CHEMISTRY AND TECHNOLOGY OF CURED AND SMOKED MEAT PRODUCTS

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Recent developments in the chemistry and technology of cured and smoked meat products are reviewed. Various factors physical, chemical and microbiological affecting water-holding capacity of cured meats and cured colour formation and its stability during storage are discussed. Methods of preparation of various types of cured and smoked meat products have been briefly described. Developments in the use of synthetic casings and skinless sausages have been mentioned. Smoke constituents, their role and physico-chemical aspects of mechanism and functions of smoking are discussed. Advancements in the methods of smoke generation, conventional smoking and smoke kilns, electrostatic smoking and smoking by use of liquid smokes have been described. Some of the methods of preparation of liquid smokes are also given.

None of the processed foods can perhaps claim an earlier origin than smoked and cured meat products but transition from primitive to latest scientific methods is surprisingly slow. It may be because the chemistry of these products has been better understood only recently i.e. in the later part of the 20th century. Further, advances in the engineering and technological aspects of food science have been outstanding in the past two decades which have enabled many countries to adopt up-to-date smoking plants working on forced draught circulation and employing stainless seel smoke chambers. These plants produce smoke externally by burning hard wood saw dust or by a friction device from hard wood logs. Temperature and humidity of the smoke chamber are controlled automatically. Liquid smokes are also increasingly used. Similarly, long curing methods are now being replaced by shorter methods involving needle injection and arterial pumping of curing solutions and employment of fool-proof chemical agents instead of trouble-creating bacteria to act as reducing agents. All these developments have resulted in producing more uniform products which meet the needs of the consumers. In India the industry is producing cured meat products on a small scale and has yet to utilize the vast technical know-how abundantly available in advanced countries.

The object of this review is to present a critical appraisal of recent knowledge on the subject.

CURING

Curing of meat started as a simple preservation technique consisting of mixing salt to meat. But, later on colour development and flavour development were also included in the process of curing. There are three important factors i.e. texture, juiciness and colour which determine the quality of cured meat products. While texture depends upon the pre and post slaughter conditions and cut, juiciness and colour can be controlled by the curing methods.

(a) *Water holding capacity* (*WHC*)

In raw meat, the protein is present in fibres delicate and soft. These soft fibres are given strength, held together and bound into bundles by a tough yet elastic substance known as connective tissue. The meat juices, containing flavour, vitamins and minerals are held in and around the muscle fibres by these sheets of connective tissue. The fact that this water is not drained off by introducing a tube into the tissue shows that this water is immobilized by some means. Only a small proportion of the 75 per cent water present can be said to be the water of hydration which is tightly bound to the hydrophilic groups of protein molecule by means of hydrogen bonds and forms the first molecular layer. Rest of the water present in meat is "free". It freezes at the same temperature as normal water and has the same solvent power. It has found that quantity of globular proteins seemed to have greater water-binding capacity. The globular protein of muscle consists of two very distinct proteins. One of these is myosin and other actin. Globular actin in presence of appreciable concentration of salt, in particular divalentcations, tends to aggregate or polymerise into fibrillar form F-actin, cations being bound in the process. If solution of myosin and F-actin are mixed, there is a sudden rise of viscosity and the solution exhibits strong streaming birefringence. The electron microscope indicates very long threads just like fibrils of muscle. So WHC of meats depends upon gel formed by means of long stretched threads of Actinomycin which is held up by sheets of connective tissue. Investigation[1] of the water of agar gels by means of nuclear magnetic resonance has revealed that the water molecules in these gels behave like intermediates between free water and ice in which oxygen atom is surrounded by four other oxygen atoms arranged tetrahedrally. The pairs of atoms are individually linked by hydrogen bonds. Thus every oxygen atom takes part in the formation of two hydrogen bonds and the whole crystal of ice is virtually one molecule. A somewhat similar situation exists in liquid water, although the amount of hydrogen bond formation decreases with increasing temperature. Structure formed with fibrils and water molecules, which is in between ice and water, is expected in meats also. There is a competition between formation of intramolecular hydrogen bonds and formation of hydrogen bonds between the same groups and water molecules. The hydrophilic groups responsible for the fast binding of water are of two types. One type includes the polar groups of the side chains of protein such as the carboxyl—, amino—, hydroxyl—, and sulphydryl groups. The other type is made up of undissociated carbonyl and imido groups of the peptide bonds in which the binding of water is due to the dipolar character of water. In protein if there are many non-polar side chains on a single-molecule, which are hydrophobic that portion tends to be located in the interior of the molecule and will carry with them part of the peptide chain to which they are attached. This part of the polypeptide chain being removed from contact with water, will presumably tend to form peptide hydrogen bonds, thereby decreasing the water holding capacity. So we can say that water holding capacity depends upon configuration of the protein and its ability to form hydrogen bond with water. From the molecular view point, detailed studies have been carried out by Mellon *et el.*[2] regarding polar amino acid chains which contribute very strongly to water absorption. Peptide groups also appear to be responsible for a major fraction of water uptake. In the light of this various factors effecting the WHC of meats are discussed below:

(*i*) *Effect of pH*—Hamm[3] has reviewed the effect of *pH* of Meat. A loosening of the microstructure and consequently an increase of immobilized water is caused by raising the protein net charge by addition of acid or base. The *pH* at which water holding capacity is at a minimum (5·0) corresponds approximately to the iso-electric point (I.P.) of actomyosin which is the main constituent of the structural muscle proteins. At the I.P., the net charge of a protein is at a minimum as illustrated below:

Proton—donator (acid)

$$\left|\begin{matrix} -COO^- & -- & {}^+H_3N- \\ -NH_3^+ & -- & {}^-OOC- \end{matrix}\right| + 2AH$$

$$\rightarrow \left| \begin{array}{ll} -COOH & H_3N^+ \\ -NH_3^+ & HOOC- \end{array} \right| + 2A^-$$

Proton—acceptor (base)

$$\left| \begin{array}{lll} -COO^- & -- & {}^+H_3N- \\ -NH_3^+ & -- & {}^-OOC- \end{array} \right| + 2B^+ \rightarrow \left| \begin{array}{ll} -COO^- & H_2N- \\ -NH_2 & {}^-OOC- \end{array} \right| + 2HB$$

By the addition of acid or base a cleavage of salt cross linkages occurs and the electrostatic repulsion between similarly charged groups increases. Each of the similarly charged ions will push away its neighbouring ions and so the long molecular chain will gradually become straightened out exposing hydrophilic groups and hence increase in WHC.

(*ii*) *Effect of sodium chloride*—Addition to sodium chloride causes a strong increase in WHC and swelling capacity of meat at its normal *pH* value[3]. The swelling effect of sodium chloride is primarily due to the influence of the chloride ion; sodium acetate at the same ionic strength shows no or only little effect. In the basic range of the I.P. a screening positive protein charges by bound anions causes a weakening of salt linkages and, therefore, a loosening of the molecular structure which permits an increased uptake of immobilized water.

$$| -COO^- \; - \; {}^+NH_3 - | + Na^+ \; Cl^- \rightarrow | -COO^- \; Na^+ \; Cl^- \; {}^+NH_3 - |$$

In the acidic range of the I.P., addition of sodium chloride causes de-swelling because binding of anions weakens the electrostatic repulsion between the positive charged groups of the protein.

$$| -NH_3^+ + {}^-NH_3 - | + 2\,Cl^- \rightarrow | -NH_3^+ \; Cl^- + Cl^- {}^+NH_3 - |$$

Strong binding of cations shows the opposite effect. This is particularly observed with salts the anions of which are only weekly bound by the positively charged protein groups, for example with acetates.

Berman & Swift[4] have reported that the addition of *NaCl* resulted in an increase of free calcium, magnesium and to a lesser extent zinc and there was little or no binding of sodium chloride. Zinc was the only electrolyte that was substantially and strongly associated or bound with soluble protein. The amounts of calcium, magnesium and zinc release, were forty fold greater than amounts of bound chloride ion and sodium ions. Effect of zinc in meat has been considered to be similar to that of calcium in that its binding to the structural proteins of meat has been assumed to have an adverse effect on water retention. As zinc does not appear as insoluble on heating, it may be bound to imidazole groups that are unaffected by heating. *NaCl* promoted the release of calcium and Magnesium. A portion of these metals are tightly bound by the structural proteins. Many authors [5,6] suggest that alkaline earth metals interlink certain protein structures by the formation of intermolecular cross-linkages between the peptide chains and that in this way they decrease swelling and WHC of such protein systems. It is to be expected that a cleavage of such cross-linkages loosens the microstructure of muscle in such a way that more water can be taken in the immobilized state.

Tencate[7] has reported that uptake of sodium chloride is not influenced by the *pH* of the meat except at the surface. Salt uptake lowers the *pH* of the meat and is thus antagonistic to its H_2O binding capacity. Water bindng capacity increases with increasing

NaCl concentrations forming a maximum between 6–10% *NaCl* and then lessens with increased *NaCl*. At lower salt concentrations, H_2O binding capacity is very much influenced by *pH* of the meat, where as in stronger brines, this influence of *pH* decreases, disappearing in saturated brines.

(*iii*) *Effect of ion exchanger*—As mentioned above even traces of bivalent metals have an important influence on water holding capacity of meat. It is possible[8] that not only the peptide chains within the same protein component of muscle are linked together by alkaline earth metals but also actin with myosin molecules. Bozler[9] found that a partial extraction of calcium by ethylene diamene tetra-acetate (EDTA) and of magnesium by polyphosphates increases the swelling capacity of muscle tissue. Hamm[5, 10] showed that a partial exchange of bound muscle calcium and zinc for sodium or potassium at pH_7 by means of cation exchanger increases the WHC of beaf muscle. Bound magnesium and bound iron are not exhangeable under these conditions. Therefore the elimination of calcium only and perhaps zinc[4] is responsible for the hydration effect produced by treatment with exchanger resin. There already exists a technical process[3] to increase the WHC of meat by treatment with foils of exchange resins.

(*iv*) *Effect of phosphates and citrates*—Anions which are able to precipitate alkaline earth metals or to form complexes with them also increase WHC. There exists[3] a direct correlation between the calcium binding capacity of anions and the ability to increase the WHC of meat in the basic range of the I.P. Therefore citrate and polyphosphates are used in practice in order to increase WHC of frank-furter-type sausages and reduce the release of water during canning of Ham[11].

Apart from this, polyphosphates[18] in cured meats help in (*i*) the adjustment of the *pH* of meat to the alkaline side (*ii*) the increase in the ionic strength of the mixture. As suggested by Berman & Swift[4] major role of polyphosphates may be binding of zinc. Yasui[11,12] *et al.* studied the interaction of Myosin with inorganic polyphosphates. The appearance of a fraction more soluble than the original myosin B is found upon the addition of pyrophosphate to a myosin B solution containing 0·6 M potassium chloride and 0·5 M magnesium thus suggesting the dissociation of actomyosin into myosin A and actin. This may result in the binding property or WHC of meat. Tripolyphosphate becomes effective after its decomposition to pyrophosphate by the Tripolyphosbates in meat. In practice tripolyphosphate may be used where curing period is prolonged for, unlike pyrophosphate which becomes ineffective through its hydrolysis by pyrophosphates in meat tripolyphosphate exhibits its influence much longer through its hydrolysis by the tripolyphosphates in meat. The effect of polyphosphates such as hydropolyphosphates may be confined to an enhancement of solubility and extractability of myosin B by increasing the ionic strength under the conditions of sausage manufacture unless tripolyphosphate or pyrophosphate are produced from hydropolyphosphate by spontaneous reversion or other type of decomposition. A meat curing process[13] has been described in which acid alkali metal pyrophosphate and a solution of alkali are simultaneously injected in such a proportion that pyrophosphate is converted into tetracid alkali metal pyrophosphate. As phosphate are expensive, use of alkali hydroxide[14] or an alkali carbonate or biocarbonate in combination with 0·25% alkali citrate or citric acid is also recommended. Sodium citrate is added first for sequestering followed by alkali with conventional pickling solution. After the cure is completed the *pH* of meat remains about 6·3–6·8. Instead of sodium citrate, sodium succinate can also be used.

(v) *Effect of coating*—To prevent moisture loss during storage, edible corn-carbohydrate coatings were tried by Allen *et al*[15]. Preliminary studies led to the formulation of meat coatings composed of corn starch and sodium alginate. These coatings required the application of divalent cation to convert the starch slurry to a plastic like coating. Calcium was the most effective salt. Coating could reduce moisture loss and showed much higher carbondioxide transmission but a lower oxygen transmission. The coatings invariably improved texture and juiciness[16] and in some cases colour, general appearance, surface texture and odour in case of fresh meat products. Flavour, however, was decidedly inferior in the coated samples.

(b) *Cured colour formation*

(i) *Mechanism*—Although it is stated in lieterature[17] that the use of trace elements in the form of physiologically acceptable salts alongwith phosphates in curing brines stabilizes the red colour of meat, generally cured colour is formed by the action of *NO* under reducing codions. Following reactions[18] may take place :

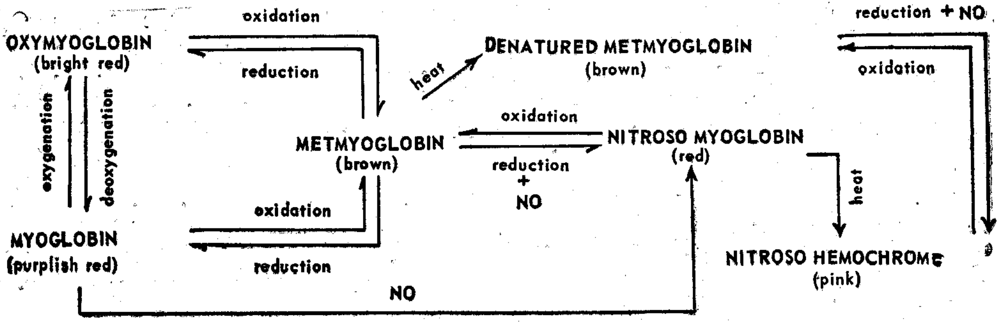

FIG. 1—Reaction involved in the stabilized red colour of meat

Myoglobin the *heme* pigment on combining with *NO* gives nitrosomyoglobin which imparts the cured colour to the meat muscle. Myoglobin is similar to haemoglobin having molecular weight about one-fourth that of haemoglobin and it contains only a single iron-porphyrin group. The pigment[19] combines reversibly with O_2 and also with *CO*. While this has less affinity for *CO* than haemoglobin it has more affinity for O_2. It acts as an efficient oxygen carrier between the circulatory haemoglobin and the enzyme system of the cell. After the slaughter of the animal, for a very short time oxygen will be available to the tissue by direct conversion of oxymyoglobin into myoglobin on the liberation of oxygen as pressure of oxygen in the blood is reduced. After this a gradual stiffening of the muscle tissue occurs, which is known as rigor mortis. At this time an aerobic glycolysis takes place and *ATP* is broken down. When *ATP* level goes down below certain critical value the contractile structure becomes rigid and inextensible due to formation of complex form Actin and Myosin. Rigor mortis begins more rapidly if death occurs during severe muscular exertion or after violent spasms or convulsions when the *ATP* stores in the muscle are already low. When *ATP* is broken, metallic cations are also released and react with charges present on the protein. At this stage equilibrium is also reached between the myoglobin and oxy-myoglobin. Since both myoglobin andoxy-myoglobin can be easily oxidised[20] by molecular oxygen, outer surface, which is in contact with atmosphere, turns into brown colour of met-myoglobin. When meat is immersed in the brine, various exchanges occur. Curing salts penetrate the meat which is the major objective of the brine procedure. Water and substances dissolved in it leave the meat. Among these substances are soluble proteins (which make the brine slightly pink, viscous and forthy), glucose and glucose phosphates, muscle glycogen, and probably small amounts of other sugars (e.g. ribose), amino acid and pigments. The significance of these substances as ingradients of the brine is not yet known in individual detail but their general significance is plain enough—they serve as food materials for the microbes. As part of this function they can act as reducing agents. For the formation of cured colour, nitric oxide is derived from nitrite salts. Nitrite salts are formed by the reduction of nitrates, agent for which are bacteria and not reducing system of meat. Slight acid sets free nitrous acid (HNO_2) which decomposes in dilute solutions to give NO.

$$3HNO_2 \rightarrow 2\ NO + HNO_3 + H_2O$$

In slight concentrated solution instead of nitrous oxide, nitric acid and nitrogen dioxide may be formed. As nitrates are poisonous in large quantities, their presence in the curing mixture is restricted to 200 ppm. When nitrate is added to curing mixtures, it not only supplies nitrite under reducing conditions produced by the bacteria but helps in the reduction of the total population of unwanted bacteria. It has been shown[21,22] that 1% of $NaNO_2$ ensures a 70% reduction in an-aerobic meat spoiling spores. With sodium chloride and sugar the nitrite is reduced to hydroxylamine which inactivates catalase so that hydrogen peroxide is formed; under these conditions clostridium is also killed. Brozdov and his co-workers[24] have reported that hydroxylamine was found in salting solution but not in meat.

Apart from increasing the salt penetration and selecting certain band of bacterial flora which helps in reduction of NO_3 to NO_2, salt also promotes the oxidation of oxymyoglobin to metamyoglobin which under reducing conditions is converted to nitrosomyoglobin by NO[19].

(*ii*) *Microbiological aspects*—Normally two processes of curing[25] are in use : (1) Brine is used only once (2) Brine is re-used. Immersion of meat in brine for 3–4 days is followed by a corresponding period of rest (storage brine). In the former case the transfusion of the brine from the raw stages when it contains only the curing ingredients, to the mature stage where it is more or less in equilibrium with meat, is slow particularly at a low temperature. A new method which completes curing in about 18 hours has been developed[26] it makes use of an equipment in which curing solution is circulated at a temperature of 50°C. It has been reported[27] that changes in a rapidly developing short life meat curing brine occur in three stages : First a gradual increase of soluble meat juice constituents with attainment of a fairly stable pH and increasing flora (primarily Achromobacter). Small almount of NO_2 developed is theoretically sufficient for colour development but its penetration into meat is slow. In the second stage full maturity is reached and good cures are obtained; greater penetration of colour occurs and NO_2 production is maintained but the Redox potential and bacterial growth are not such that appreciable nitrate is destroyed and acidity decreased. In the third stage bacterial population is increased to a point where NO_2 is lost by reduction to N at a faster rate than it is formed so that pH increases, organic matter precipitates and KNO_3 is wastefully consumed. The brine becomes uncontrollable and progresses to an off condition. Reduction of NO_3 occurs at the expense of lactate which is oxidized to CO_2. At this stage brines are rested for some time and bacterial population is brought down. Karakoevg[28] *et al.* have described a method of regenerating 'off' brines with the aid of electrolysis. They claim that micro-organisms and proteins are considerably decreased by this method.

Bacteriology of meat curing brines has been discussed in detail by Ingram[25]. Bacteria causing food poisoning are not halophilic but effect of salt is so much reduced in intensity at low temperatures that bacteria can survive for long periods in brine. Examples of such cases are Salmonella, Coli-averogenes bacteria and Staphylococci. In order to avoid such cases only meat which is free from these bacteria should be used for curing and perfect hygienic methods should be followed in the curing cellar.

Ingram[25] has also discussed desirable changes caused by bacteria in brines and their-control.When brine is used once or with short brines of salt-content below 20%, the production of nitrite mounts with the bacterial numbers, reaching a very high level after a few weeks. The nitrate, not being replenished, is then rapidly used up, after which the nitrite itself is destroyed and the brine becomes alkaline and cannot be used further. The flora is commonly composed predominantly of a single species. In long term bacon brines with more than 20% of salt, the flora is very heterogeneous. All the organisms could not be studied and no correlation between poduction of nitrite and number of counts could be established. Moreover, a proportion of the bacteria are capable of reducing nitrite further. In such cases concentration of nitrite is kept at a desired level by adjusting the salt concentration for if it is below 100 ppm there will be imperfect colour fixation; more than 2,000 ppm or 7 ppm HNO_2[29] is likely to cause green discoloration. Nitrite content of a brine will diminish if salt concentration is raised. This may be helping the adjustment between the bacteria producing nitrite and those destroying it. It has been reported that, in a particular brine, reduction of nitrite began when no more nitrate remained. If this is true for all the brine then curing can be regulated by controlled bacterial reduction of nitrate to nitrite which can be slowed by raising the salt concentration and decreasing the temperature and vice versa. Eddy & Kitcher[30] determined effects of salt concentration, temperature and bacterial population on rate of conversion from nitrates to nitrites which were decreased by increasing the salt concentration and decreasing the temperature. Apart from salt concentration the source of salt used is also an important factor in the curing process. Solar sea salt may have a satisfactory chemical composition but contains many micro-organisms which are able to grow in saturated $NaCl$ medium. Work by Leistney[31] showed that (*i*) species of Spirillumi, Akaligines, Achromobacter, Vibrio, Pseudomonas and Micrococcus improved colour formation in cured meats, (*ii*) Micrococcus especially and its mixed cultures improved flavour and (*iii*) preservation of cured meats was improved by species of Lactobacillus, Micrococcus and possibly vibro. Optimum curing by infusion is done by using a mixture containing several strains of the following genera : predominent Micrococcus; ample Alkaligines; Achromobacter, Vibro and Lactobacillus; and moderate Pseudomonas and yeast. Addition of 1-3×10° cells/ml. in the infusion brine is desirable.

(*iii*) *Use of chemicals*—It has been found that curing reactions are enhanced by the use of chemicals such as erythorbate, ascorbic acid, isoascorbic acid and their sodium salts. The mode of action of ascorbic acid is still not very clear. It has been shown by Lugg[32] *et al.* that nitrite in concentration of 0·001 to 0·007 milli mole of $NaNO_2$ to 8 ml. solution containing ascorbic acid, considerably oxidised ascorbic acid to dehydroascorbic acid and to some extent to other substances which cannot be converted to ascorbic acid by H_2S. In this process NO may be liberated and dehydroascorbic acid may oxidize oxymyoglobin to metmyoglobin. In the absence of dehydroascorbic acid NO is liberated at the expense of one mol of HNO_3 which is oxidized to HNO_3. As pointed out by Watts & Lehmourn[34] ascorbic acid also acts as reducing agent in the conversion of Metymyoglobin to myoglobin which in turn unites directly with NO to form nitrosomyglobin. This is confiremed by Fox's[33] finding. He studied invitro formation of nitrosyl myoglobin using purified myoglobin, nitrite and ascorbate and found that the reaction is dependent on pH and increased below pH 5·4 but is independent of myoglobin. Formation of myoglobin from metmyoglobin is dependent on metmyoglobin. There is an interesting finding of Praizler[35] that the rate of development of cured meat colour is accelerated in presence of enediol containing compound such as ascorbic acid when the meat to be cured is vacuum treated and in this case requirement of ascorbic acid also goes down. This clearly shows that due to vacuum oxymyoglobin gets converted into myoglobin which directly combines with NO to give cured colour. In this case two steps, namely, its oxidation to meta then reduction of myoglobin, are avoided. According to Fox[33] in presence of ascorbic acid complex and nitrite gleening of heme pigment is stopped. Support for ascorbic acid converting metmyoglobin to myoglobin by reduction is further given by the findings of Coleman[36] *et al.* who injected ascorbic acid with a syringe and hypodermic needle into several parts of a piece of dark coloured beef and this was changed to bright red colour in the areas about the injected regions. It has been shown by Gram *et al.*[37] that the addition of ascorbic acid (0·01–0·02 % at 3°C) preserves oxyhaemoglobin. Addition of KNO_2 (0·02%) to pure haemoglobin solution causes rapid oxidation to the brown metemyglobin and other oxidation products, but in the presence of ascorbic acid (0·1%) methemyoglobin is formed which is stabilized with additional amounts of ascorbic acid.

Other compounds which have accelerating effect similar to ascorbic acid have also been reported. Some of these are ascorbates[38], iso-ascorbic acid[40] and its sodium salt, erythorbate[39], nicotinic acid[38], cystein[47] and glutathione[41]. It has been shown[40] that activity of ascorbic acid, iso-ascorbic acid and their sodium salt is the same. As compared to erythorbates, ascorbates have the advantage[39] that residual nitrite is less and more of it remains after the initial curing step to provide for the additional protection. This is most beneficial when the colour at the uncooked stage is very important. Cost of ascorbate, however, is enough to make its indiscriminate use out of question. But when final product is cooked full conversion of pigment to nitrosoform is not quite so important as full conversion can be obtained during heating process. The presence of ascorbic does not contribute appreciably to the increase in degree of conversion which even without these is around 85–95%.

One advantages of the use[25] of ascorbic acid or chemical reducing agent is that it can completely dispense with the use of microbial flora for the curing reaction to take place. Even completely sterile brine[25] can be used and difficulty in controlling the reaction and hazards of imperfect control can be avoided. Not only this but much saving in the time for curing is also there. But by this process flavour due to microbial flora which usually develops in the cured meats is absent.

It has been stated earlier that formation of nitrosyl myoglobin from myoglobin is rapid at low pH values. The addition of citric acid, lactic acid, hydrochloric acid, gluconic and other similar acids had got unfavourable effect on meat as lowering of pH reduces the water binding capacity. In order to adjust acidity of meats, lactones[42,43] are successfully used. They do not effect emulsifying or water binding of meats. These compounds are sugar derivatives derived from gluconic acid and called glucona delta lactones. With the addition of lactones pH drop is gradual and the initial nitroso pigment is higher. Addition of lactones decreases residual nitrite level and stability of cured colour increases progressively with increasing amount of lactone added. Lately, number of such compounds said to accelerate with nitrite and nitrite salts have been reported[44]. Hydroxy carbonyl such as 2-keto-gluconate and methyl-2-ketogluconate can be used with nitrates and acidic alpha-hydroxy carbonyl compounds[45] such as ethyl-2-ketogluconate, methyl-2-ketogluconate, 2-ketogluconic acid and 2-ketogluconic acid can be used with nitrites. It has also been reported[46] that cured colour is improved by the inclusion of maleic acid or its salts together with nitrites.

Other important chemicals used in curing mixtures are phosphates. Their usefulness in increasing the water binding capacity has already been discussed. Phosphates favourably effect the cured meat colour[47] by decreasing the tendency of cut meat to lose its fresh pink colour when meat is washed or exposed to water. Phosphates are useful as antioxidants[48] particularly when combined with ascorbic acid[49]. Apparently these two agents provide a synergistic effect and so it helps in suppression of oxidation reactions which lead to loss of flavour, colour and rancidity. All treated phosphates do not provide protection against rancidity; while pyrotripoly and hexameta phosphates are effective ortho phosphate[18] salts are not.

Sugars are more commonly used in curing mixtures. It was believed that sugars were necessary for the reducing bacteria to grow but later it was proved to be unnecessary[50]. Sweetening which brings down the harshness, is the only effect. For enhancing or intensifying the flavour of cured meats; monosodium glutamate and hydrolysed proteins are in common use. It has been reported that glutamates[38,51] also help the formation of cured colours with ascorbic acid. This synergistic effect results from the amine content of the glutamate which further protects the liable ascorbic acid from oxidation and results in a more complete and rapid cure. Spices and various other seasonings are used in special products like sausages. Lately milk proteins and other vegetables are also being used in sausage preparations. When the former is used it is necessary that it should be calcium free and for this purpose. ion exchange resins column may be used.

(*iv*) *Penetration of curing salts*—As stated earlier, during first stage of curing, NO_2 developed is theoreticatlly sufficient[33] but penetration into meat is slow. In order to help penetration a device known as stitch pumping is developed. The meat is stitch pumped by means of a hollow perforated needle attached to a pump which provides the pickle under pressure[52]. In this manner the pickle is infused into the deep area where absorption of curing ingredients would otherwise take the longest time. A refinement of the above procedure is pumping of curing pickle in desired amounts into the vascular system of the piece of meat being cured[52,13] This provides a relatively uniformly dispersed cure, almost immediately, throughout the entire piece. The process is followed by the application of dry cure or immersion in pickle. Curing by this method drastically reduces the time required. A recent development[52,53] is an equipment in which stitch pumping of meats is done automatically by multiple needle or manifold heads, where the hollow perforated needles are spaced at relatively short distances (1–2 in.). Machines of this type have been developed for the pumping of bone-in-product the needles being retractably mounted. Such types of equipment have not only drastically cut the time taken for curing but enabled the use of chemical reducing agents as is mentioned earlier.

(*c*) *Spoilage and its control*

(*i*) *Microbial*—Spoilage[25] of cured meats occurs as : (1) a surface slime caused by micrococci producing off flavours, (2) greening caused by particular streptococci or lactobactlli. Spoilage of meat is greatly retarded by dipping it into an aquous solution of antibacterial and antifungal agents. As suggested by Pagans[54] *et al.* treatment with a solution containing chlorotetracycline-HC1 5–23 and mystatin 5–10 ppm for 1–2 hrs at 5°C reduces microbial counts to an appreciable extent. Use of sorbic acid[55] or its salts is also recommended. Growth of bacteria on the surface of meats can also be reduced[56] by scrubbing with HCHO solution.

(*ii*) *Cured, colour stability*—Main problem with cured meat products involves the colour stability of the finished cured pigment. Hornsey[57] estimated the stability of cured colour of light. According to him light catalyses fading by oxidation in presence of air or some other substance i.e. NO. Exposure to light, even when curing is done, not only results in immediate loss of colour but initiates continuing loss even when the sample is subsequently stored in the dark. Hashimoto *et al.*[58] studied oxidation of nitroso myoglobin. Its oxidation to metmyoglobin is accelerated by light. By the addition of reducing agent this could be prevented even in light. In further study[59] with cooked cured colour i.e. nitroso haemochrome was oxidised to the ferric hem compound, hematin. This was also completely inhibited by a reducing compound. Watts[60] found that the pink cured meat pigment i.e. ferrous NO haemochrome can be retained by maintaining SH groups. When destruction of the porphyrin ring occurs (greening reaction), the original pink colour cannot be regenerated by Na ascorbate or $NaNO_2$. Destruction can be retarded by an antioxidant in conjunction with a copper chelating agent. As has already been stated ascorbic acid alongwith phosphates prevents discolouration during storage. In case sodium erythrobate is used higher level of NO is helpful[42] in the stabilization of colour but in other study it has been shown that by reducing residual free NO through lactones better prevention of colour is achieved.

SMOKING

Subject of meat smoking process has been reviewed by Draudt[61]. Smoking of meat and fish is primarily meant to preserve them, and make them more palatable.

(a) *Smoke constituents and their role*

Smoke is a hetrogeneous and complex mixture of varied type of constituents-volatile and non-volatile. These are distributed between liquid droplets formed by condensation and the vapour phase according to the partition low. Smoke is produced by slow burning of saw dust or by some other means i.e. friction, fluidisation by hot air etc. This has the distillation as well as oxidation effect. Some of the formaldehyde, creosote, phenols and pyroligenous acids are distilled and cellulose, hemicellulose and lignin are oxidised. Some of the constituents react with each other leading to condensation and polymerisation. Spanyar[62—65] *et al.* determined components of smoke after absorbing in water and by condensing. The smoke was developed from 0·5 g. of saw dust in a closed apparatus in which the highest tempertures of smouldering saw dust and space were respectively 210–365°C and 180-250°C. They determined components of smoke from 6 types of hard wood (moisture 10·5–15·4%, ash 0·44–1·86%), spruce (moisture 10·7%, ash 0·29%), and pine (moisture 10·5%, ash 0·26%) respectively which are reproduced below :

TABLE 1

SMOKE COMPONENTS ($g/100g$ SAW DUST) IN DIFFERENT WOODS SMOKES

	6 hard woods	Spruce	Pine
Monocarbonyls	1·70– 2·50	3·06	3·10
Hydroxycarbonyls and dicarbonyls	1·86– 4·95	6·30	6·12
$HCHO$	0·11– 0·16	0·21	0·20
AcH	0·63– 0·88	1·15	1·10
Me_2CO	0·37– 0·47	0·69	0·54
Furfurol	0·18– 0·35	0·21	0·18
Alkali soluble reducing substances	4·56– 9·75	7·83	7·40
Reductone	0·13– 0·32	0·21	0·29
Dehydro-reductone	0·66– 2·16	2·10	1·80
Total acids	2·08– 6·79	3·07	3·17
Esters	6·69–10·47	8·08	11·16
Phenols	0·14– 0·36	0·29	0·29

pH values of the smokes vary from 3·8–4·8

They also reported that neither moisture content of saw dust nor the smouldering temperature range of 194–270°C to 365–436°C had significant effect on the above constituents of the smoke and that when the smoke flowed and cooled, the amounts of hydrocarbonyls, dicarbonyls, monocarbonyls, *AcH* and alkali soluble reducing substances decreased and at the same time secondary reactions involving polymerization of the above named constituents took place. They further analysed acids in the smoke by various analytical methods principally chromatographic and found 40% acetic acid and 30% formic acid. They also found malonic, succinic and various aromatic compounds; 18 of the last were separated and 6 identified as syringic acid, vanillinic acid, β-resorcylic acid, syringaldehyde, vanillin and ethyl vanillin. Johnsen[66] analysed condensate of saw dust containing 50% moisture by chromatographic methods and found that chief carbonyl was diacetyl and chief phenols were guaiacol and 2,6-dimethoxy-pyrogallol. Commins & Lindrey[67] earlier determined phenols in wood smoke and found that *O-m*-and *p* cresols, 1-and 2-naphthol and 3 isomeric dihydroxy benzines are present in γ amounts. They also suspected the presence of guaiacol and methyl ethers of the phenols.

Smoking greatly alters the appearance of the meat, adds rich brown colour to it and provides a protective coating, which is said to be due to resinous matters in smoke. Non-steam distillables of smoke constituents make it dark brown, but golden brown clour is desirable and can be attained by suitably scrubbing smoke with water before use. Heat of the smoke and some of the constituents mainly acids, have coagulating effect on proteins of the exterior of the product being processed. Heat of smoke also accelerates nitrate-nitrite action if the product is cured.

Flavour and other properties of smoked meats very much depend upon the type of smoke. Quality of smoke may vary with type of wood but it is believed that by the partial control of temperatures and rate of combustion and oxidation, quality of smoke can be controlled. The most desirable curing smoke[6,8] is produced within the range of 300–350°C. At lower temperature and with a severaly restricted air supply larger percentage of carboxylic acid is produced adversely affective flavour and odour characteristics. At generating temperature[8] above 350°C, more complete combustion results in less smoke being generated and in the increase of the level of undesirable polycyclic hydrocarbons. Formation of carcinogenic[69] compounds of smoke, benzopyrine and dibenzenthracene can be minimised by controlling temperature of smoke below 300°C or redistilling smoke components below 200°C.

Phenolic constituents of the smokes are responsible for bacteriostatic as well as antioxidant action of smokes. Flavours are mainly the contributions of acids, phenols and carboxyles. Ockerman *et al.*[70] isolated volatile compounds from dry cured hams and identified them by gas chromatography and infra-red spectroscopy. These compounds were as follows : formaldehyde, acetaldehyde, propionaldehyde, isobutyraldehyde, n-valeraldehyde, isovaleraldehyde, acetone, diacetyl, methyl ethyl ketone, formic acid, acetic acid, propionic acid, butyric acid, isocaproic acid. They did not find mercaptans. Ratio among the carbonyl compounds and volatile acids remained constant but 2-butanone increased and formic acid decreased. Total quantities of carbonyl derivatives and volatile acids increased with the aging period.

(*b*) *Mechanism of smoking*

According to studies by Foster *et al.*[71] smoke constituents are adsorbed from the vapour phase by the wet surface, but it is not advisable to surmise from a single observation. Any attempt to correlate effect of different physical or chemical phenomena with smoking will lead to confusion, more so when data available are meagre. Delezal[72] studied the effect of relative humidity on quality of smoked products and efficiency of smoking. He reported that increase in relative humidity (about 80%) enhances organoleptic acceptability of products, and reduces smoking time and heat losses. Micro-organism count of finished products was less while phenols content was increased. This might be due to better adsorption due to lesser rate of evaporation resulting in low intersticial flow of moisture. Another finding of Ziemba[73] is that intensive precipitation of smoke particles on vertical surfaces of products being smoked requires fine dispersion of smoke obtained by increasing the cirulation of air and keeping the humidity low. Probably increased circulation of air could give scrubbing action but effect of low humidity cannot be explained in terms of adsorption theory. It has also been reported by Tilgner & Piebizyk[74] that rate of deposition of the smoke on fish increases with the optical density of the smoke.

There is an interesting finding of Spanyar[64] and coworkers that smoke constituents precipitated in the smoke chamber decreased as the smoke temperature decreased from 80°C to 28°C; below this range specially at about 10°C, there was a marked reduction. The amount of precipitate on the smoke chamber walls is smaller than that on either natural or synthetic sausage casings. They have also reported that precipitations of smoke constituents and their penetration on natural and synthetic casing, meat, fat etc. vary and are characteristic for individual materials. This leads to the belief that apart from adsorption, deposition of smoke particles also takes place.

Foster[71] *et al.* have stressed upon the quality of smoked meat without mentioning the duration of smoking. The rate of smoking will be quicker with the deposition of smoke particles. This has been noticed in electrostatic method of smoking. Reports[75] that flavour of electrostatically smoked and conventionally smoked meats are similar may be because the volatile components are alike in both cases since the volatiles adsorbed from the gaseous phase and those present in particle phase will be almost similar. Difference may be in the non-volatiles which do not contribute towards flavours. As regards Foster & Simpson's finding[75] that water samples smoked at 55°C have similar amounts of volatile phenols but approximately three times the amount of non-volatiles compared with water exposed at 30°C, the explanation with regard to volatiles and non-volatiles present only in gaseous phase in respect to quantity adsorbed may not hold good as adsorption is a complex phenomena which will vary at different temperatures and from susbstance to substance. Particle phase may contain proportionately more non-volatiles than volatiles and this may be the probable reason that at higher temperature more of non-volatiles are deposited.

There is every possibility that smoke constituents react chemically with the substance smoked. According to Spanyar[62] *at al.* smoke deposition varies from substance to substance. Smoking removes the ammonia odour from the dog fish[76], related sharks and skates, containing upto 5% of urea which is easily converted into ammonia. Formaldehyde which is present in smoke combines chemically with ammonia. Patents of so called flavours which impart smoked meat flavour to the product are also reported. These are prepared[77] from the components of the destructive distillation of wood or distillation products of condensed smoke and amino acids such as cysteine.

(c) *Smoke generators*

Rasmussan and associates[78] evolved a friction type of smoke generator. The unit produces smoke through the abrasion created when a weighed wooden log is brought vertically into contact with a horizontal high speed rotating metal disc. Greater control of temperature, denseness and humidity of the smoke to the desired level is possible by this new type of smoke generator. Further this smoke contains 4 to 8 times more of steam volatile constituents including phenolic compounds. American Meat Institute Foundation[79] designed a smoke generator wherein the smoke produced is passed through expanded metal and washed with water from spray nozzle. This smoke had a distinct beneficial effect in the product. It has been reported that some people liked smoked products using this friction type of smoke generator while others liked products smoked using conventional type. Ways and means to suitably modify friction generated smoke are to be developed. Nicol[80] developed smoke generator in which destructive distillation of saw dust takes place in the form of fluidised bed in a stream of hot gas. Fluidisation of saw dust was achieved by reducing the moisture in it to about 20% which is passed through 20 mesh sieve. Conical shaped reactor is so devised as to keep under fluidisation long range of particles below 100 mesh as well as some fibres upto 1/2 in. long. Heated air is blown at a speed of 10 ft^3/min. and saw dust feed to reactor is regulated by special mechanism consisting of air jet and rotating worm at low speed. In the normal operations the work ing temperature is maintained at 350±5°C. By the use of this device saw dust consumption is decreased by 75%.

Simpson[81] has described an interesting two-stage laboratory smoke generator. In this blocks of wood are pyrolysed in a stream of inert gas maintained at temperature upto 450°C. This resulting smoke is partially oxidised in the second stage of the generator by mixing with controlled quality of heated air. With the apparatus it has been found that 3 : 4-benzopyrene and 1 : 2 : 5 : 6 dibenzanthracene are not formed if the temperatures in the first and second stages are not allowed to exceed 400°C and 375°C respectively. Fish smoked using this smoke was found to be only slightly less palatable as compared to fish smoked by traditional method.

(*d*) *Smoke kilns*

Need for smoke houses where temperature, humidity, circulation and denseness of smoke could be controlled was felt as early as 1942 by Cutting and Reay[76]. They developed smoke house in which temperature was controlled & smoke was uniformly distributed by circulation fans. Such smoke house was further improved[82]. A smoke house[83] siuitable for the small scale producer of smoked fish was also developed. Mixed with air, the smoke is sucked by a fan into a duct over the top of the kiln and propelled along it. It is then diverted vertically down one end of the kiln and through louvres to pass horizontally through the smoking chamber. At the other end of the smoking chamber the smoke is sucked by the fan through louvres and is partly recirculated. Thermostatically controlled heaters in the duct maintain the temperature of the smoke. For ease of handling, the fish are smoked on trolleys. Such type of smoke house usually met with the following difficulties[84] : (*i*) Inconvenience in the measurement and control of humidity. Because of tar accumulation on the wicks in the atmosphere of smoke it was difficult to measure and hence control humidity. This was removed by employing a special type of cloth for the wicke and preheating to dry bulb temperature the distilled water to be used as wetting agent; (*ii*) Lowering of the heating capacity of the coils resulted due to accumulation of tars. This could be avoided by the use of modified construction of coils, by the use of wide fin spacing and special material of construction which can withstand strong alkali cleaning agent; (*iii*) It was found that circulation fans, controlling ambient temperature (most critical variable in smoke house control), used to collect heavy accumulation of tars in the ducts-nozzles and housings which was amazingly fast. This could be avoided when axial-flow-elbow fan was used. All steel construction of the fan was able to withstand alkali washing; (*iv*) The fourth defect was that around exhaust fans fresh air used to enter changing ambient conditions. This could be removed by pressurising the chamber.

In a smoke house[85] there is no humidity control as there is no need of additional moisture. Smoke and temperature are uniformly distributed by the use of special squarrel-cage blowers with each heater and rotary dampers to dispense smoke evenly. Smoke is introduced into heaters between fans and heating coils. Blower was replaced by turbine type fans. Before introducing smoke into the house it is washed with water sump, to wash out tars.

Meat processors in different countries are now erecting[86,106] automatically controlled air conditioned smoke houses with improved uniformity of heat control. Internal temperatures of products are controlled within 2°C whereas in the old brick houses it was not uncommon to find variations from 10–30°C. One such smoke house can handle 7,000 pounds of bacon in 5 hrs., 9,000, pounds of ham in 10 hrs. and 6,00 pounds of baloney in 8 hrs. In such smoke houses both large and small franks can be processed at the same time with no variation in temperature. Ziemba[87] described two new, smoke-cook-cool processess for frankfurters which are continuous 'VISKING SYSTEM' and 'FRANK SYSTEM'. Former employs heated air for cooking and water sprays for chilling and later uses salt-sugar solutions for heating and chilling, after smoking in a chamber where smoke density is adjusted by visual inspection. This system is adaptable to any standard smoke generator. Low velocity smoke and heated air mixture raises the internal temperature of the products to 50°C. The smoking time is adjustable to fit product requirements. Based on measuring optical density of smoke an instrument for measuring and recording density was developed at Torry Research Station[88]. Portable smoke density meter[89] and smoke density integrator[90] have also been reported.

Various patents have been taken for methods of heating, ready-to-eat smoked items to the pasteurization temperature to destroy trichinosis worms and inactivate the enzymes contained in the meat. The control of temperature is very important. The meat which is taken out of the cooler after curing is brought to an external temperature of 60–70°C. In the intervening period the meat product undergoes a wide range of temperatures. During this time, the meat is at a temperture of 27–44°C which is favourable to bacterial growth. This is a very critical point. The temperature must rise above 44°C, so as to kill the bacteria which grow at a faster rate during this time lag. It is also necessary to control internal temperature of meat. According to Tilgner[91] internal meat temperature range should not exceed 76–82°C. Swartz & Stough[92] have taken a patent on a meat smoking process in which temperature of the smoking zone and the internal meat temperatures are continually monitored, with the former being maintained at 15–20°C above the latter. Union Carbide Corp[93] have devised a method of cooking sausages in a heated gas stream moving at 2,000 feet per minute. Salwski[94] has taken a patent for heating sausages by means of an electric current conducted through the sausage. A new and noval heating method[95] which has not yet found a wide spread application in the meat industry is the radio frequency heating, which ensures uniform heating simultaneously throughout the mass.

(*e*) *Electrostatic smoking*

When smoke particles are charged and meat is grounded, smoke is deposited on meats electrostatically. As a result, smoke is not dissipated, but goes directly to the grounded meat[96]. Smoke from the generator is passed through a charging grid having d. c. voltage of 100 kW. Hams or other products are passed on a conveyor at earth potential through the charged smoke particles, which collect on them. Sikoski[97] discussed the absorption and condensation of materials from the vapour in the smoking process. He also outlined parctical applications of elctrostatic procedures, in which the selective deposition of charged particles is enhanced. Gorelova *et al.*[98] determined 3, 4-benzopyrene in smoked fish by different methods and found that electrostatically smoked fish contained more 3, 4-benzopyrene than that prepared by the usual method. These carcinogens can be avoided by controlling the smoke generation. It has been reported[99] that smoked meat prepared by friction type generator is free of possible carcinogens.

Since electrostatic method of smoke curing is very quick, additional drying is necessary using infra-red lamps or other heat sources. The kiln developed by 'Industrienlagen W.E.B. Esfurter Matzerei & Speickerban[81], of Erfurt is typical, of the trend in kiln design. In this after passing through the predrying area, the fish is cooked between specially designed infra-red heaters mounted in front of aluminium reflectors and then passed into an electrostatic smoking chamber. The fish is subsequently chilled in the final section of the kiln and is ready for immediate packing. Experiments have indicated that in order to do efficient job of ionising or charging coating particles, a direct current voltage upto 100,000 volts is required. Equipment producing this must be relatively inexpensive, safe, fully reliable and also simple to operate. Electrostatic deposition requires very small currents and can be limited to amounts that are not dangerous. Power pack transforms normal line alternative current to a very high voltage and then rectifies it to direct current in a vacuum tube circuit.

Advantage of electrostatic smoking lies in the fact that there is a saving of labour through switch over from the batch to continous process, economy in the consumption of saw dust, convenience to control and uniform smoke deposition on the product. However, the increased prime cost and higher operating cost of electrostatic precipitation would, presumably, be expected to out weigh the above advantages. A technological analysis by Tilgner & Pietrzyk[100] regarding the smoking kiln operating on the Gdansk sea coast showed that the Torry type kiln was only marginally inferior to kilns fitted with electrostatic smoking facilities. Electrostatic smoke kilns are particularly suitable where labour charges are high and electricity is cheap.

(*f*) *Liquid smokes*

In the olden days products from destructive distillation of wood were used in the smoking of foods mainly to accelerate the smoking process, but this practice was discouraged, as firstly this was not able to impart desired keeping quality and often products were not bacteriologically pure and secondly it imparted to the product undesirable substances which were not allowed by the existing food laws. Recently the use of liquid smoke is progressively increasing as it simplifies the whole process. Aslo it is possible to eliminate carcinogenic compounds by suitable treatment. There are different methods of preparing liquid smoke : (*i*) Electro smoke solution[101]—Smoke from moist saw dust of broad leaf trees is passed through a cylindrical electrode. d.c. voltage of 100 kV. causes smoke and vapour to condense and fall into a well. Water is added and the soluble component dissolves to form an 8--10 Baume solution transparent and light brown in colour, which is very stable and has the flavour characteristics of smoked food. A 3-4 Baume dilution of this smoke solution with the adition of some salt, exerts high osmotic pressure on the immersed product and will cure even large fish in few hours, with high uniformity of penetration. ~~Canners can~~ smoke products quickly by putting small amounts of this liquid into cans of raw meat or fish before processing; (*ii*) Iwatare[102] absorbed concentrated extracts of dry distillate of wood with benzene on starch and gum arabic; (*iii*) In a method developed by Lapszin[103], smoke solution was obtained by extracting with water the condensate of products of wood gasification. Undesirable volatile materials were removed from the extract by beating to a specific gravity of 1·28—1·30 (final temperature 135-140°). Dilution with water (1 : 6-7) and filteration removed insoluble resins and carcinogens. Fish treated with this preparation had less aroma than that smoked in the conventional way. This could be corrected by adding 0·25–0·50% phenol and oxy-products extracted from a resin obtained by dry distillation of birels wood; (*iv*) Sokolov[104] obtained a liquid smoke which when added to sausage imparted a smoke flavour comparable to that obtained by normal smoking. The following steps were used. Drying of hard wood at 80–90° to 5% moisture dry pyrolysis of the wood and collection of the fractions, boiling within the range of 120–190° at atmospheric pressure or (for better quality) at 500-600 mm. *Hg*; (*v*) There are liquid smoke flavouring products in the market which are prepared using fractionated products from the condensed smoke or distillation of wood and reacting with amino acids such as cysteino.

Tilgner[105] presented a method of smoking meat products by immersion in liquid preparations followed by infra-red heating of the products. He stated that quality of liquid preparations depends on the relative composition of smoke constituents, which should be approximately that of common curing smokes used in gaseous state or erosol. Gorelova *et al.*[98] prepared liquid smoke from dry resinous products of wood distillation for fish smoking and were found to be free from or contained very little 3, 4-benzopyrene. Oils derived from dry wood distillation free from 3, 4-benzopyrene were used in the modified smoking processes. They imparted to the processed fish the desired flavour and other properties of ordinary smoked fish. Smoked fish processed by these substances contained considerably less 3, 4-benzopyrene than regularly smoked fish.

Lapshin[106] reported at the first international conference on smoking, the process of smoking by dipping or spraying which is extensively practised in the U.S.S.R. It was reported that the concentration at which the dip is applied to the fish is critical, absorption of the various smoked constituents being apparently a selective process. Fish cured by the dipping process were reported to contain substantially similar quantities as fish smoked by the traditional method and were claimed to be only slightly less palatable.

The favoured method of using the smoke concentrate involves three stages—dipping, drying and subsequent light traditional smoking to intensify the smoky flavour. Fish cured in this way were reported to gain a higher consumer acceptance than those cured either by the single dipping or by the traditional process. The smoke solution used is free from 3, 4—benzopyrene and the fish prepared by this method contained very little of this compound depending upon the length of contact with the smoke.

PRODUCTS

Some of the cured meat items available in the market are corned beef or mutton pastrami and peppered beef. Various types of Hams and Bacons are made from pork and various types of sausages mainly from pork but in some items beef is also mixed. While it is not possible to allot separate processing method for each product, as processing method varies from country to country and also with manufacturers, brief description of methods [107,108] of preparation are given :

Corned beef or mutton—After deboning of meat through coarse cutter in the form of long strips about 3/4 to 1″ thick, it is parboiled and fat and connective tissues are trimmed to avoid much gelatin in the can. Then the strips are coarsely cut and mixed thoroughly by mechanical means with curing ingredients in the form of slurry. This is filled into tappered cans with artificial head space introduced by inserting plunger into contents and vaccum sealed. Cans are retorted at 235–250°F and given a 'process' which amounts to incomplete sterilization but which in combination with the effect of the curing ingredients has proved to give a safe product of satisfactory life. Unilever Ltd. [109] has taken a patent for a curing method. When the curing salt is applied to the surface of sliced meat prior to packing in sealed air-impermeable containers for maturation.

Pastrami—Pastrami is usually made from the naval portion of the beef plate, which is cured, covered with pepper and spices and smoked after cooking.

Peppered beef—Peppered beef is usually made from the rounds, cured and smoked, ready-to-eat.

Hams from pork are marketted as number of types and varieties; these are cured by short term brines and then either markette d green (unprocessed), sweat pickled or smoked. Pork shoulders, picnics and buts are also available in these forms. Swee's pickles hams or green hams are subjected to ordinary air drying from 30 days to one year and marketted. They are to be parboiled before cooking. This type of a product is some times highly seasoned. For canning deboned hams are used which are shaped in a press and filled into open top cans of characteristic shape and double seamed under vacuum. Most canned hams are given a pasteurization heat treatment and marketted under refrigeration. More recently some heat sterilized canned hams are being marketted which can be held at ambient temperature. Smoked hams are seasoned by pepper or blended with berries etc. and smoked after aging or aged after smoking. A process for the preservation of smoked meats in which meat is placed in an evacuated flexible bag which is hermetically sealed and the product sterilized has been patented by Mol[110].

Bacon is produced from fat bellies, cured by long term brines and smoked. It is available as a slab, stick, or slice. Canadian bacon is made from fresh Canadian backs. It is sometimes smoked ready-to-eat or canned. A method for bacon preparation has been reported by Draudt & Marper[111] in which cured bellies are compressed while heating, smoked again compressed and chilled before slicing.

The word 'sausage' usually associated with fresh ground pork items[112] applies to a broad variety of products including bologna, wiencers, loaves, liverwurst scrapple etc. More than a hundred different kinds of sausages are offered. Three classes of sausages are marketted in the United States : (1) Raw compositions or more or less finely ground meat or vegetables; (2) Compositions with some foods partially heat treated or otherwise processed; (3) Fully processed sausage compositions that are intended to be 'ready-to-eat' vary in moisture content from about 15% in 'Land-jegget', 25% in 'dry salami' and 80% in 'head cheese'.

Sausage processing consists of grinding and blending the meat, seasoning it, stuffing shaping or molding it, adding a preservative and sometimes smoking it. Packaging of pork sausage in sheep intestines (generally for breakfast link sausage) and hog bun (for liver sausage) and the small intestines of the hog is widely used and has very excellent consumer acceptance.

During the past few years, there has been considerable market testing of synthetic casings[112]. Apart from uniform product, bacterial load in the synthetic casing is almost zero and it has an increased shelf life when compared with the well-handled sheep casing or hog casing.

Various plastic coatings are reported. Plastic casings[113] for meat products are formed from solutions of coagulable derivatives of dextran with a natural unhydrolysed dextran produced from unrefined sugar by means of dextran synthesizing leuconostor sources. A porous regenerated cellulose web[114] of improved wet strength comprising hemp bfire bounded together with a regenerated cellulose in an amount sufficent to maintain the porosity of the web is reported. Shiner *et al.*[115] have devised an improved method for producing cellulosic sausage casings by annular extrusion of solutions of regeneratable cellulose derivatives. Synthetic hardened[116] albumin meat casings are produced by adding a ketoaldehyde, preferably pyruvic aldehyde, to the fibrous albunin composition before shaping it.

Skinless sausages[117] have also been marketted, for example skinless weiners are made with an artificial casing which is peeled off after smoking, before the product is marketted. These products are excellent only when temperatures are rigidly controlled and bacteriological problems are well understood. Armour and Company[118] have patented a method for freeze drying process for preparation of storage stable sausage meat compositon. These sausage skins[119] can be made of copolymers of ethylene and iso-olefins, exemplified by isobutylene. For skinless sausage and similar meat products an antiseptic and impact resistant coating of hydrophilic sugar esters such as glycerol monostearate, sorbitol monopalmitate, glycerol mono-oleate or the like has also been reported[120].

CONCLUSION

Though considerable progress has been made in the field of smoking and curing of meat, yet many questions need to be satisfactorily answered. What are the smoke components? What is the role of ascorbic acid, lactones and other similar compounds in curing and preservation of cured colonies? What are the effects of smoking? What is the mechanism of smoking? What is responsible for smoked meat flavours? What is the degree of success in the use of liquid smokes currently coming in the market? Various processes in the manufacture of smoked and cured products are streamlined. But satisfactory methods of regulating smoke density in the smoke house are yet to be developed Also, we have to see whether products cured synthetically by chemical and mechanica. means, without time being allowed for maturation shall completely replace the traditionally cured meats. Improved methods of heating in the smoking operation, using radio frequency and accelerated freeze drying methods for drying them are to be worked out. Suitable flexible packaging and coating materials are to be developed for the light weight packs which are convenient to carry. The packaging and/or coating materials should be able to prevent oxygen permeability and moisture vapour transmission and be preferably transparent, stiff and durable. Such type of packed products specially ready-to-eat items useful for the fighting army and packaged products suitable for tropical climate which can be stored at ambient temperatures should be developed for the needs of this country.

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