stress.
  - container transport to reduce loading and unloading stress
  - the use of controlled temperature vehicles
  - sufficient food and water intake

Carcass quality effects

- Mortality of animals during transport
- Carcass damage
- Skin blemish in pigs
- Broken bones in poultry
- Reduction of live weight and carcass yield by inanition and transport

Carcass quality effects

- Mortality of animals during transport
- Death of an animal results in total loss of value.
- The problem affects mainly pigs and broiler chickens
- Two major factors influence the incidence:
  - environmental temperature (above 18°C there is a very rapid increase in mortality)
  - genotype (pigs reared in hotter countries appear to be tolerant of higher temperatures to some degree).
- The mortality is higher in longer journeys.

Carcass damage

- Carcass damage can take the form of bruising, skin blemishes or, particularly in poultry, broken bones.
- In a bruise, blood from damaged blood vessels accumulates.
- In terms of quality, in red meat species bruising is an aesthetic rather than a hygiene problem

Skin blemish in pigs

- A related problem is the superficial skin damage caused by fighting in pigs, particularly between unfamiliar animals.
- The factors that affect agonistic behaviour in pigs
  - competition for food (factors that promote hunger, increase aggression)
  - competition for space (having sufficient space is important)

Broken bones in poultry

- Broken bones are a particular problem in poultry (especially in hens).
- The high level in hens is attributable to the weakness of the skeleton caused by demineralization of the bones
- Broken bones may cause bone splinters in the meat (dangerous to the consumer)

Meat Quality

- Agricultural systems go through three phases of development.
- 1. the aim is simply to produce enough to satisfy requirements
- 2. when this aim has been achieved to develop production systems that are more reliable and efficient
- 3. when we can produce enough and produce it efficiently, the quality of the product tends to be improved

- First we learn how to rear enough pigs so everyone can eat pork → then we do it efficiently so the pork costs less → and last, we try and produce pork of better quality.

Types of quality

- Two overall types of quality can be distinguished:
- **Functional quality**
  - refers to desirable attributes in a product (red meat to be tender and chicken to have good flavour)
- **Conformance quality**
  - is producing a product that meets the consumer's specification exactly
    - we want pork chops to be trimmed so there is exactly 5mm of fat overlying the lean,
    - or we want 'portion sized' chicken breasts to weigh exactly a certain amount.

Types of quality

- Quality has a number of different components.
- While certain of these are of interest to everyone, others are only immediately important to some sectors.
  - **Meat yield** mainly concerns the **farmer** and wholesaler
  - **Technological characteristics** mainly the processor and palatability – what the meat is like to eat – the **final consumer**.

The major components of quality

Yield and gross composition	Quantity of saleable product Ratio of fat to lean Muscle size and shape
Appearance and technological characteristics	Fat texture and colour Amount of marbling in lean (intramuscular fat) Colour and WHC of lean Chemical composition of lean
Palatability:	Texture and tenderness Juiciness Flavour
Wholesomeness:	Nutritional quality Chemical safety Microbiological safety
Ethical quality	Acceptable husbandry of animals

Yield and composition

- The yield of product is important because it determines how much you have to sell.
- Higher yields mean more product and potentially greater profit.
- The absolute yield
  - lean and fat
- The relative amount
  - lean is important

Yield and composition

- A higher ratio of muscle to fat is preferred since the majority of consumers (in Europe and North America).
- However, fat is also associated with flavour development and so at least a minimal level is desirable.
- Above this level, fat will need to be trimmed leading to waste and reduced overall value.
- The shape of muscles is important
  - affects attractiveness of meat (rounded muscles are more attractive than thinner, flatter ones)

Appearance characteristics

- Appearance is important
  - the only criterion that the consumer can use to judge the acceptability of most meat at purchase.
- The lean has a characteristic colour appropriate for each species and muscle.
  - In general, it should be bright in colour, and red or pink rather than brown, purple or grey.

Technological characteristics

- Waterholding capacity (WHC) - technological property of meat – drip of the extracellular water from meat.
- WHC influences of the juiciness of fresh meat after cooking.
    - Meat with low WHC loses a lot of fluid in cooking and may taste dry and lack juiciness.
    - Loss of drip leads to weight loss in fresh meat, and in processed meats poor WHC may reduce yield of product.

Palatability

- Palatability or eating quality has three main characteristics.
  - texture
  - juiciness
  - flavour/odour

Wholesomeness

- The wholesomeness of meat has two components.
- 1. meat should be safe to eat
- without
  - parasites (that may also infect humans), and microbiological pathogens
  - hazardous chemicals (residues from previous veterinary medication of the animal, growth promoting agents, contaminants such as pesticides)

- 2. People prefer meat with positive benefit to their health.
  - minerals, vitamins and high value protein, and possibly essential fatty acids

Ethical quality

- The meat should come from animals which have been bred, reared, handled and slaughtered in ways that promote their welfare and in systems which are sustainable and environmentally friendly.

Problems of conflicting requirements for different quality characteristics

- Achieving some quality characteristics may be incompatible with achieving others.

- **Juiciness** is associated with higher levels of intramuscular (marbling) fat, but larger amounts of fat is undesirable from the point of view of health.
- **Nitrite** is used in the production of cured meats like ham and bacon.
- It reacts with the myoglobin to give the attractive characteristic pink colour of these products.
- It also inhibits the growth of pathogenic bacteria like *Clostridium*, but the consumption of nitrite has been implicated in the potential development of some cancers.

5. Slaughter Line

Killing of animals for food is a necessity, however it should ALWAYS be done in a HUMANIC way, with RESPECT to the ANIMAL!

Slaughter line

1. Transport
2. Ante-mortem inspection
3. Lairage – Housing
4. Stunning and slaughtering
5. Exsanguination – Bleeding
6. Hide removal including heads, horns and legs
7. Abdominal and thoracic evisceration
8. Carcass splitting
9. Post-mortem inspection
10. Cleaning, weighing, classification
11. Classification
12. Chilling

1. Transport

- Respect biological needs of animals (temperature)
- Exclude stress and overloading (max. 200 kg live weight on 1 m^2)
- Moderate distances – as short as possible
- Character of transport must be adjusted to the animals – (acceleration, speed, brakes, steering etc.)
- Poor transport conditions
  - possible consequences:
    - stress, injury, death
    - weight losses, low quality,
    - post mortal changes (PSE, DFD)
    - economical losses

2. Ante mortem inspection

- Each animal is evaluated visually.
- Apparent clinical signs of disease or distress are identified.
- NEGATIVE - cleared for slaughter
- POSSITIVE
    a) '**suspect**' – further inspection
    b) '**condemned**' - animal is not accepted and excluded from human consumption

3. Lairage – Housing

- Rest several (2-4) hours before slaughtering to calming of animals
- Respect biologic needs and welfare of animals:
  - appropriate climate (temperature, ventilation)
  - avoid stressors (insects, noise, light)
  - friendly treatment with animals
  - separate bulls (aggressivity, sexual activity)

- Dirty animals can be washed with mild-warm water
  - to clean their skin
  - to calm them

4. Stunning and slaughtering

- Stunning is the process of rendering animals immobile or unconscious, without killing the animal, prior to their being slaughtered for food.
- History
  - simply struck while fully conscious – non-human
- Modern methods
- In modern slaughterhouses a variety of stunning methods are used on livestock.
- Methods include:
  - electrical stunning
  - gas stunning
  - percussive stunning

4. Stunning and slaughtering

- **Electrical stunning**
  - Electrical stunning is done by sending an electric current through the brain and/or heart of the animal before slaughter.
- **Gas stunning**
  - With gas stunning animals are exposed to a mixture of breathing gases (carbon dioxide for example, but historically carbon monoxide was used) that produce unconsciousness or death.
- **Percussive stunning**
  - a device which hits the animal on the head, with or without penetration
  - captive pistol
  - percussive stunning produces immediate unconsciousness through brain trauma

5. Exsanguination – Bleeding

- Continued cardiac rhythms after stunning – help to better exsanguination
- Proper exsanguination – direct cause of death
- Hygiene – blood is easy to spoilage → remove maximum blood from carcass
- If the blood is intended for human consumption as food
  - special treatment (cooling, veterinary control etc.)
  - minimise the interval after stunning

6. Hide removal including heads, horns and legs

- The purpose - to avoid the contamination (pollutions) from the body surface.
- It is different at individual animal species:
- Dehiding
  - hogs, cattle
- Scalding (only epidermis + hairs or feather)
  - poultry
- In the same time horns, hoofs, etc. are removed
- Maintain of hygienic process (exclude pollution of clean meat by skin).

7. Abdominal and thoracic evisceration

- Removing the viscera is needed as fast as possible- avoid microorganisms to transfer into the meat Evisceration is completed by:
  a) removal of viscera (rumen, intestines, liver and spleen)
  b) removal of the heart and lungs
- Viscera is removed by opening the peritoneal cavity (abdomen) along the ventral midline of the carcass
- Abdominal cavity hole is opened very carefully to avoid any no rupture or cutting of intestines (potential contamination with content of the digestive tract).
- All parts are transported on inspection to assure the health and safety of the carcass.
- Intestines are processed to packaging material in meat production.
- Liver, kidney
  - because of lower shelf-life → fast cooling and special treatment

8. Carcass splitting

- Split laterally down the centre of the vertebral column using a hanging band saw.
- Axes, saws, modern automatic halving apparatus
- Large carcasses are halved to
  - facilitate manipulation (lower weight)
  - facilitate veterinary control
- Smaller carcasses (poultry, sheep, and goats) are not splitted.

9. Post-mortem inspection

- Each carcass is examined by veterinary doctor.
- Anatomic-pathologic changes testify the diseases or parasites.
- Suspect animals are suspended and samples are sent for the laboratory control.
- Carcasses judged to be suitable for human consumption are signed by a stamp or brand.

10. Cleaning, weighing, classification

- Weighing – prior to decontamination
- Cleaning – remove visible contamination
- Decontamination by hot water, steam or lactic acid
- Followed by classification

11. Classification

- Classification of meat is done from different points of view.
  - the content of muscles
  - appearance
  - fat and other aspects (PSE, purity…)

- Evaluation of various attributes depends on the countries.

12. Chilling

- Carcasses are generally chilled for 36 to 48h
- Carcass chilling should be initiated within 1h of exsanguination
  - to 4°C or less
  - Slow and regulated cooling before rigor mortis
    - to avoiding cold shortening

- Chilling media:
  - cooled air
  - water spraying
  - combination of both

Cold shortening

- Cold shortening is the result of the rapid chilling of carcasses immediately after slaughter, before the glycogen in the muscle has been converted to lactic acid.

- The cold temperature induces an irreversible contraction of the muscle (the actin and myosin filaments shorten).

- Cold shortening causes meat to be as much as five times tougher than normal.

Traditional vs. modern

- Several different levels of slaughtering technology can be seen all over the world.
- Comparing the traditional manual butcher's work with modern automatic lines reveals numerous differences in
  - productivity and environmental aspects
  - great differences in hygiene and food safety.

Traditional butcher's

- A high ratio of human work is typical.
- The personnel come into direct contact with the food.
- The microorganisms contamination may be transferred
  - from animal to animal (direct)
  - from animal to personnel and then onto other animals (indirectly).
- It is not easy to decontaminate the hands of the butcher after each operation (the hot water sterilisation is not possible as with machines).
- A man cannot be exposed to adverse climatic conditions (low temperature).

Modern technology

- The many advantages of the maximal automatization
  - higher productivity
  - higher speed of all processes
  - avoiding of unpleasant work functions, etc.

- Opposite to personnel
- It is easier to maintain a suitable environment.
- A machine can not be ill or a carrier of pathogens (after disinfection).
- It is easier to decontaminate apparatus after each operation using hot water (>82°C).
- The reduction of human labour by automation leads to better quality, significantly lower the dangers and thus increase the meat safety.

6. Meat Hygiene and Spoilage

Meat for human consumption

- Meat can be, or become, unacceptable for human consumption either because
  - the living animal has a disease
    - disease can make the meat **aesthetically unacceptable,**
    - more importantly, can lead to **transmission of infection** to humans.

  or
  - the meat becomes spoiled
    - spoilage occurs *post mortem* either by chemical breakdown (oxidation of fats to produce rancidity)
    - or by the growth of microorganisms

Disease and the contamination of meat

- Transmission of disease
  - by contact with infected meat
  - inhalation of spores (anthrax, tuberculosis and brucellosis)
  - by ingestion of infected meat (salmonellosis, parasites -trichinosis, tapeworm)

Transmission modes of various types of disease from meat animals.

Disease	**Responsible organism**	**Transmission**
Anthrax	*Bacillus anthracis*	Hides and hair
Tuberculosis	*Mycobacterium tuberculosis*	Carcasses and milk
Brucellosis	*Brucella abortus*	Skin surfaces
Food poisoning	*Salmonella spp. etc*	Ingestion of meat
Trichinosis	*Trichinella spiralis* (nematode)	Ingestion of pork
Taeniasis	*Taenia saginata* (beef tapeworm) *= Cysticercus bovis*	Ingestion of beef
	Taenia solium (pork tapeworm) *= Cysticercus celullosae*	Ingestion of pork

Sources of contamination

- Meat from healthy animals is sterile.
- In living, healthy animals, bacteria in the gut are usually prevented from invading the surrounding tissues and the blood system, or their growth is controlled.
- Meat is subjected to contamination from a variety of sources
    - **internal** - from animal - skin, hooves, hair, intestinal contents, excrement
    - **external** - contamination and cross-contamination can also come from slaughtermen’s hands, arms and clothing, and equipment used in the carcass dressing process
        - knives, cutting tools, personnel, polluted water, air, faulty slaughtering procedure, postslaughter handling, and storage.

Prevention of contamination

- To prevent contamination of the meat is essential follow:
  - strict hygienic conditions in the slaughter
  - hygiene of equipments
  - personal hygiene

Slaughter conditions

- Slaughter conditions have been implicated as important parameters affecting carcass contamination.
- The most important factors in handling fresh meat
  - speed of handling
  - control of temperature
  - good hygiene conditions

- Slaughter practices are required to minimize physical and microbiological contamination of carcasses.

Slaughter conditions

- **'Clean' and 'dirty' areas of the slaughter plant must be kept separate** and personnel not be allowed to move between them.
- **Dirty areas** include
  - the lairage
  - the raceways leading to the stunning point
  - the stunning pen or stunning box
  - scalding tanks for pigs and poultry (very dirty → source of contamination)

Equipment

- The equipment, and slaughter facilities should be properly designed, cleaned, and disinfected.
- The floor and walls of slaughter facilities should be smooth to allow proper cleaning and disinfecting.
  - reduce microbial contamination of meat

Equipment

- Important source of contamination
  - knives, steels, and aprons of personnel who handle carcasses before skinning
  - protective gloves
  - surfaces of cutting tables

- Hygienic practices correlate with carcass contamination levels, especially the frequency of disinfection.

Personnel

- High frequency of slaughterhouse workers contaminated with bacteria indicate that they play a major role in the cross-contamination of carcasses.
- The most important human sources of bacterial infections are the oral and nasal cavity, digestive tract, and the skin.
- Good personal hygiene measures are necessary for reducing carcass contamination.
- Hot water (44°C) hand rinse can remove 90% of the microbial contamination from a slaughterhouse worker's hands.

Carcass decontamination

- To prolong shelf life it is obviously beneficial to reduce microbiological contamination of the carcass before further butchery and processing.
- Decontamination is very important to reduce carcass spoilage and consequently improve meat hygiene.
- The major cause of spoilage is accumulation of microorganisms, specifically bacteria.

Method of decontamination

- Microbial contamination of meat starts during processing on the slaughter line.
- First, the microorganisms reach the carcass surface from where they may penetrate into deeper layers of the meat.
- Reducing this primal surface contamination and avoiding or limiting the microbial growth would improve safety and external shelf life.
- **Water sprays**
- **Chemical methods**
- **Physical decontamination methods**

Method of decontamination

- **Water sprays**
  - Washing with hot water is one of the many potential methods for reducing levels of pathogenic bacteria (80-100°C) on the surfaces of carcasses.
  - The possible heat damage to the appearance of carcass surface.

Method of decontamination

- **Chemical methods**
  - chlorine, chlorine dioxide
    - is useful in water immersion chilling systems where contact time is prolonged
  - hydrogen peroxide, ozone
  - organic acids (acetic, propionic, lactic, and formic acids)
  - trisodium phosphate Na_3PO_4

Method of decontamination

- **Physical decontamination methods**
  - UV - ultraviolet light
  - ionizing radiation such as gamma and X-rays
    - Ionizing radiations can be very effective, particularly against pathogens.
  - ultrasound

Meat spoilage through micro-organisms

- Microorganisms attack
  - **Protein**
    - production of very unpleasant putrefactive odours
  - **Carbohydrate**
    - causing intensive sour taste or acidity
  - **Fats**
    - production of rancidity
- These various bacterial impacts result in meat spoilage or decomposition.

Microbial contamination

- Microbial contamination can be divided into two sorts:
  - by pathogenic bacteria
  - by spoilage microorganisms

Food poisoning bacteria and source of contamination

Bacterium	**Source**
Salmonella spp.	Gut of animals
Staphylococcus aureus	Skin, nose, cuts in man and animals
Clostridium perfringens	Gut of animals
Clostridium botulinum	Soil
Campylobacter jejuni	Gut of animals
Listeria monocytogenes	Gut of animals
Escherichia coli O157	Gut of animals
Yersinia enterocolytica	Gut of animals

Food poisoning bacteria

- Food poisoning bacteria grow best at 37°C (but will multiply at other temperatures).
- Over 70 °C
  - they multiply more slowly and eventually stop dividing and may be killed
- Below 5°C
  - stop dividing
- Some bacteria form spores
  - much more resistant than the vegetative cells
  - not destroyed by normal cooking methods

Thermophilic MO – optimal growth temp. approx. 55°C (45 - 70°C)

Mesophilic MO – optimal growth temp. approx. 35°C (10 - 45°C)

Psychrofilic MO – optimal growth temp. approx. 15°C (5 - 20°C)

Pathogens

- Pathogenic bacteria may cause disease
  - through infection (*Salmonella* and *Yersinia*-Plague)
  - or through producing toxins (*Clostridium* and *Staphylococcus)*
  - or may be both infectious and produce toxins (*Streptococcus)*

Toxins

- The importance of toxin formation is
  - that the toxin can be present even after the bacteria have been killed.
- The species ***Clostridium botulinum***
  - causes very severe, often fatal, food poisoning - **botulism**
  - it can grow in tins of meat if these have not been sterilized adequately
  - is a strict anaerobe
    - multiplying only in the absence of oxygen

Botulinum toxin

- Neurotoxin botulotoxin
- One of the most effective poisons
- Small quantity leading to severe illness
  - Lethal dose is 1.3-2.1 ng/kg intravenously, 10-13 ng/kg when inhaled.
- It is resistant to hydrochloric acid (gastric juice and digestion).
- Is thermolabile, and it destroys the temperature above 60 °c
- The germination of spores and growth of clostridium is inhibited by the nitrite used in the production of cured meat 120–200 mg/kg.

Spoilage microbes

- Microbes that cause spoilage can be bacteria, yeasts or other fungi (moulds).
- ***Pseudomonas***
  - is one of the commonest and most important spoilage bacteria found on both red meat and poultry.
  - on the surface of carcasses stored in chill rooms (psychrophilic).
- ***Lactobacillus***
  - under anaerobic conditions (for example in vacuum packages)

Spoilage microbes - moulds

- Moulds are considerably less important than bacteria as spoilage organisms (in the meat).
- Fungi will grow where too little water is available for the proliferation of bacteria.
- They may therefore be a problem on frozen meat where the storage temperature is too high.

Impact of bacteria on meat

- Meat spoilage
  - putrefaction (breakdown of protein)
  - slime
  - sourness (product of lactic acid)
  - discoloration
  - rancidity
- Food/meat poisoning
  - infection (ingested with contaminated food, bacteria multiply and produce toxins in consumer's organism, cause illness)
  - intoxication (microorganisms – bacteria, moulds – multiply in contaminated food and produce toxins by consumer, causes illness)

Microorganisms causing microbiological spoilage of meat

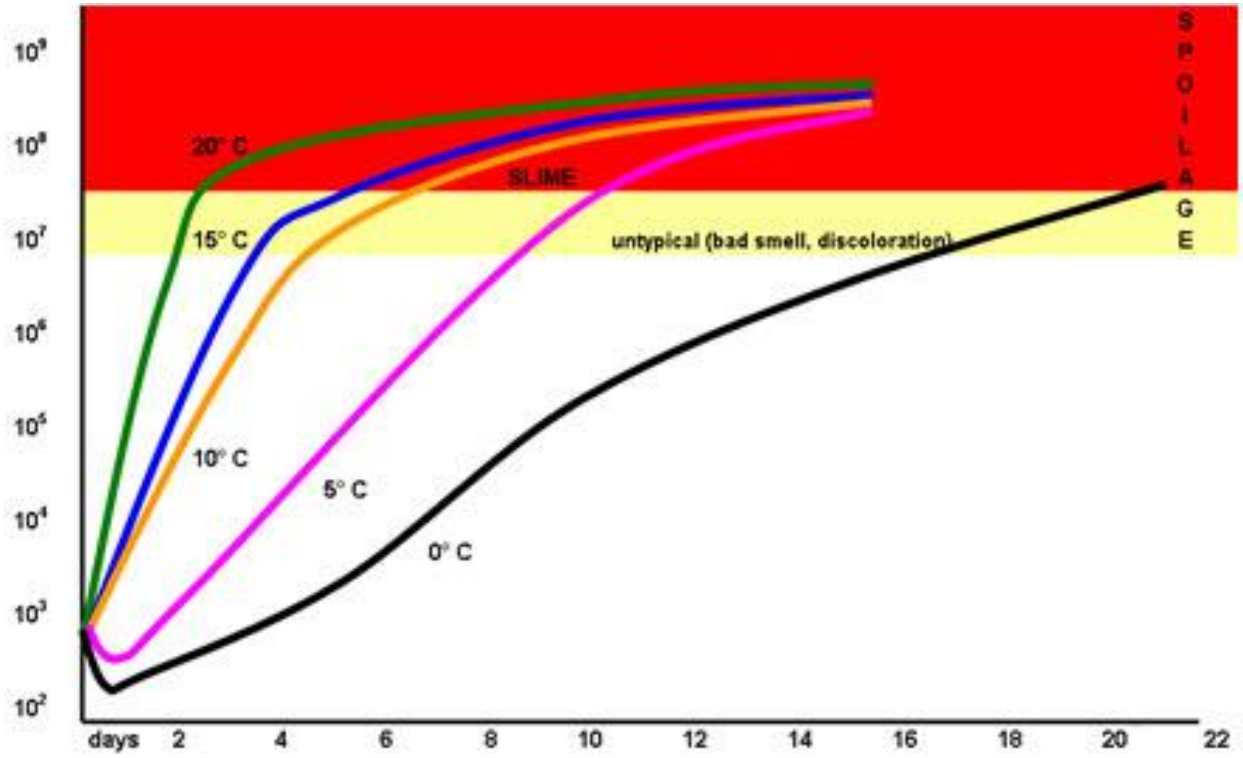
Type of spoilage	**Type of Microorganisms**
Putrefaction	Pseudomonas ("Cold room flora"), *Clostridium*
Souring	*Lactobacillus, Enterococcus, Pediococcus* ("Lactic acid bacteria")
Fermentation	Yeasts (Saccharomyces), Enterobacter, Lactic acid bacteria
Turbidity	Lactic acid bacteria, Enterobacter (e.g. vacuum packed meat, sausage slices)
Greenish discoloration	Lactic acid bacteria
Slime formation	Pseudomonas, Streptococcus, Enterobacter (on open meat), Lactic acid bacteria (on vacuum packed meat and meat products), Yeasts (on raw fermented products such as raw hams)
Rancidity of fats	Mainly due to presence of oxygen, but certain microorganisms are also capable of causing fat deterioration.
Mould growth	*Penicillium, Aspergillus*

Factors affecting bacterial growth

- Important factors are
  - temperature
  - oxygen availability
  - pH
  - moisture availability of the substrate - water activity (a_w)

Temperature

- Temperature is the most important with growth rate.



Growth of microorganisms on meat (starting from same initial bacterial loads/approx. 1000 per gram meat , but different storage temperatures, 0°C, 5°C, 10°C, 15°C). At 20°C spoilage on the second day at 0°C spoilage after more than 20 days.

pH values

- Bacteria will grow better at neutral pH values (around pH 7) than at lower or higher values.
- The acidification that occurs in normal meat *post mortem* therefore tends to inhibit growth.

Microorganisms	pH_{min}	pH_{max}
Bacteria	4.4	9.0
Yeasts	2.1	9.0
Moulds	1.6	11.1

Redox potential

- Oxygen availability
- Bacteria can be grow
  - in the *presence* of oxygen (strict or obligate aerobes)
  - in the *absence* of oxygen (strict or obligate anaerobes)
  - grow in the presence or absence of oxygen (facultative anaerobes)

- Aerobes grow on meat surfaces.
- *Clostridium* grow only deep within meat where oxygen from the air cannot penetrate.

Water activities a_w

- a_w express the amount of free water available for microorganisms
- Solutions containing high concentrations of salt have lower water activity values.
  - salt, sugar
  - freezing
  - drying

7. Meat Preservation

Why preserve meat?

- Delays product spoilage
- Extends life of the product
- Improves product quality

Preservation of meat

- Because it is high in protein and moisture, meat is potentially an ideal medium for bacterial growth.
- Many techniques reduce or eliminate this growth and so preserve the meat longer.

- Drying
- Curing and smoking
- Irradiation
- Cooling (freezing)
- Cooking
- Canning/sterilization of meat products
- Fermentation

Drying

- The simple ***dehydration*** or ***drying of lean meat*** under **natural conditions** has been practised for centuries.
- Drying reduces the water activity.
    - under the minimum of growth level of certain microorganisms
    - the minimum levels differ – depending on the species of microorganism
- the meat may also be salted, seasoned
- It is still a popular method in many countries, in particular where no cold chain is available.
- Biltong in South Africa, jerky….

Types of meat suitable for drying

- Dried meat can be stored under ambient temperatures for many months.
- Best suited
  - lean meat (deterioration of fatty tissue through rancidity cannot be stopped)
  - **beef** and **buffalo meat**
  - **goat** and certain **game meats** (deer, antelopes)
- Less suitable
  - **mutton**
  - **pork** (even very lean muscle parts contains higher amounts of fat, which is prone to oxidation and quickly rancid)

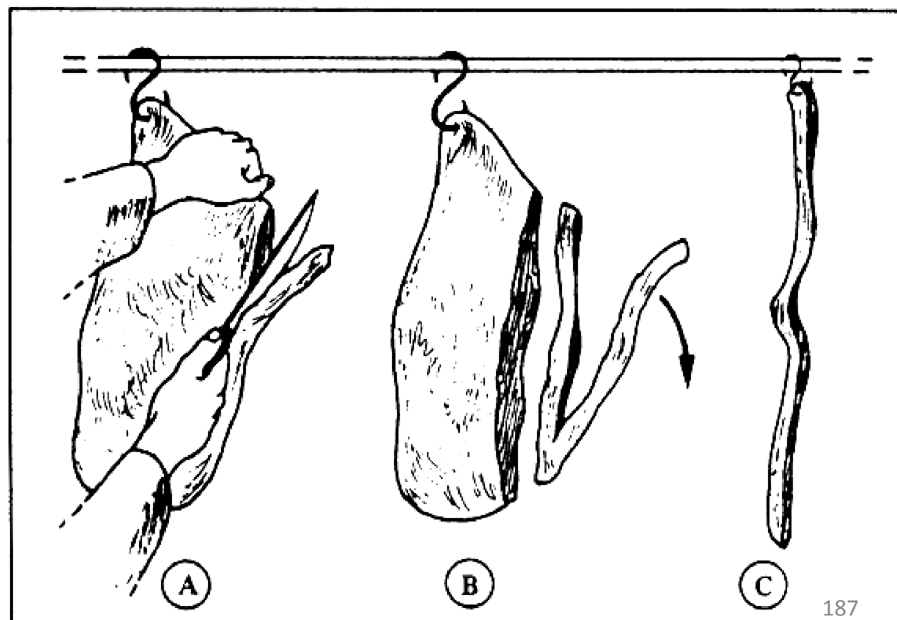
Preparation of meat for drying

- The meat is exposed to the open air and solar radiation and quickly loses substantial amounts of its moisture.
- Meat cuts for drying
  - in ***narrow strips*** (with a rectangular cross-section of 1 x 1 cm)
  - in ***flat pieces*** (with cross-sections of 0,5cm x 3 to 5 cm)

Cutting of meat in the flat pieces in preparation for drying

Narrow strips

In large thick meat pieces, the moisture content in the centre would remain high for too long and, given the high ambient temperatures, could easily lead to microbial ***spoilage***, as microorganisms still would find good conditions for growth.



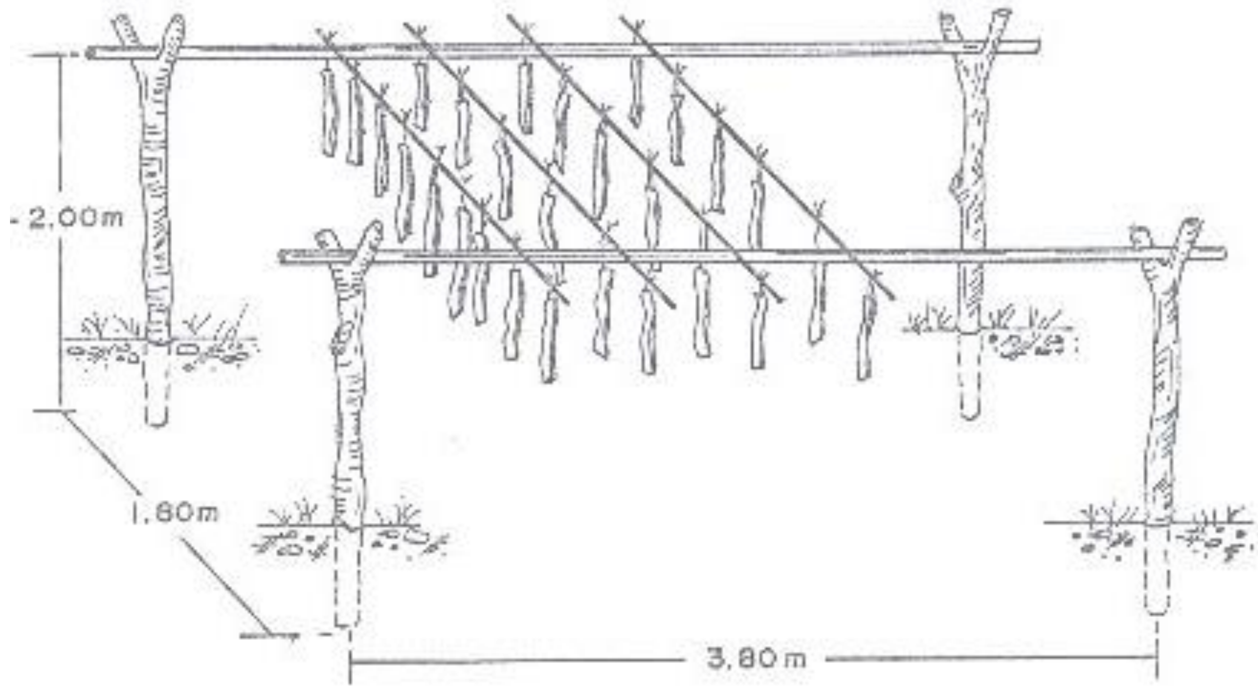
Meat drying techniques

- For the traditional drying of meat
  - Sun drying
  - Solar drying

- A modern technique is freeze drying
  - Convection Air Drying
  - Lyophilisation

Sun drying

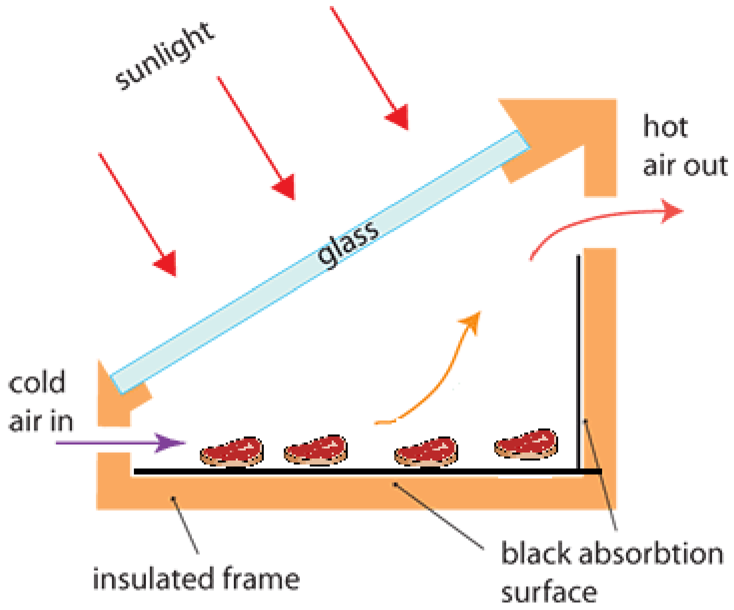
- The basic traditional drying method characterized by direct solar radiation and natural air circulation on the product.
- For sun drying, the meat is sometimes dipped in salt solution (approx. 14% common salt - helps to limit microbial growth on the meat surfaces and protects to some extend against insects).
- Disadvantages
  - exposure to contamination
    - from dirt, wind, rain, insects, rodents and birds
  - quality deficiencies
  - difficult to control
- Sun drying is the cheapest method of drying foods.



2,00m
1,80m
3,80m

Solar drying

- Solar drying is an extension of sun drying that uses radiation energy from the sun.
- The solar dryer has a absorbing surface which collects the sun light and converts it to heat.
- The product is dried in a closed space
- Better protected against
  - weather (rain)
  - mechanical impurities (dust)
  - insects and pets
- Disadvantages
  - limit its use in large-scale production
  - higher cost



Convection air drying

- This is the simple drying technique, which takes place in an enclosed and heated chamber.
- The drying medium -hot air-
  - pass over the product in open trays
- Temperature and humidity of air are usually regulated

Lyophilisation

- A modern technique is freeze drying (lyophilisation).
  - Water is sublimated from the meat (it passes directly from ice to vapour without an intervening liquid phase).
  - Better quality
    - meat structure undamaged

Quality Changes During Drying

- Changes of the shape of the meat (shrinkage)
- The meat pieces become
  - smaller
  - thinner
  - to some degree wrinkled
  - darker in colour
  - texture changes from soft to hard.

- Heating at 60°C is cause of the denaturation of the muscle proteins.

Quality Changes During Drying

- The fact that dried meat is no longer comparable to fresh meat in terms of appearance and sensory and processing properties.
- Main advantage
  - is significant extension of the shelf-life (in particular in the absence of refrigeration).
- Most nutritional properties of meat (protein content) remain unchanged.

Curing

- The preservation of the meat by using salts.
- Like drying, salting was discovered a long time ago.
- develops the characteristic desirable taste and flavour in the product
- Using salt
  - sodium chloride, NaCl,
  - potassium or sodium nitrate (KNO_3, $NaNO_3$)
  - sodium nitrite ($NaNO_2$)
- Main reasons
  - pink colour-the nitrite reacts with the haem pigments in the meat to give the attractive typical of hams and other cured products
  - development of flavour in cured meats
  - inhibiting the growth of bacteria, in particular *Clostridium botulinum*.

Other curing ingredients

- In normal curing processes various other substances may be included in the salt mixture.
- **Polyphosphates** improve water-holding capacity (WHC)
- **Sugars** (sucrose or glucose) impact flavour
- **Ascorbic acid** (vitamin C) may be added - this acts as a reducing agent and inhibits the breakdown of the nitrosylmyoglobin so preventing discoloration.

The curing proces

- There are very many types of cured products and curing processes.
- **dry curing**
  - the salts are added as a solid by being rubbed into the surface of the meat.

- by **immersion** in a solution of the salts (brine) – most commonly
  - first injected with brine - particularly for boneless hams
  - after injection - tumbling or massaging in rotating drums, may be used to help even distribution

Dry curing

Injection

Immersion

Smoking

- Cured meat – next step - smoking
- Complex process of food preservation
- Smoking helped preservation
    - by drying the meat surface
    - through the action of antimicrobial substances naturally present in the smoke
    - inhibit fat oxidation
    - main use now is in contributing to the flavour
- Traditionally, the smoke was produced by burning hardwood sawdust (from trees such as oak and beech)
- nowadays liquid smokes, containing the active ingredients of actual smoke, but in a liquid extract, are often used

Products

- The main cured meat is pork
  - less beef, sheep meat
- Pork is cured into
  - bacon is made from mainly the back and belly
  - ham is made from the legs
    - *Cooked hams*
      - Cured hind legs and shoulders from pigs may be cooked to produce hams.
      - These can be dry-cured or, more commonly now, produced by immersion in brine.
    - *Dry cured hams and sausage*
      - number of hams are made for eating without cooking

Bacon

- The half carcasses (sides) are prepared by removal of head, feet, backbone and other bones.
- Sides are injected with brine (20% NaCl, 0.2% $NaNO_3$, 0.1% $NaNO_2$), increasing their weight by about 10%.
- The pumped sides are stacked in tanks and covered with brine for up to 5 days.
- They are removed from the brine and stacked for up to 7 days to mature (when normal bacon flavour and colour develop). This is ‘green’ bacon.
- The green bacon is smoked if desired (using wood smoke).

Irradiation

- Meat can be rendered sterile, and therefore preserved, by exposing it to ionizing radiation (X-rays, gamma rays).
- Advantages
  - very large pieces of meat can be processed,
  - practically all microorganisms are killed
  - minimal change in the physical or chemical composition of the meat
- Disadvantages
  - some destruction of vitamins
  - the potential production of off flavours
  - off flavours can be caused by fat oxidation

Refrigeration

- Cooling carcasses as soon as possible after dressing, and keeping meat at low temperatures, can considerably reduce the **rate of spoilage** and the **growth of pathogenic bacteria**.
- Fresh meat can normally be stored for 5–7 days at refrigerated temperatures.
- Benefits of chilling
  - by lower temperatures is reduced or prevented microbial growth
  - It reduces evaporative weight loss
  - makes the fat firmer

Freezing

- Freezing can be a very effective way of storing meat.
- Meat freezes at about -1.5°C but the lower the temperature of storage the more stable will be the product.
- This is mainly because low temperatures inhibit chemical spoilage and microbial spoilage.
- Storage at -18°C
  - beef for 6–12 months
  - pork for 6 months
  - poultry for 3 months.
- Freezing kills some microorganism vegetative cells by
  - thermal shock
  - ice formation (damage of cells)
  - dehydration
- Spores are generally resistant to freezing.

Cooking

- The main reason we cook meat now
  - is to make it palatable (very little meat is eaten raw)
  - very important additional benefit of cooking is to make meat safer to eat
- Cooking kills bacteria, especially important in the case of pathogens.
  - To do this the temperature needs to be high enough for long enough.
  - The centre of the meat must reach at least 70°C for 2 min, or an equivalent combination of temperature and time.
- Cooking also improves sensory characteristics by developing flavour

Changes caused by cooking

- Flavour develops on heating with characteristic flavours produced by different cooking methods,
  - partly because of the differences in the intensity of heating (roasting leads to drying of the meat surface and production of many more volatile flavour components than boiling)

Changes caused by cooking

- Temperature also affects appearance.
- ‘Doneness’(the condition of being cooked to a desired degree) is attributable to denaturation of the haem pigments to give a progressively more brown appearance.
- Beef cooked to 60°C (**rare**) is quite red inside
- At 65 - 70°C (**medium rare or medium**) it becomes pink–brown
- at 80°C (**well-done**) brown.
- At higher temperatures the surface brown colour is enhanced by dehydration and the products of Maillard browning reactions

Effects of cooking on nutrients - Proteins

- **Collagen and elastin**
  - are two important insoluble proteins in meat, and because they are not soluble they are not easily digested.
  - Tough meat (meat containing a lot of collagen and elastin) must be cooked in a way that will make it tender.
  - Tough meat needs to be cooked slowly using low temperatures; converts the tough collagen into easily digested gelatin (a soluble protein).

Effects of cooking on nutrients - FATS

- When fats are heated they melt
- Fats are stable to heat and can be heated almost to their boiling point before they start to break down.
- When fats are heated too much, they break down, producing an unpleasant-smelling smoke – “smoke point“

Smoke point of fats and oil

Fat/Oil	**Smoke Point °F**	**Smoke Point °C**
Avocado Oil	570°F	271°C
Butter	250-200°F	120-150°C
Canola Oil (refined)	400°F	204°C
Coconut Oil (extra virgin)	350°F	177°C
Coconut Oil (refined)	450°F	232°C
Corn Oil	440°F	227°C
Flax seed Oil	225°F	107°C
Ghee (clarified Butter)	485°F	252°C
Lard	370°F	188°C
Olive Oil (extra virgin)	375°F	191°C
Olive Oil (virgin)	391°F	199°C
Olive Oil (extra light)	468°F	242°C
Peanut Oil	450°F	232°C
Sesame Oil (unrefined)	350°F	177°C
Soybean Oil (refined)	460°F	238°C

Effects of cooking on nutrients - Carbohydrates

- When exposed to dry heat, carbohydrates are broken down and darken in colour (sucrose browns on caramelization and finally becomes black)
- The Maillard Reaction
  - is a reaction between amino acids and sugars that gives browned food its desirable flavour.

Effects of cooking on nutrients - Vitamins

- Dry-heat cooking methods destroy those vitamins, which are unstable to heat.
- Vitamin C is destroyed at quite low temperatures, and so all methods of cooking cause some loss of this vitamin
    - some loss during cooking cannot be avoided.
- Two of the B vitamins, thiamine and riboflavin, are unstable at high temperatures.
- Vitamins A and D are insoluble in water and stable except at high temperatures.

Effects of cooking on nutrients - Mineral elements

- Heat does not affect mineral salts found in food because they are stable substances that do not break down at the temperatures used in cooking
- Moist-heat methods of cooking (stewing and boiling), cause loss of salts, which are soluble in water.
- Boiled fish, meats, vegetables is rather tasteless because of the considerable loss of mineral salts that occurs during cooking.
- The salts are present in the water in which the food has been boiled, and this liquid can be used for making a tasty sauce or soup.

Cooking methods

- Cooked food is food that has been changed in various ways by heat treatment.
- The heat may be
  - dry or moist
  - applied by means of fat
  - by microwave of infrared radiation

Cooking methods

- **Dry-Heat methods –** baking, roasting (100-300 °C)
- **Moist-Heat methods –** water, steam
  - it is a relatively quick method of cooking because water has a great capacity for holding heat and for transferring this heat rapidly to food by means of convection.
- **Frying -** food is cooked in hot fat, quick method of cooking because of the high temperature used.
- **Microwave Cooking -** the heat is generated within the food, microwaves penetrate the food and are converted into heat within the food
  - Microwaves can only penetrate food to a depth of 3–5 cm; thus, small pieces of food are cooked very quickly.

Summary of cooking methods

Method of Heating	Method of Cooking	Description
Dry heat	Baking Roasting Grilling	Cooking carried out in an oven Baking with the addition of fat Baking with the addition of fat
Moist heat	Boiling Stewing and poaching Steaming Pressure cooking	Using boiling water Using hot water below its boiling point Using steam from boiling water Using water boiling above its normal boiling point
Fat	Frying	Using hot fat
Infrared	Similar to rapid grilling	Using infrared radiation
Microwave	Similar to rapid grilling	Using microwaves

8. Canning and Sterilization of Meat Products

Types of heat treatment

- A. Heat treatment at temperatures below 100°c also called "pasteurization" or simply "cooking".
  - Products are heated at temperatures below 100°c or maximum up to 100°c and still contain a certain amount of living microorganisms.
  - To prevent the growth of microorganisms must be stored cold (0- 5°c).
  - Most common for milk, fruits juice, limited in meat products (some types hams , sausages)
- B. Heat treatment at temperatures of above 100°C, called "sterilization"

Sterilization

- Sterilization is the complete destruction or elimination of all vital organisms in a food product.
- Sterilization destroys yeasts, moulds, vegetative and spore formers bacteria (such as *Bacillus* and *Clostridium*)
- Sterilization allows the food products to store and distribute with extended shelf life.
- Sterilization procedures involve the use of heat, radiation, or chemicals, or physical removal of cells.
- Commercial sterility is defined
  - as a product that has been optimally processed so, that under normal conditions, the product will neither spoil nor endanger the health of the consumer and also retain the organoleptic properties and nutrients

Sterilization – effects on the quality

- From the microbial point of view, it would be ideal to employ very intensive heat treatment which would eliminate the risk of any surviving microorganisms.
- Intensive heating foods can lead to
  - **Degradation of their sensory quality**
    - Soft texture, jelly, fat separation, discolouration, undesirable heat treatment taste
  - **Loss of nutritional value**
    - Destruction of vitamins and protein components
- Heat sterilization
  - **Intensive enough for the microbiological safety of the products**
  - **As moderate as possible for product quality reasons**

Sterilization process

- The meat products are exposed to temperatures above 100°C
  - usually ranging from 110-121°C, depending on the type of product.
- The temperature must be reached **inside the product**
- Products are kept for a defined period of time at temperature levels required for the sterilization.
- Phase 1 = heating phase
  - The product temperature is increased by means of a heating medium (water or steam) from ambient to the required sterilization temperature.
- Phase 2 = holding phasing
  - The temperature is maintained for a defined time.
- Phase 3 = cooling phase
  - The product has to be cooled mainly to arrest further heat treatment and avoid over cooking.

Methods of sterilization

- The food sterilization methods are divided into two categories:
- Sterilization by heating (thermal processing)
- 1. Bulk canning - in-container sterilization
- 2. Aseptic processing - a sterile (aseptic) product is packaged in a sterile container

- Sterilization without heating (non-thermal processing)
- High pressure, irradiation, ultrasound, magnetic field, using electricity

Sterilization equipment

- The food processing industry produces a wide range of products in a variety of containers.

  →wide range of processing techniques, retort designs, and operating procedures

- Autoclaves
- Retorts

Processing equipment

- **Batch systems**
  - The retort is filled with product, closed, and then put through a processing cycle.
  - Batch retorts are available in a number of configurations for various applications, including static (horizontal, vertical), rotary, steam heated, and water heated with or without air.
- **Rotary autoclaves**
  - the basket containing the cans rotates during sterilization
  - for cans with liquid or semi-liquid content as it achieves a mixing effect of the liquid/semi-liquid foods resulting in accelerated heat penetration.
    - shorter sterilization process → better quality
- **Continuous retorting systems**
  - Containers are continuously fed into and out of the retort.

Packaging of canned foods

- The container is an essential factor in the preservation of foods by canning.
- **Hermetically sealed container**
  - container that is designed and intended to be secure against the entry of microorganisms and maintain the commercial sterility of its contents after processing.

Types of containers

- It is then most important for the success of the canning operation to use good-quality, reliable containers and properly adjusted closing machines.
- Metal packaging
    - most of the thermally preserved products are in metal containers
- Glass jars
- Plastic
- Aluminum/plastic laminated pouches

Metal packaging

- Steel, tin, and aluminum are used mainly for canned foods and beverages.
- The most common use of metals for packaging is in tin-coated steel and aluminum cans.

- Tin coated or lacquered steel
    - Product in the can must be stable and perfectly sealed.
    - Tin coating or lacquering is an important part of can manufacture.
    - The lacquer – acrylic, epoxy, phenolic or vinyl resin.
    - The interior coating has to withstand sterilization temperatures and action of acids.

Metal cans

Advantages

- their strength providing mechanical protection
- effective barrier properties
- resistance to high temperatures
- providing stability during processing
- opacity (advantage for light-sensitive products), but disadvantage in that contents are invisible)

Disadvantages

- of metal cans
- heavy mass
- high cost
- tendency to interact with contents
- internal and external corrosion

Aluminium

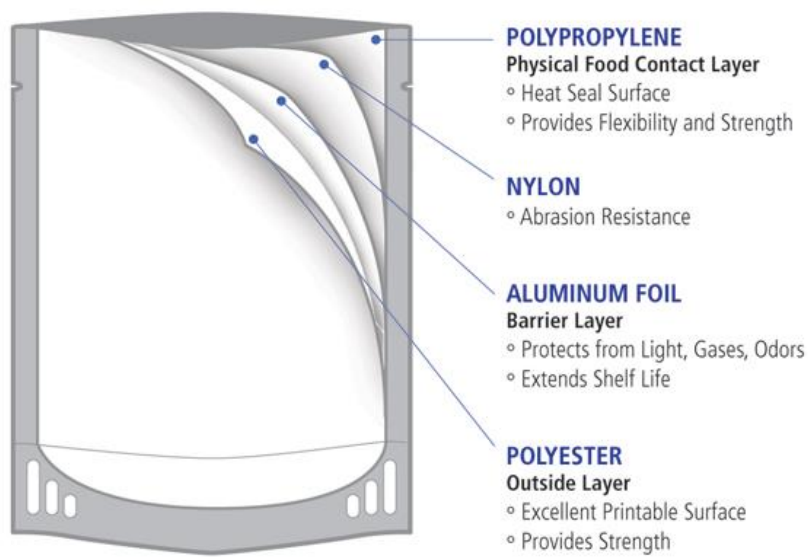
- Aluminium is frequently used for smaller and easy-to-open cans
- Aluminium are lightness (three times lighter than steel), strength, corrosion resistance, electrical conductivity, appearance, and ease of recycling.
- It has the barrier properties of steel, but without the corrosion problem.
- It has excellent strength so that thin films can be made.
- It can be extruded into complex shapes.
- They are less rigid but more expensive than steel plate cans.

Glass jars

- Sometimes used for meat products
- Consist of a glass body and a metal lid
- Advantages
  - inert (completely neutral in contact with foods)
  - transparency
  - can be recycled
- Disadvantages
  - fragility
  - heavy mass

Plastic

- Limited use because of thermolability
- often combined with other materials
- Thermo-stabilized laminated food pouches (multilayers) made of
  - laminates synthetic materials
  - laminates of aluminium foil with synthetic materials
- ready-to-eat meat …
- Advantage
  - Light
  - Easy to store



Groups of meat canned products

- Cooked hams or pork meat
- Sausages with brine of the frankfurter type
- Sausage mix of the bologna or luncheon meat
- Ready-to-eat dishes with meat ingredients
- Soups with meat ingredients such as chicken soup
- Fish and seafood

Quality of canned foods

- The purpose of heat sterilization is to extend the shelf life of foods while minimizing the changes in nutritive value and eating quality.
- Generally, the heat process itself has a major effect upon the quality of a food product and is responsible for a range of changes.

Quality of canned foods

- **Colour**
  - The time–temperature combinations used in canning have a substantial effect on most naturally occurring pigments in meat foods (acceptable change in cooked meats)
  - Sodium nitrite and sodium nitrate are added to some meat products to reduce the risk of growth of *C. botulinum* - red-pink colouration
  - Loss of colour is often corrected using permitted synthetic or natural colours.
- **Flavour and Aroma**
  - In canned meats, there are complex changes having a significant effect on the flavour of foods (pyrolysis, deamination and decarboxylation of amino acids, Maillard reactions and caramelization of carbohydrates, and oxidation of lipids)
  - Desirable changes cooked meat

Quality of canned foods

- **Texture**
  - shrinkage and stiffening of muscle tissues are caused by coagulation and a loss of water-holding capacity of proteins
  - softening is caused by hydrolysis of collagen
- **Nutrients**
  - Canning causes the hydrolysis of carbohydrates and lipids, but these nutrients remain available and the nutritive value of the food is not affected.
  - Proteins are coagulated in canned meats, losses of amino acids are 10%–20%.

Quality of canned foods

- **Minerals**
  - Heat does not affect mineral salts found in food because they are stable substances that do not break down at the temperatures used in cooking
- **Vitamins**
  - destroy thermolabile vitamins - C, B
  - vitamins A and D stable at higher temperatures

Aseptic processing

- Products are sterilized **prior to packaging** by continuous processes so that their organoleptic and nutritional quality is not significantly affected.
- Products such as puddings, sauces, dips, and pastes are currently aseptically processed.
- Aseptic processing of foods is a process that enables products, sterilized in bulk, to be filled and sealed into sterile containers, under aseptic conditions.

Aseptic sterilization

- Application of the aseptic process involves
  - (a) sterilization of the product
  - (b) sterilization of the packaging material
  - (c) maintaining sterility during the filling and sealing operations.
- The advantages
  - a higher quality product
  - A wide variety of packaging materials of different sizes and shapes can be used (can be used containers that are unsuitable for in-package sterilization)

Sterilization systems

- The production of a sterile product by continuous-flow sterilization involves
  - (a) heating the product by passing it through a suitable heat exchanger to raise it to operating temperature
  - (b) passing the product through a holding section for a predetermined time to effect sterilization
  - (c) cooling it to a temperature of 35°C or less prior to aseptic filling.

- Aseptic packaging refers to the filling of a cold, sterile product under sterile conditions into a pre-sterilized container and closure under sterile conditions.

Purpose of packaging

- The function of packaging is to surround or wrap meat products with suitable protective material.
- The basic purpose of packaging
  - to protect meat and meat products from undesirable impacts on quality including microbiological and physiochemical alterations.

- But the further growth of microorganisms, which are already present in meat and meat products, cannot be interrupted through packaging only.
- To reduce microbial growth, packaging has to be combined with other treatments
  - Refrigeration - slows down or stop the further growth of microorganisms
  - heating/sterilization - reduces or completely eliminates contaminating microorganisms

Purpose of packaging

- Packaging protects foodstuffs during processing, storage and distribution from:
- Contamination by dirt (by contact with surfaces and hands)
- Contamination by micro-organisms (bacteria, moulds, yeasts)
- Contamination by parasites (mainly insects)
- Contamination by toxic substances (chemicals)
- Influences affecting colour, smell and taste (off-odour, light, oxygen)
- Loss or uptake of moisture (evaporation or water absorption)

Requirements for packaging materials

- Packaging films should be:
  - flexible
  - mechanical strength
  - light weight
  - odourless
  - hygienic (clean and toxicologically harmless)
  - easy recycling
  - resistance to hot and cold temperatures
  - resistance to oil and fats
  - good barrier properties against gases and mointsture
  - sealing capability
  - low-cost

Barrier against gases

- Good barrier properties against **oxygen**
  - Oxygen negatively affects unpackaged meat and meat products during prolonged storage periods.
    - It changes the red meat colour to grey or green
    - causes oxidation and rancidity of fats resulting in an undesirable off-flavour.
- The best protection will be achieved using **oxygen-proof packaging** films together with **vacuum packaging** of the product.
- **Prevention of evaporation of product moisture**
- Fresh meat or fresh sausages, cooked ham, etc. have a relatively high moisture content
- weight and quality losses can be significant by evaporation during storage
- The packaging material
  - **water-vapour-proof**

Plastic material

- Polyethylene terephthalate (PET)
- Polyethylene (PE)
    - High density polyethylene (HDPE)
    - Low density polyethylene (LDPE)
- Polyvinyl chloride (PVC)
- Polypropylene (PP)
- Polystyrene (PS)
- Polyamide (nylon) (PA)
- Cellulose (cellophane- trademark)

Types of packaging films

- Practically all films used for meat packaging derive from synthetic "plastic" materials.
- The most common synthetic materials used for meat packaging are:
  - Polyethylene (PE) (oxygen + , water vapour -)
  - Polypropylene (PP) (oxygen + , water vapour -)
  - Polyvinylchloride (PVC) (soft) (oxygen + , water vapour -)
  - Polyethylene terephthalate (PET) (oxygen ± , water vapour -)
  - Polyamide (PA) (oxygen - , water vapour +)

+ = relatively permeable

- = relatively impermeable

Foils

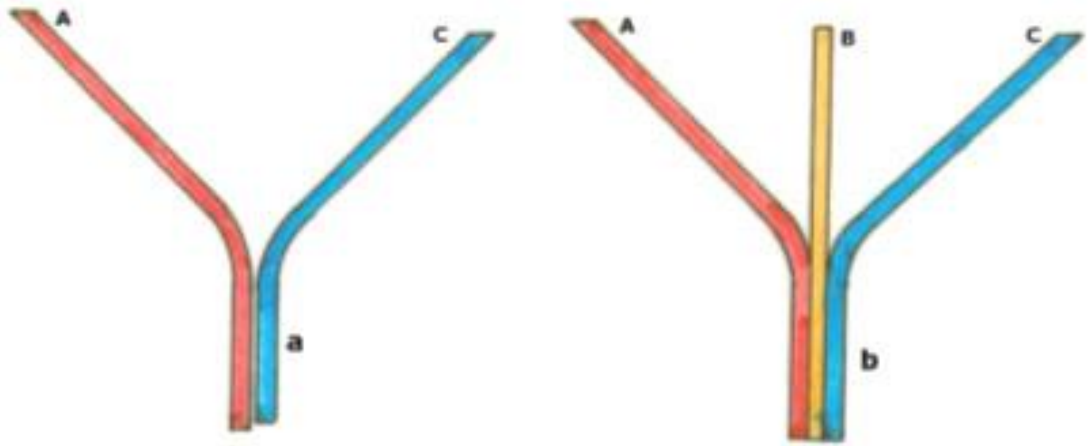
- Foils are selected based on their different properties related to oxygen and water vapour.
- For the various purposes in the meat industry packaging films can be divided into
    - Single-layer films
    - Multi-layer films

Single-layer films

- **Wrapping** of meat pieces, processed meat products, bone-in or boneless meat cuts
- **Freezer storage**
  - For meat blocks, meat cuts or smaller portions of meat or meat products
  - Single-layer films are stretched tightly around the meat surface before freezing
  - To avoid evaporation, ice formation and freezer burn
- Wrapping of **chilled meat portions** for self-service outlets (supermarkets, at home etc.)
- Used foils are pe, soft pvc
- Suitable for shorter storage
- Low water vapour permeability
- Oxygen permeability

Multi-layer films

- Practically all the other films used for meat packaging are designed as strong **oxygen** and **water-vapour barriers**.
  - to achieve these requirements, films with good barrier properties for oxygen and water vapour respectively **are combined**.



Typical multi-layer films (a = two layers, b = three layers)
Layer A: Outside layer (mechanically strong, gas barrier to oxygen)
Layer B: Middle layer (barrier to oxygen)
Layer C: Inside layer = sealant layer, serves as barrier to water vapour

Multi-layer films

- A very efficient combination is PA/PE.
  - PA is used as the outside layer (A)
  - PA is relatively oxygen proof but permeable to some extend to water vapour.
  - PE is used as the inside layer (C)
  - PE has the opposite properties, it is water vapour proof but permeable to oxygen.
  - Also PE has good thermoplastic properties and is therefore well suited for heat sealing.
- Middle layer (B)- additional layers for stronger oxygen barriers

Vacuum bags

- Used for vacuum packaging machines are composed of two or more sheets of multi-layer films
- The air is excluded from the package and the damaging effects of oxygen (rancidity or discoloration) of the packed products are significantly slowed down or not develop at all.
- **Small to medium-size vacuum bags**
  - for processed meat products in slices or as entire pieces
- **Shrinkable films**
  - for larger sized products
  - the product in its package of synthetic film is sprayed with or dipped into hot water (80^{o}C).
  - The contact with the hot water causes the shrinkage of the thermoplastic film and results in tight impermeable wrapping of the goods.

Skin packaging

- For this method the products are placed in the packaging machine, usually on a rigid film, which serves as the bottom layer of the final package.
- Another flexible film (top layer, which is heated for increased flexibility) drapes itself from above around the product, resembling a tight “skin” on the product surface avoiding wrinkles.
- Individual product portions are cut apart along their sealing layers

“Form-shrink” packaging

- Products e.g. meat cuts, chicken carcasses, sausages, smaller portions of meat products, are placed between two shrinkable films, which are moulded without wrinkles around the goods.
- This technology is cost-effective
  - in terms of usage of packaging films (fully utilized)
- but requires high-tech equipment
  - for large-scale industries

Modified-Atmosphere Packaging (MAP)

- (MAP) is a technique used for prolonging the shelf-life of fresh or minimally processed foods.
- The air surrounding the food in the package is changed to another composition.
- MAP is used
  - for perishable products like meat, fish, fruits and vegetables.
  - to slow down the growth of microorganisms (both spoilage and pathogenic)
- Usually combined with refrigeration

Modified Atmosphere Packaging (MAP)

- MAP packages are firstly subjected to a vacuum.
- A mixtures of gases is the introduced into the air-free space before sealing.
- The gas mixture usually contains nitrogen (N_2) and carbon dioxide (CO_2).
- **N_2** - nitrogen
  - is inert, i.e. it does not react with meat product components such as fat or myoglobin.
  - Its function is to replace the atmospheric oxygen (O_2) and thus prevents O_2 induced negative impacts (oxidative rancidity)
- **CO_2 –** carbon dioxide
  - has a protective function, as it inhibits to some extend the growth of bacteria and moulds.
- The gas mixture commonly - 20%-30% CO_2 and 70%-80% N_2.
- The packaging materials used are gas proof multi-layer films composed of PE, PA and barrier layers.

9. Meat Products

Processed meat products

- The main ingredients of processed meat products
  - animal tissues - *muscle meat* and *fat*
  - tissues such as *internal organs*, *skins* and *blood*
  - ingredients of plant origin

Meat processing technology

- Meat processing technology
  - the steps and procedures in the **manufacture of processed meat products**.
- **Processed meat products**
  - food of animal origin, which contribute valuable animal proteins to human diets.

Selection and grading

- The first preparatory step for processing of meat into meat products is
  - the product-oriented selection of raw animal materials
    - according their quality and processing suitability and the characteristics of the meat products to be fabricated
- Some meat products require
  - lean meat without adhering fat or connective tissue
  - a higher fat and/or connective tissue contents.
  - firm animal fats
  - soft fats
- Choosing appropriate raw materials is indispensable for efficient meat processing and is best done by visual **selection and grading** according to the tissue-specific properties.

Grading scheme for manufacturing-meat from pigs

Whole muscle hams and all products where the meat structure remains visible

Grade Pork 1 (P1)
Pig meat, all visible fats and connective tissues removed

Grade Pork 2 (P2)
Pig meat, 10% visible firm and soft fats and some soft connective tissues

Fresh sausages, dry fermented sausages and luncheon meat

P3 is used as raw material for finely-chopped meat mixes

Grade Pork 3 (P3)
Pig meat, 15-25% firm body fats, visible connective tissues removed

Grade Pork 4 (P4)
Pig fat, back fat (firm tissue)

P4 is used as the fat portion of raw-fermented, raw-cooked sausages

It can be incorporated in finely chopped meat mixes of the raw-cooked type in quantities of up to 25% of the overall fat portion added

Grade Pork 5 (P5)
Pig fat, body fats (soft tissue)

Grade Pork 6 (P6)
Pig skin, free of hair and fatty tissue

Pork skin is collagen rich and in precooked form a valuable material for the manufacture of some meat products of the precooked-cooked type

Non-meat ingredients

- Along with the main components meat and animal fat, a wide range of substances of non-meat origin are used as ingredients in processed meat products.
- Some of them are absolutely necessary - salt and spices.
- Others are used for specific products.
- categorizing non-meat ingredients by source
  - chemical substances
  - plant origin
  - animal origin

Chemical substances used as ingredients

- Salt (for taste, impact on meat proteins, shelf-life)
- Nitrite (for curing colour, flavour, shelf-life)
- Ascorbic acid (to accelerate curing reaction)
- Phosphates (for protein structuring and water binding)
- Chemical preservatives (for shelf-life)
- Antioxidants (for flavour and shelf-life)
- Monosodium glutamate MSG (for enhancement of flavour)
- Food colouring substances (synthetic and of plant origin)

Ingredients of plant origin

- Spices
  - All spices are of plant origin (pepper, paprika, chilli, marjoram, thyme, cumin, nutmeg)
  - Used in small quantities to provide or add flavour and taste to meat products
- Binders
  - Plant origin with high protein content
  - are used as to increase water binding and fat retention
  - The most commonly
    - isolated soy protein (90% protein) and
    - wheat gluten (80% protein)
    - protein isolates from legumes (less important)

Ingredients of plant origin

- Meat extenders (if rich in proteins)
  - Soy flour (50% protein)
  - Soy concentrate (70% protein)
  - Other food legumes (beans, peas, lentils)
- Fillers (if rich in carbohydrates)
  - Cereal flours from wheat, rice and corn
  - Starches from wheat, rice, corn, potato
  - Breadcrumbs
  - Cereals without milling, e.g. rice, corn
  - Roots and tubers, e.g. sweet potato
  - Vegetable e.g. onion, carrots, celery
  - Polysaccharides

Non-meat ingredients of animal origin

- Milk casein (90% protein; used in small quantities (2%); have functional water and fat binding properties)
- Whole milk or non-fat dried milk (=skim milk) (sometimes used in indigenous meat preparations as a protein extender)
- Gelatine (binding properties and meat extender)
- Blood plasma (predominantly binding properties)
- Eggs (extender and binding ingredient for meat pieces and fried sausages)

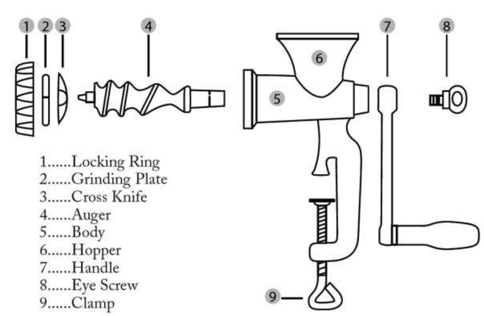
Meat processing technology

- Meat processing technologies include:
  - Cutting/chopping/comminuting (size reduction)
  - Mixing/tumbling
  - Salting/curing
  - Utilization of spices/non-meat additives
  - Stuffing/filling into casings or other containers
  - Fermentation and drying
  - Heat treatment
  - Smoking

Meat grinder

- Meat grinder is used to force meat by means of a feeding worm (auger) under pressure through a horizontal cylinder.
- At the end of the barrel is a cutting system consisting of
- Star-shaped knives rotating with the feeding worm
- Stationary perforated discs (grinding plates)

- Modern grinders include equipment to the separation of hard particles, such as bones, tendons, cartilages and foreign objects.



Hand grinder

Table grinder

Floor model grinder

Bowl cutter (bowl chopper)

- The bowl cutter is the commonly used meat chopping equipment designed to produce small or very small lean meat and fat particles.
- Bowl cutters consist of
  - horizontally revolving bowl
  - set of curved knives rotating vertically on a horizontal axle at high speeds of up to 5,000 rpm
- Volumes ranging from 10 to 2000 litres
- The process of chopping in a bowl cutter is used for producing fine comminuted products such as frankfurters, bologna, liver sausage etc.

Mixer / Blender

- Mixers are used to blend meat and spices, or coarse and finely chopped.
- Some mixers are designed as vacuum mixers (exclusion of oxygen)
  - advantages for the development of desirable product colour and texture

Filling machine

- Used for filling all types of meat batter in containers
  - casings, glass jars, cans etc.
- Piston stuffer
  - The most common type of filling machine in small and medium size operations.
- A piston is moved inside a cylinder forcing the meat material through the filling nozzle into the containers.

Large piston stuffer – filling funnels

Manual piston stuffer

Clipping machine

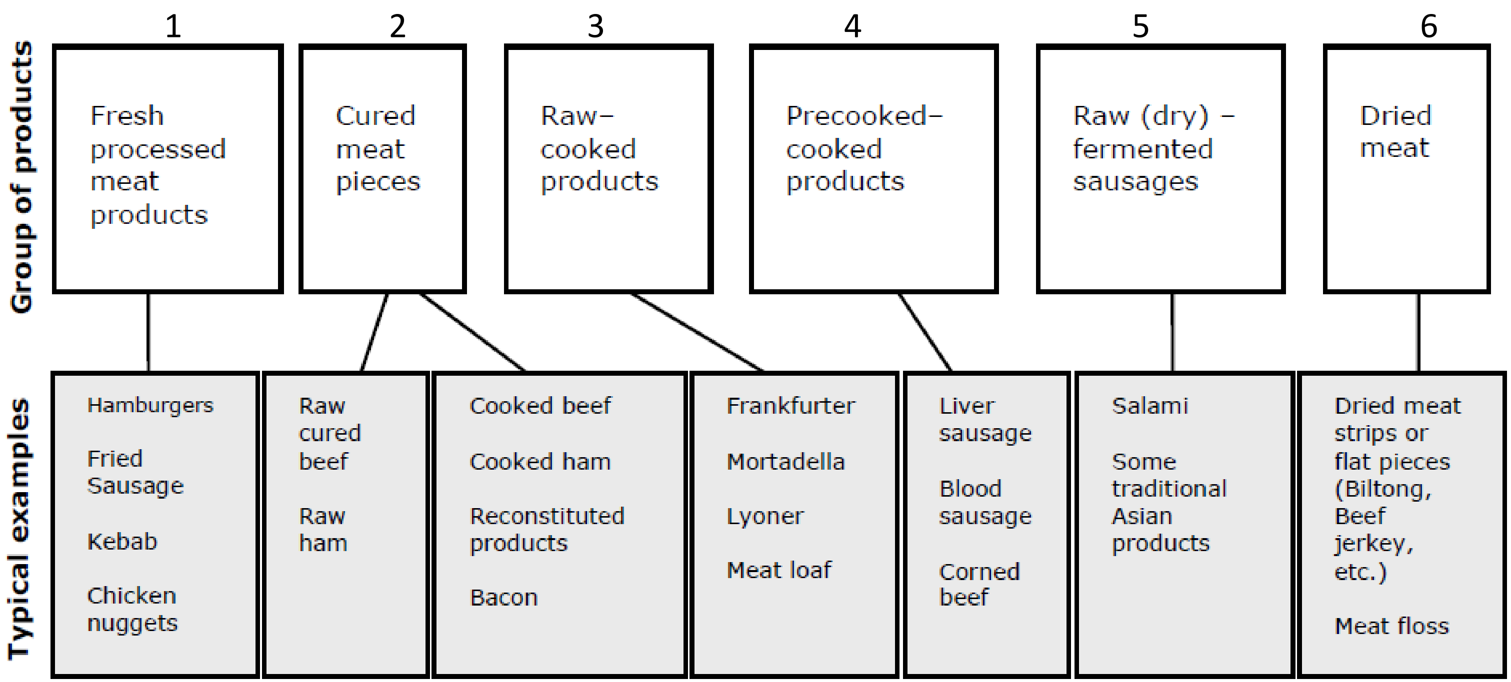
- Clipping machines place small aluminium sealing clips on the sausage ends
  - replace the manual tying of sausages.
- Used for artificial or natural casings
- Can also be connected to filling machines

Brine injector

- This equipment serves for the injection of brine into meat.
- Brine is water containing dissolved
  - salt and curing substances (nitrite, phosphates, spices, sugar, soy proteins.
- The injection is done by introducing pointed needles into the muscle tissue.
- Brine injection is mainly used for the various types of ham, bacon and other whole muscle products.

Meat products

- Based on the processing technologies used are categorized processed meat products in six broad groups:



1. Fresh processed meat products

- This group comprises
  - meat mixes composed of finely comminuted, minced or sliced muscle meat
  - with varying quantities of animal fat adhering to the muscle meat or added separately.
  - Flavouring is done by adding common salt and spices;
  - curing is not practiced
  - other non-meat ingredients
- The heat treatment (frying, cooking) is only applied immediately prior to consumption to make the products palatable.
- In many instances, the consumer cooks the products prior to serving and products are consumed hot.

Production steps for preparing fresh sausages

Step 1: Material composition
Left: back fat, middle: salt (above) and spices (below), right: lean meat with adhering fat and without coarse connective tissue

Step 2: Mixing of ingredients

Step 3: Grinding of mixture

Step 4: Casing preparation (soaking and rinsing natural pig casings)

Step 5: Sausage stuffing (manual stuffer)

Step 6: Portioning and twisting

Step 7: Final fresh product

1. Fresh processed meat products

- The products:
  - sausages e.g. frying sausages (the fresh meat mixes are filled in casings)
  - burgers, patties, kebab, etc..
- Storage and preparation for consumption
  - Fresh processed meat products are highly perishable products and subject to fast microbial spoilage and oxidative rancidity.
  - They should be heat-treated and consumed as soon as possible after production, or must be stored immediately under refrigeration.
  - Their maximum storage life is normally three days at +4°C or below.
  - If the product is deep-frozen at -18°C, the storage life can be extended up to three months.

2. Cured meat cuts

- Cured meat cuts are made of entire pieces of muscle meat and can be sub-divided into two groups
  - cured-raw meats (Prosciutto, Jamón)
  - cured cooked meats

- The curing for both groups, cured-raw and cured-cooked, is in principle similar:
- The meat pieces are treated with small amounts of nitrite (dry salt or as salt solution in water).

2. Cured meat cuts

- **Cured-raw meats**
  - do not undergo any heat treatment during their manufacture.
  - processing period comprises
    - curing, fermentation and ripening
    - in controlled climatized conditions, which makes the products palatable.
  - The products are consumed raw/uncooked.
- **Cured-cooked meats**
  - after the curing process of the raw muscle meat, always undergo heat treatment to achieve the desired palatability.

2. Cured meat cuts

- **High quality** products and regional delicacies
  - cured and cooked **entire pieces of muscle meat**
  - meat pieces may consist of defined muscle groups, such as ham or large back muscle.
- **Medium quality cured-cooked**
  - meat products are normally **reconstituted** from smaller size lean muscle parts, which are cured, tightly filled in special containers and cooked
- **Low-cost** market so-called **"re-formed"** products
  - products, small muscle pieces and lean trimmings are mixed with brine (water, salt, binders, extenders, etc., stuffed into casings or cans and heat treated.

3. Raw-cooked meat products

- The product components
  - *muscle meat, fat* and *non-meat ingredients*
    - processed raw (“**raw**”=uncooked) by comminuting and mixing in a first phase.
- The resulting mix
  - is heat-treated or “cooking”, in order
    - to obtain a firm-elastic texture typical for ready-to eat raw-cooked products
    - to achieve palatability
    - a certain degree of bacterial stability

3. Raw-cooked meat products

- Very popular in most parts of the world
- The raw-cooked meat products account for 50% or more of all further processed meats on the market.

- **Classical raw-cooked products** “all-meat”
- **Extended raw-cooked meat products**

3. Raw-cooked meat products

- **Classical raw-cooked products** “all-meat”
  - products of relatively high quality and good nutritional value
  - contain meat and fat as the main components and water as the major non-meat ingredient.
  - Ingredients of plant origin, if any, are used in small quantities and do not serve as an extender but as binders, e.g. soy isolate (max 2%)
- The most common are
  - the small-calibre
    - “Frankfurters” and “Vienna sausage” and the
  - large calibre
    - “Bologna” and “Lyoner”

3. Raw-cooked meat products

- **Extended raw-cooked meat products**
  - lower quality
  - contain higher amounts of low-cost non-meat ingredients mostly of plant origin for cost-reduction
  - “hotdogs” or cheaper sausages, “luncheon meat”, meat loaves, non-fermented dry sausages (cooked)
- **Raw-cooked sausages of smaller diameters** (frankfurters, hotdogs or Viennas) are mainly consumed hot.
  - They are heated up immediately before consumption.
  - These small calibre sausages are mostly filled in edible casings
- **Larger calibre sausages**
  - mainly eaten cold
  - casings are removed and the sausage is cut into thin slices

Production steps for preparing raw-cooked meat products

Typical composition of finely chopped product: Ice, fat (above), beef, pork (below)

Additives and spices: Phosphate, ascorbic acid (above), garlic, spices (middle), curing salt (below)

Step 1: Mincing of meat and fat (3 mm grinder disc)

Step 2: Dry-chopping of lean meat, curing salt and phosphates

Step 3: Ice is added to the dry-chopped lean meat

Step 4: Fat is added to the lean batter

Step 5: The mixture is finely chopped until +12°C is reached

Step 6 : Filling of product mixture into a long strand of natural hog casings

Step 7 : Sausages (linked and twisted to size) are put on a stick for smoking

Step 10 Cooking

Step 8 : Product is filled into an individual casing of larger calibre

Step 9 : The sausage end is sealed using a metal clip

Step 11 Smoking

4. Precooked-cooked meat products

- There are two heat treatment procedures involved in the manufacture of precooked-cooked products.
  - **The first heat treatment** is the precooking of most of the raw meat materials at temperatures below 100°C, usually in the range of 80°C.
  - **The second heat treatment** is the cooking of the finished product mix at the end of the processing stage.
    - At pasteurization temperatures (around 80°C)
      - sausages are filled in natural and artificial casings
      - limited shelf-life and the need for refrigeration
    - At sterilization temperatures (above 100°C)
      - canned products are filled in glass jars, tin or aluminium cans
      - have extended shelf-life and do not require refrigeration

4. Precooked-cooked meat products

- The raw meat materials used for precooked-cooked products
  - **lower-grade muscle trimmings**
    - **fatty tissues, head meat**, **animal feet**, **animal skin**, **blood**, **liver…**
- Good nutritive value
- Attractive and palatable varieties of animal food items
- Also contain cereals, herbs, vegetables, nuts and other plant materials, depending on local availability and consumption habits

4. Precooked-cooked meat products

- **Liver sausage / liver pate products**
  - The most popular precooked-cooked products
  - The basic product mix
    - Liver
      - major component
      - contributes to its unique flavour and taste.
      - Liver contents (10% - 35%) - more gives a bitter taste in final products
    - Lean meat
    - Softer or firmer fatty tissues preferably from pigs
    - For low cost products other soft animal tissues (for example hearts, lungs …)

4. Precooked-cooked meat products

- **Liver sausage / liver pate products**
  - The most popular precooked-cooked products
  - The basic product mix
    - Liver
      - major component
      - contributes to its unique flavour and taste.
      - Liver contents (10% - 35%) - more gives a bitter taste in final products
    - lean meat
    - softer or firmer fatty tissues preferably from pigs
    - for low cost products other soft animal tissues (for example hearts, lungs …)

4. Precooked-cooked meat products

- **Blood sausages**
  - mixtures of raw un-coagulated blood and other food ingredients (meat, fats and non-meat ingredients) filled into casings with subsequent heat treatment.
  - blood content of between 5-30 %
- **Cereal sausages**
  - content sizeable quantities of various non-meat ingredients such as breadcrumb, rice, potatoes, barley grain…) are used
  - mixture of pre-cooked lower value animal parts
  - deriving from animal heads and feet, bone scraps and any other edible tissues
  - liver or blood

4. Precooked-cooked meat products

- Cooked gelatinous meat mixes
- These products usually contain higher amounts of
    - head trimmings
    - veal and pork feet, tongues
    - other animal tissues according to local preferences
- All raw materials are precooked to some degree
- After cooking, they are cut into small pieces or ground, salted and seasoned.
- The uniformly blended mixes are filled in casings of larger diameters (natural or synthetic) and subsequently cooked.

5. Raw-fermented sausages

- Raw-fermented sausages
  - receive their characteristic properties through fermentation processes
    - tangy flavour
    - chewy texture
    - intense red curing colour

- Typical raw-fermented sausages are uncooked meat products and consist of
  - coarse mixtures of lean meats
  - fatty tissues (in most products, uniform fat particles can clearly be distinguished as white spots embedded in dark-red lean meat)
  - salts, nitrite (curing agent), sugars and spices

5. Raw-fermented sausages

- **In addition to fermentation**
  - **ripening phases** combined with moisture reduction are necessary to build-up the typical flavour and texture of the final product.
- not subjected to any heat treatment during processing
- in most cases distributed and consumed raw
- Winter salami (uherák), Lovecký salám, Fuet

6. Dried meat products

- Drying may be
  - the single dehydration of fresh meat for extension of storage
  - one of various processing steps during the manufacture of specific meat products.
- After completion of the drying process,
  - the dry meat is normally packaged, preferably in moisture-proof plastic bags to avoid absorption of moisture during storage.
  - For consumption
    - to eat directly (sometimes very hard)
    - to be **rehydrated** by submerging it in water
    - it can be **directly added** to meals

Processed products made of chicken meat

- Chicken sausages
- Chicken ham
- Chicken nuggets

Chicken sausages

- The modification of traditional red meat recipes
  - red muscle meat was replaced by poultry meat and pork fat by fat rich chicken skin.
- Chicken frankfurter and chicken bologna
  - finely comminuted products (raw-cooked products)
  - Lean chicken meat and skin is finely dispersed in the sausage batter.
  - filled in small casings (18-22mm),
    - chicken frankfurters
  - larger casings (40-60mm)
    - chicken bologna

Chicken ham

- Raw meat material may come from
  - chicken breast - higher quality
  - all parts of the chicken carcass – lower quality
- The meat material is tumbled together with brine containing curing salt, phosphates and spices.
- non-meat ingredients

Chicken nuggets

- The meat selected for the chicken nuggets is mixed with spices, salt and herbs
- ground to the desired particle size (1-5 mm)
- The ground mixture is spread in a tray to the desired thickness and frozen or formed into a various shapes.
- After that the nuggets are cut out, breaded and fried.

Chicken nuggets

Ground chicken meat
With salt and spices, to be frozen for chicken nuggets manufacture

Raw chicken nuggets cut-out from frozen block

Coated for frying

Chicken nuggets

Meat products

- Several hundred different meat products
- Each with its individual product name and taste characteristics
- Many of the different products with different product names have great similarities

References

- Toldrá F. 2010. Handbook of Meat Processing. Blackwell Publishing, 2121 State Avenue, Ames, Iowa 50014-8300, USA.
- Feiner G. 2006. Meat products handbook. Woodhead Publishing Limited, 6000 Broken Sound Parkway, NW, Suite 300, Boca Raton, FL 33487, USA.
- Kerry Joseph, Kerry John, Ledward D. 2002. Meat processing, Improving quality. Woodhead Publishing Limited, 2000 Corporate Blvd, NW, Boca Raton FL 33431, USA.
- Heinz G, Hautzinger P. 2007. Meat processing technology for small- to mediumscale producers. RAP PUBLICATION 2007/20, Bangkok.
- WARRISS PD. 2000. Meat science, An Introductory Text. CABI Publishing, 10 E 40th Street, Suite 3203, New York, NY 10016, USA.

This Textbook is the output of the project „Increasing of education quality and strengthening of research capacities at the Bamyan University (Afghanistan)" No. 22-ČRA18-04_01 and was financed by the Czech Republic Development Cooperation program

Quality, Storage and Processing of Meat Products
Klára Urbanová
© Czech University of Life Sciences Prague, 2018
Number of pages 303
First edition
ISBN 978-80213-2853-2