MEAT QUALITY

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Meat is the edible postmortem component from live animals. The animals include domesticated cattle, buffaloes, sheep, goats, pigs and poultry birds. Meat is skeletal tissue from an animal carcass. The animal carcass is devoid of skin and internal organ meats. The organ meats such as liver, heart, kidney and lungs are considered as variety meats. The carcass is in the range of 45 – 50 % of live animal weight. The carcass yield in the case of pigs is around 70 % of live weight because the skin is edible and comes along with the carcass. Also the birds, especially broiler chickens, yield carcass with skin as high as 65 – 70 % of live weight.

The carcass of slaughtered animals consists of 3 parts: muscle, fat and bone. The Carcass composition differs significantly between different meat animals (Table 1). Muscle is the major constituent of the slaughtered weight of the animal. Fat deposits and sometimes bones are often processed and marketed along with muscle.

Consumer expects certain quality characteristics in foods. Quality is degree of excellence. Quality embraces intrinsic composition, nutritive value, degree of spoilage, damage, deterioration, hazard to health, esthetic considerations, yield and profitability to the producer.

The following aspects pertaining to meat quality are studied in this topic:

1. Nutritional quality of meat
2. Meat quality parameters for consumers
3. Cold contraction and rigor mortis
4. Pale, Soft and Exudative and Dark, Firm and Dry muscles
5. Meat emulsions
6. Estimation of proximate composition of meat.

1. NUTRITIONAL QUALITY OF MEAT

Meat has been used as human food since time immemorial. Meat components are moisture, protein, lipid, ash and carbohydrate. These components vary in meats from different animal species considerably. Accumulation of lipid is the most significant variation. On average most meats contain about 18 % protein, 5 % lipid (including essential fatty acids), 1 % ash (potassium, phosphorus, sodium, chloride, magnesium, calcium and iron), 1 % carbohydrate (glycogen antemortem and lactic acid postmortem) and the rest 75% as moisture. Protein is main nutrient in meat with essential amino acids and excellent digestibility. Digestibility of meat proteins is more than 90% as against about 65 % in the case of plant proteins. Meat also provides many vitamins and all B - vitamins.

2. MEAT QUALITY PARAMETERS FOR CONSUMERS

The meat quality parameters for the consumers are its color, flavor and texture (tenderness and juiciness). The distribution of fat inside the muscle (intra - muscular fat) is called as marbling and is important characteristic of quality in meat animals. The degree of marbling depends on maturity of the animal and feeding practice. Marbling should be moderate to give proper taste and flavor. Too little marbling gives dry and flavor - less product. Too much marbling lowers the eating quality of meat as consumers prefer lean meat. Marbling also imparts juiciness to meat.

Color: Color is a visual indicator of meat quality. Color of meat varies from pale pink to dark red. Darker color is due to older age of animal. High degree of microbiological contamination and too much drying can cause discoloration of meat. The color of fat varies from creamy white to orange yellow. Dark yellow color of fat indicates older animal.

Flavor: Raw meat has a serum - like or blood - like bland flavor. During conversion of muscle to meat, the flavor components become more intense as the meat passes into rigor. There is a gradual loss in flavor during storage. This occurs even in frozen condition possibly due to the loss of highly volatile substances. Undesirable flavor may arise due to microbial growth, chemical deterioration and tainting by extraneous agents. On cooking, the flavor is altered to produce delicious flavor of cooked meat.

Feeding of different plants affects meat flavor. Sheep fed with lucerne, white clover and sweet glycine results in sharp odor; ryegrass, panic grass, green grass and kikuya grass gives strong meat odor; and rape grass causes sickly odor.

Meat texture: Postmortem handling of carcasses influences the quality of meat especially texture (tenderness and juiciness). Texture is rated most important among eating quality attributes.

The overall impression of texture involves:

i. The initial ease of penetration of meat by teeth.
ii. The ease with which the meat breaks into fragments and
iii. The amount of residue remaining after chewing.

3. COLD CONTRACTION AND RIGOR MORTIS

After death of the animal there is a discontinuation of blood supply to muscle and anaerobiosis sets in. The obvious physical change is the loss of extensibility in muscle, called as *Rigor mortis*. The lactic acid formed in the glycolysis goes on accumulating giving rise to acidification. Acidity of muscle is measured by pH.

The pH is defined as the logarithm (to the base 10) of the reciprocal of the hydrogen ion concentration, which is mathematically expressed as

$pH = \log_{10} 1 / (H^+) = - \log_{10} (H^+)$.

The pH begins to decline from about 7.0, its pre - slaughter value, until it reaches 5.3, called as ultimate pH. The rigor sets in and cross - bridges formed between actin and myosin proteins to form actomyosin complex giving rise to inextensibility and rigidity.

The contraction undergone by the muscle during rigor is temperature dependent and drastic shortening occurs at very low and very high temperatures. Rapid chilling of carcasses / muscles soon after slaughter results into contraction of muscles. This cold contraction produces toughening in meat. The meat so toughened cannot be improved by aging or cooking. When carcass / muscle is hold at 15 - 20 °C, the cold shortening is minimal.

Toughening due to cold contraction on rapid chilling can be overcome by postmortem conditioning of carcass. The carcass conditioning technique involves suspending the carcass through pelvis instead of conventional Achilles tendon (Fig. 1) and holding initially at 20 - 25 °C for 6 - 8 h followed by chilling at 3 – 4 °C for 16 - 18 h. After about 24 h, the carcass can be fabricated into cuts, which can be merchandised as chilled precut meat or frozen and stored (Fig. 2). Pelvic suspension of carcass stretches muscles, especially thigh muscles. Stretched muscles are tender.

Rigor shortening and cold shortening occurring in muscle postmortem are two different phenomena as explained below:

Rigor shortening: It occurs slowly in muscles after many hours of slaughtering. It occurs at low pH (< 6.0) and at low ATP levels (< 1 mmoles / g) in muscles postmortem. It occurs in both red and white muscles.

Cold Shortening: It occurs more rapidly in a few minutes after reaching low temperature when the muscle pH is still high (> 6.0). It occurs at high ATP levels (> 5 – 6 mmoles / g) in muscles postmortem. This occurs more in red muscles from sheep, goat, buffaloes and cattle and to less extent in white muscles from rabbit and pig.

Advantages of carcass conditioning are:

- The technique can be easily adopted in the existing meat chilling plants. It only requires S - type hooks for fastening through pelvis instead of gambrel for Achilles tendon.
- It improves the eating quality characteristics of meat.
- It reduces the cooking time by 50 % and saves fuel energy.
- It renders choice cuts suitable for roasting and broiling.

- In India large quantity of meat comes from aged animal. This meat is quite tough. The tenderness of meat from these animals can be significantly improved by this carcass conditioning process.

4. PALE, SOFT AND EXUDATIVE (PSE) AND DARK, FIRM AND DRY (DFD) MUSCLES

State of animal just prior to slaughter and conditions of slaughter influence the meat quality. Although meat is normally used or processed after it has gone in to full rigor, pre – rigor muscle has some advantages over post – rigor meat. The advantages are:

- A higher water holding capacity
- Greater ability to emulsify fat
- Formation of more stable emulsion
- A more stable red color
- A lower susceptibility to oxidation and
- Economical due to rapid turn over and greater energy saving.

The manner in which the live animals are handled prior to slaughter and carcasses / muscles post - slaughter results in the muscle conditions, viz., pale, soft and exudative (PSE) and dark, firm and dry (DFD) muscles (Fig. 3). The characteristics of PSE and DFD muscles are explained below.

Pale, Soft and Exudative (PSE): The characteristics of PSE muscles are:

i. Muscle is light or pale in color, soft, watery, lean and has open structure. Pale color results from light colored precipitates of sarcoplasmic proteins masking the usual red color.
ii. Muscle exudate renders meat unattractive and accumulates as excess fluid in prepackaged fresh chops and roasts.
iii. PSE condition occurs normally in pork and occasionally in beef.
iv. Open structure allows taking up of curing salts more readily.
v. Due to rapid drop in pH, it retards microbial growth and hence incidence of spoilage is less.
vi. PSE condition results from an extremely rapid rate of glycolysis postmortem – especially in stress susceptible pig - while muscle temperature is still high. Rapid fall in pH results in precipitation of sarcoplasmic proteins on the myofibrils.
vii. Glycogen content is lower and lactate concentration higher (even double) in PSE than in normal muscle.
viii. Adenosinetriphosphate (ATP) and creatine phosphate (CP) concentrations are also lower.
ix. Time taken for completion of rigor is greatly reduced in PSE muscle.

x. PSE muscle proteins are more easily soluble in salt solution and its collagen is more heat labile.

Dark, Firm and Dry (DFD): The characteristics of DFD muscles are:

i. Muscle is dark in color, firm in texture and dry to touch.
ii. DFD is associated with low glycogen reserves and low reducing sugar levels at the time of slaughter.
iii. Meat feels sticky to touch and has closed structure and high pH.
iv. Muscle does not absorb curing salts readily and hence more susceptible to bacterial spoilage.
v. Absence of glucose at the surface of DFD meat allows the spoilage microflora to degrade the amino acids and form odorous compounds earlier in spoilage process.
vi. DFD meat has objectionable soapy taste.
vii. Incidence of DFD can be reduced by minimizing the amount of stress during handling of live animals and during slaughter.
viii. DFD muscle proteins are less soluble in salt solution and its collagen is less heat labile.

5. MEAT EMULSIONS

Oil does not mix with water because of interfacial tension between the two layers. The chemical compound that can reduce the interfacial tension and helps mixing the oil and water is called emulsifier. Proteins are natural emulsifiers because they contain hydrophilic and hydrophobic (lipophilic) amino acids. An emulsion is a heterogeneous system consisting of atleast one immiscible liquid intimately dispersed in another in the form of droplets of diameter less than 0.1 µm. Emulsifying capacity of meat is measured as ml oil emulsified per 100 g soluble proteins.

Amino acid composition and sequence, molecular weight, conformation and charge distribution on the molecule affect functional properties of proteins. Emulsion type meat products have better sensory quality attributes.

Oil - in - water and water – in - oil (Fig. 4) are two types of emulsions, which are explained as below:

Oil – in – water: The characteristics of oil – in – water are:

i. Oil droplets are dispersed in water.
ii. Water is a continuous phase.
iii. Electrical current is conducted,due to transmission through the continuous water phase.
iv. Emulsions are creamy.
v. Favored by hydrophilic emulsifiers.
vi. Stabilized by sodium soaps.

Water – in – oil: The characteristics of water – in – oil are:

i. Water droplets are dispersed in oil.
ii. Oil is a continuous phase.
iii. Electrical current not conducted, due to the insulating properties of discontinuous nature of the water phase.
iv. Tend to be oily and grainy.
v. Favored by hydrophobic emulsifiers.
vi. Stabilized by magnesium and calcium soaps.

Functional properties of proteins include solubility, water holding capacity, fat binding (emulsifying) capacity, gelation and elasticity. The functional properties affect the taste, flavor, texture and acceptability of products.

Water holding capacity: The ability of muscle to hold fast its own water as well as added water is called as water holding capacity of muscle. Muscle proteins are water holders in meat. Hydration of meat is closely related to juiciness quality of meat, which in turn influences the tenderness and taste of meat. Drip loss, thawing loss, cooking loss and expressible juice measure water holding capacity of meat. Water is present in meat in two forms, viz., bound water and free water, which are explained as below.

Bound (fixed) water: The characteristics of bound water in muscle are:

i. Bound water is a true hydration, structural or protective water.
ii. It is only 4 - 5% of total water, tightly bound on surface of protein molecule.
iii. Non - polar amino acid residues bind this fraction of cellular water.
iv. Bound water is hardly influenced by changes in structure and charges of muscle proteins.
v. Bound water is vital for survival of the living organism and it cannot be frozen or evaporated without destroying the organism.

Free (loose) water: The characteristics of free water in muscle are:

i. Free water is immobilized water and is biologically active.
ii. Free water is immobilized by myofibrillar proteins.
iii. It is located in myofibrils and sarcoplasmic reticulum. This water is held by polar groups of side chains of proteins; eg. – COOH, - NH_2, - OH, - SH and peptide bonds.
iv. Free water is highly influenced by changes in structure and charges of muscle proteins.
v. Free water is needed by biosystems at the peak of biological activity.

6. ESTIMATION OF PROXIMATE COMPOSITION OF MEAT

Meat is minced and aliquot samples are taken for estimation of moisture, lipids (fat), ash and protein by the methods briefly described below:

i. Moisture content

Ten g minced meat in Petri dish is transferred to oven maintained at 100 ± 2 ºC, keep there for ~18 h, take out Petri dish from oven, cool in desiccator, weigh and calculate moisture content.

Moisture content in sample = Weight of fresh sample - weight of dried sample
Moisture content, % = (Moisture content in sample / Weight of fresh sample) X 100

ii. Fat (Ether extract) content

Powder the dried meat sample in Morter and Pestle, 2 g dried meat sample is taken in thimble and fat extracted by petroleum ether (boiling point 40 – 60 ºC or 60 – 80 ºC) in Soxhlet Extraction Unit and fat content is calculated.

Fat content, % (dwb) = (Fat content in dried sample/ Weight of dry sample) X 100

Fat content (% wwb) in fresh sample =

$$\frac{\text{(Fat content, \% dwb) X (100 - \% Moisture content of fresh sample)}}{100}$$

iii. Ash content

15 g minced meat in crucible is incinerated by holding crucible with sample on flame till smoke subsides, transferred to Muffle furnace maintained at 450 – 500 ºC for 16 - 18 h. The furnace is switched off, crucible is transferred to desiccator, cooled, weighed and the ash content calculated.

Ash content, % = (Ash content in sample / Weight of fresh sample) X 100

iv. Protein content

Muscle protein contains 16% nitrogen. Estimation of nitrogen in meat is done and the nitrogen content is then multiplied by 6.25 (= 100/16) to obtain protein content (Protein = N x 6.25) in muscle.

Reagents

Digestion mixture: 98 g K_2SO_4 + 2 g $CuSO_4$
40% NaOH; N/10 H_2SO_4; N/10 NaOH

Methyl red indicator: 0.1 g of indicator dissolved in 60 ml ethanol and 40 ml distilled water.

Two g minced sample in Kjeldahl flask, add 1 g digestion mixture, 20 ml concentrated H_2SO_4 and glass beads to prevent bumping, heat till digest is clear, cool, add excess of 40% NaOH (about 40 ml), distill to liberate ammonia and receive ammonia in 25 ml N/10 H_2SO_4. Titrate excess acid in the receiver against N/10 NaOH using 3 - 4 drops of methyl red indicator. A reagent blank is similarly digested and distilled to obtain blank titre value (B).

$$\text{Protein content in fresh meat, \%} = \frac{(C - B) \times 14 \times D \times 6.25}{A \times 1000} \times 100$$

where,

A = Weight of fresh minced sample, g,
B = ml of alkali required for neutralization of 25 ml of N/10 H_2SO_4
C = ml alkali required for back titration to neutralize excess acid,
D = Normality of alkali

CONCLUSION

Meat supplies micro (vitamins and minerals) and macro (proteins and lipids) nutrients to the human body. Cattle, buffaloes, sheep, goats, pigs and chicken are the main meat producing animals in India. Color, flavor and texture (comprising tenderness and juiciness) are the prime meat quality parameters of which texture is rated highest by the consumers. Handling of animals during slaughter and subsequent storage of carcass affect meat quality. Improper handling and processing lead to undesirable PSE and DFD conditions in meat. Suspension of carcass by pelvis soon after slaughter and dressing, holding at above 20 ºC till the muscle pH is 6.0 or below followed by chilling at 2 - 4 ºC for overnight improves tenderness quality of meat by preventing cold contraction of muscles. Pre – rigor meat is better than post - rigor meat for the preparation of meat products. Meat proteins are excellent emulsifiers as they contain both hydrophilic and lipophilic amino acids.

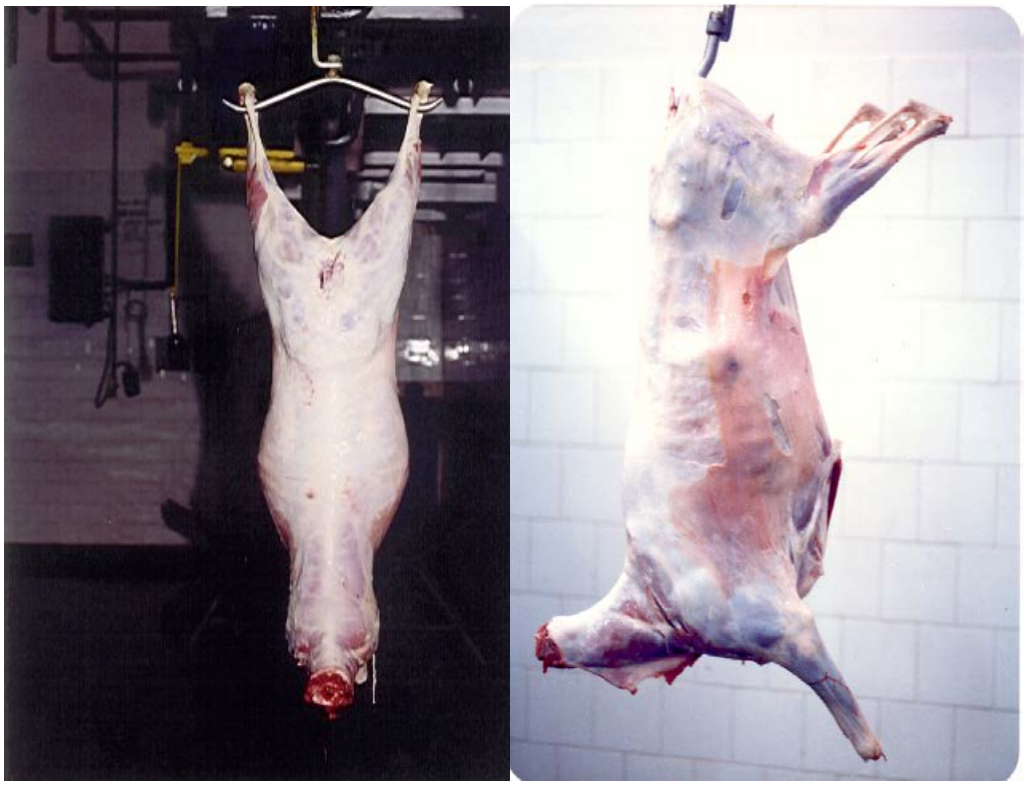
Table 1. Composition of carcasses from lamb, pork and broiler chicken

	Lamb[a]	Pork[a]	Broiler chicken[b]
Live weight, kg	17	110	2
Body components, (As % live weight)			
Carcass (Dressing) yield	45	73	77
Non - carcass	-	27	23
Carcass skin	-	5	9
Carcass fat	1.5	23	7
Carcass bone	11.9	9	22
Carcass muscle	32.4	36	39
Meat / bone ratio	2.3	4.0	1.8

Source: [a]Robert G Kauffman 2001; [b]Javeed Ahmed and Mahendrakar 1996.

Observation:

- Carcass composition differs significantly between different meat animals.



Achilles tendon suspension Pelvic suspension

Fig. 1. Carcass suspension postures

Source: Dani *et al* 1982; Mahendrakar *et al* 1990.

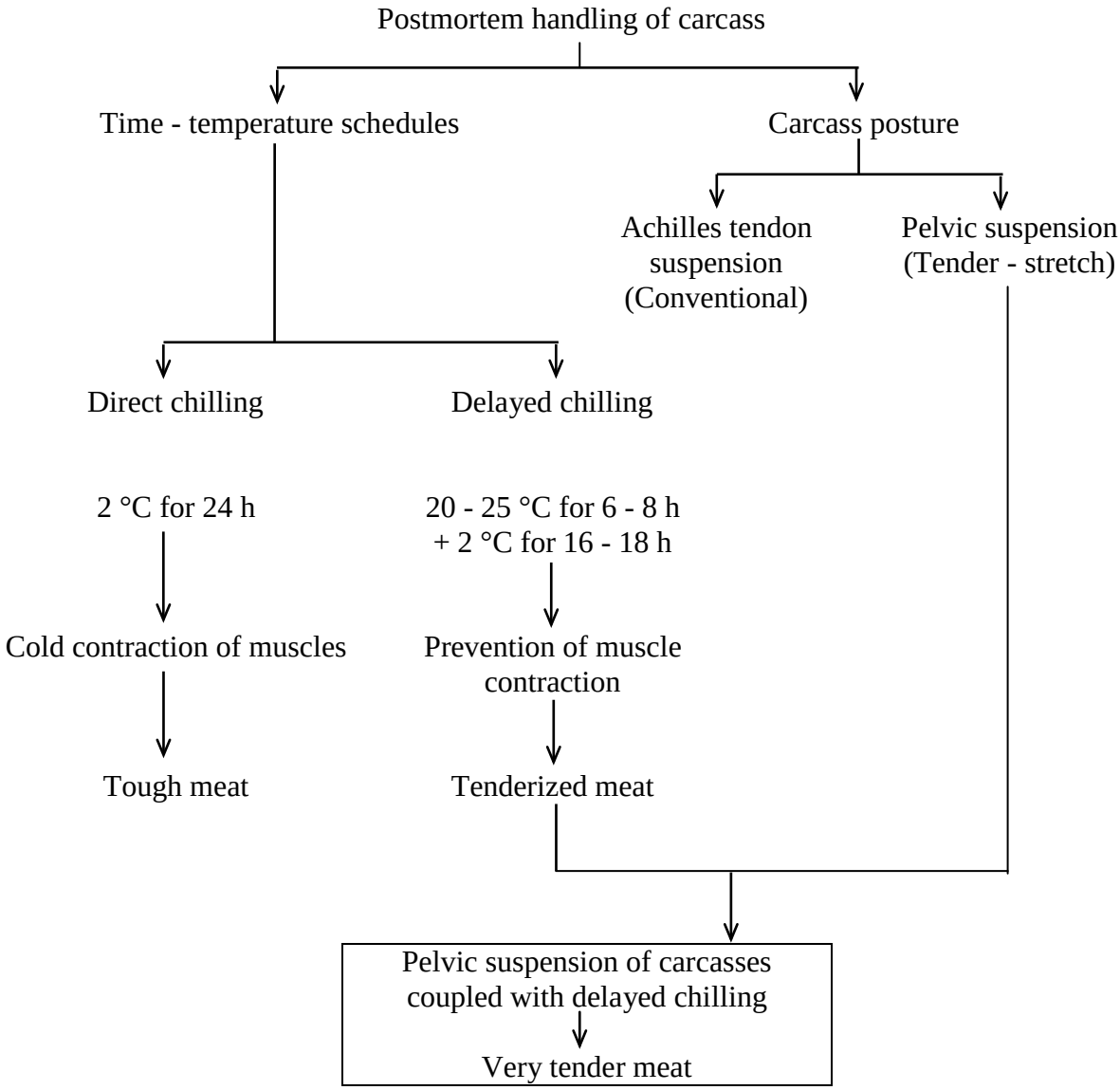


Fig. 2. Carcass conditioning technique to tenderize meat

Source: Mahendrakar *et al.* 1990.

Fig. 3. PSE and DFD meats

Source: Google search on images of PSE and DFD muscles **(**in Jan 2016)

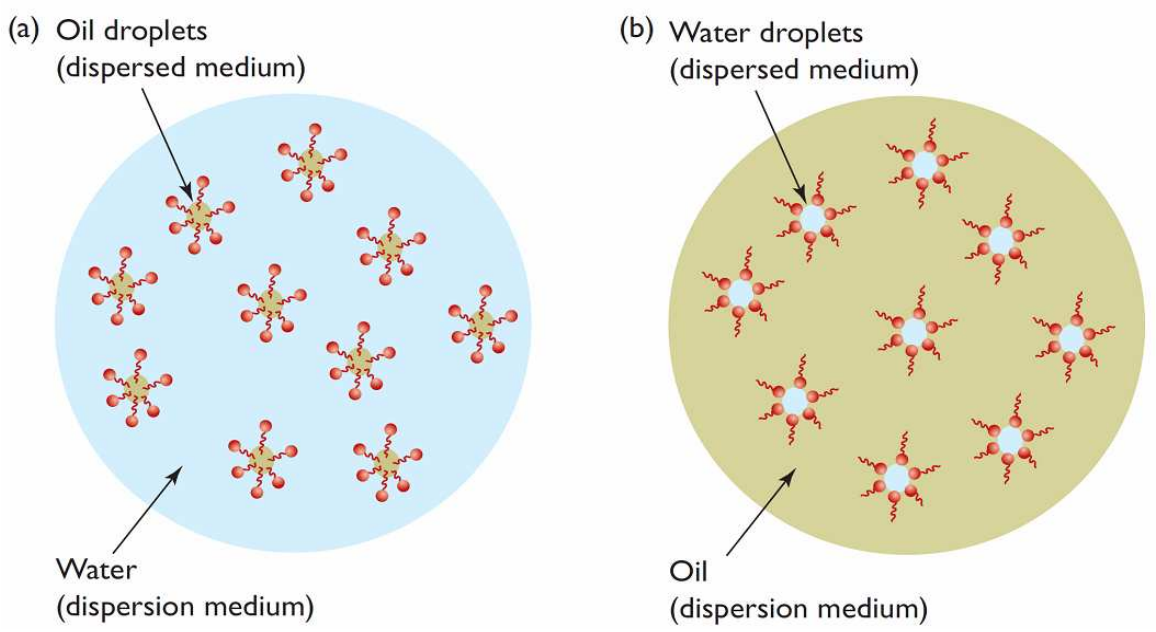


Fig. 4. Different types of emulsions

Source: Google search on images of meat emulsions **(**in May 2016)