Innovative technologies for the quality improvement of buffalo meat

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Summary

Buffalo meat has great potential to provide nutritional security to a considerable population of the world. Salient characteristics of buffalo meat make it more suitable for processing into meat products. Tenderization technologies for spent buffalo meat will find more utility among the consumers. Domestic refrigeration and freezing significantly improves the texture, juiciness and aroma of buffalo meat. High voltage stimulation significantly increases myofibrillar fragmentation. Preblending with antioxidants extends shelf life of ground buffalo meat. Vacuum packaging enhances ageing related changes in myofibrils. Nisin significantly inhibits the growth of Listeria monocytogenes. Ginger and cucumis improve the tenderness. NaCl and tetra sodium pyrophosphate significantly increase emulsifying capacity and decrease cooking loss. Acetic: lactic acid combination can be used as decontaminant and preservative. Irradiation inhibits Pseudomonas and Enterobacteriaceae. Pressure treatment decreases contribution of connective tissue to toughness. These innovations will greatly improve buffalo meat quality for sustaining production and utilization.

Keywords:*Buffalo meat, quality, chilling, freezing, electrical stimulation, antioxidants, enzymes, food additives, high pressure, packaging, irradiation*

Introduction

Buffalo, a triple purpose breed of bovine family is popularly known as 'black diamond'. It has potential to produce high grade meat and meat products. There are 171.93 million numbers of buffaloes in the world. It accounts 11.30% of the total population of cattle and buffaloes. The total buffalo meat production in the world is 7.10 million tons contributing 2.73% total meat production in the world (FAO, 2007). Buffalo meat has great export potential and contributes to the foreign exchange revenue of the exporting countries.

Most of the buffaloes are slaughtered at the end of their productive or working life and therefore, the meat is dark, coarse and tough. Nowadays, with changes in living standards and food consumption pattern, consumers demand quality meat with more emphasis on tenderness which is often not obtained from the aged and spent animals. As a consequence, majority of the meat is losing its popularity and demand. Some quantity of meat produced is used for the development of various comminuted meat products. A practical method for improving tenderness of such meat to an acceptable level would definitely increase retail value and marketing opportunities.

Buffalo meat has increased tenderness compared to beef owing to its higher calpain activity in early postmortem (Neath et al., 2007). Various post-mortem treatments can appreciably improve tenderness and other market- oriented quality attributes of meat. Prolonged storage of buffalo meat in refrigerators significantly increased the tenderness (Kandeepan & Biswas, 2005). Plate frozen meat samples scored high in texture, juiciness and aroma (Syed Ziauddin et al., 1993).

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High voltage stimulation significantly decreases cohesiveness, increases myofibrillar fragmentation (Soares & Arêas, 1995). Preblending with sodium ascorbate, alpha tocopherol acetate and carnosine extended the shelf life of ground buffalo meat up to 8 days under refrigerated storage (Sahoo & Anjaneyulu, 1997a&b; Das, Anjaneyulu & Biswas, 2006). Vacuum packaging enhances ageing - related changes in myofibrils (Sekar et al., 2006). Increasing concentration of nisin at low temperature storage significantly inhibited the growth of *L. monocytogenes* in buffalo meat mince (Pawar et al., 2000). Ginger and cucumis can be used as an effective alternative to papain for improving the tenderness of buffalo meat (Naveena, Mendiratta & Anjaneyulu, 2004). Treatment of buffalo meat with NaCl and tetra sodium pyrophosphate significantly increased pH, water holding capacity, emulsifying capacity and decreased cooking loss (Anjaneyulu, Sharma & Kondaiah, 1989). 3% acetic: lactic acid combination can be used as decontaminant and preservative without affecting the colour and odour of buffalo meat (Surve et al., 1991). Irradiated meat was completely free of *Pseudomonas* spp. and *Enterobacteriaceae* throughout storage (Naik et al., 1994). High pressure treatment decreased the connective tissue contribution to toughness of buffalo meat (Robertson et al., 1984). Blade tenderization can markedly improve the palatable characteristics of buffalo rumen meat (Anna Anandh et al., 2008).

The type of technologies used has distinct effects on various physicochemical, functional, microbiological and sensory quality parameters of buffalo meat. This has direct implication on the acceptability and marketability of the buffalo meat and meat products.

Domestic refrigeration

To adjust to a fast growing lifestyle of urbanization, people hardly find time to purchase meat daily. Hence they purchase meat in bulk to meet their equirements. This meat is stored igerator and consumed in defintervals. Refrigerator preserved undergoes various physicochemistological, microbiological and y changes that may affect the quality. The deterioration of meat in refrigerator storage may have mpact on consumers' health.

7 day freezer stored buffalo meat d a pH much lower than the 7 iller stored meat (Kondaiah et 36; Kandeepan & Biswas, 2007a). creased significantly with pro- freezer storage due to the fact eat undergoes autolysis result- decrease in extract release volERV) and water holding capacity with increase in pH (Strange et 77). Chilling resulted in poorer than with freezing. The loss of in prolonged storage of meat e due to the rate in post mortem , ice crystal formation, high ionic th, protein denaturation, drip nd above all, the bulk of meat and capacity of refrigeration faawrie, 1998).

of freshly slaughtered buffalo was significantly higher than of meat (Kandeepan & Biswas,). The significantly ($P< 0.05$) lower in chiller may be due to a comely higher pH, total plate count creased thiobarbituric acid value ge et al., 1977). TBA value of fresh meat was significantly lower f chiller and freezer stored meat t al., 1988; Kandeepan & Biswas,). The higher TBA value was attributed to oxygen permeof the packaged meat leading to xidation.

increase in tyrosine value duriller and freezer storage may be ted mainly to intrinsic (autolysis) es in meat and partly to bacteion. 4 days chiller stored buffalo showed a significant chilling loss eepan & Biswas, 2007a). On the day, the frozen (-10 ± 1°C) buffalo meat showed a significant drip loss. This marked increase in drip during prolonged days of storage was due to shortening of the sarcomere, increased enzyme activity, degree of fibre distribution and translocation of water (Ramsbottom & Koonz, 1939).

Moisture content of the freshly slaughtered buffalo meat was higher than of chiller and freezer stored meat, but a slight difference was observed between 4 days chiller and freezer stored meat (Kandeepan & Biswas, 2007a). The loss in moisture during refrigeration was due to evaporation of moisture from meat in chiller (Arief et al., 1989). It was due to sublimation of surface water of meat to colder surfaces in vicinity of the freezer (Taylor et al., 1990).

Buffalo meat stored for 4 days in chiller (4±1°C) showed a significantly lower protein content than freezer (-10±1°C) stored meat (Kandeepan & Biswas, 2007a). The lower protein content of chilled meat might be due to increased microbial growth resulted from higher water activity (a_w) and enzymatic autolysis (Rao et al., 1998). This significant loss in later days of frozen storage might be a result of ice formation raising the solute concentration in the tissue.

During preservation by domestic refrigeration (chilling and freezing) total lipid content of the buffalo meat decreased with the increase in storage period (Kandeepan & Biswas, 2007a). A marked difference in chiller might be attributed to exposure of strong light, as in display cabinets, which accelerated oxidation of fats causing discolouration. Lipid oxidation occurred during freezer storage of meat was mainly due to losses in triglyceride fraction.

The chiller storage increased but freezer decreased the microbial counts. The values of odour and flavour scores decreased, but texture, tenderness and juiciness scores increased significantly during prolonged storage. Chiller stor-

age showed shrinkage and kinking of muscle fibres. Contrastingly, freezer showed separation of muscle fibres, transverse breaks and different configuration of structural damages due to ice crystal formations (Kandeepan, Biswas & Porteen, 2006). Sixty days of frozen meat increased some of the sensory parameters of buffalo meat. A storage period up to 4 days in chiller (4±1°C) and 30 days in freezer (-10±1°C) would satisfactorily maintain the buffalo meat quality (Kandeepan & Biswas, 2007b).

During the delayed chilling (2-3°C, 18 h), the muscle pH decreased to 6.0 (from the initial value of 6.5) in 3 h, whereas it took 5-6 h in direct chilling (2-3°C, 24 h). The reduction in Instron firmness values was 10.3-33.6% and in cohesiveness values that was 13.2-22.2% in delayed chilled muscles compared to direct chilled ones (Rathina Raj et al., 2000). This significant ($P \leq 0.001$) observation indicated a definite improvement in the texture quality of muscles subjected to delayed chilling. However, no definite trend was observed in the values of elasticity, cooking loss and water holding capacity of muscles due to direct or delayed chilling.

Industrial freezing

Frozen storage life is influenced by packaging, storage temperature, relative humidity, moisture loss during freezing and variation in the products themselves. Susceptibility to oxidative rancidity is a major determinant of effective storage life. Another determinant is the degree of processing, chopping or grinding. Each one reduces effective storage life, almost certainly by increasing cellular damage and increasing the surface area exposed to the deleterious effects of oxygen.

A marginal increase in pH values and drip losses were observed in buffalo meat frozen by plate and blast freezing, stored at −15 ± 3°C for 3 months (Syed Ziauddin et al., 1993). Drip losses were lower in blast frozen samples. WHC, cooking losses, thermal shrinkage and Warner Bratzler shear values indicated inconsistent results during storage. Similar observations were recorded with regard to tyrosine and TBA values. No significant differences in the physicochemical characteristics were observed between meat cuts and minced meat. Plate frozen meat samples scored higher for texture, juiciness and aroma. Both the plate and blast frozen meat samples, however, were similar in overall quality according to taste panel results.

Electrical stimulation

Among different methods, electrical stimulation has received considerable attention and proved most effective for improving quality of meat in the last few decades. Electrical stimulation (ES) produced tenderization of different carcasses by causing early onset of rigor, increasing rate of pH and glycogen decline, thereby preventing cold shortening induced toughness (Hwang, Devine & Hopkins, 2003). Moreover, ES provides commercial advantage by reducing ageing time, guaranteeing greater improvement of quality and palatability characteristics.

Low voltage (330V, 50Hz & 10 pulses/sec) electrical stimulation was found effective in improving majority of important carabeef quality characteristics (Biswas et al., 2007). High voltage electrical stimulation (700 *V*, 1400 *V* peak, pulses 1 *s* on/1 *s* off, 60 *Hz*, 2 *A*) on buffalo carcasses resulted in a significantly more rapid pH fall in *Longissimus dorsi thoracis* muscle when compared to non stimulated controls ($p < 0.01$), during the first 24 *h* after slaughter (Soares & Arêas, 1995). The *IMP/ATP* ratio on the same period showed a much more rapid increase for the stimulated muscles (1.07 and 1.16 at times 1 and 2.5 *h post mortem* vs. control values of 0.77 and 0.83, respectively). Sensory and instrumental evaluation of texture of meat cooled by two distinct processes showed that tenderness at 24 *h post mortem* was higher in the stimulated muscles compared to non-stimulated controls, irrespective of the cooling process adopted. High voltage stimulation significantly decreases cohesiveness, increases myofibril fragmentation. SDS polyacrylamide gel electrophoresis of the myofibrillar proteins showed a weakening of Troponin T band during 6 *days* of ageing in non-stimulated control muscles, whereas electrical stimulation accelerated the process of ageing over 3 days.

Electrical stimulation significantly lowered the moisture percentage between 24 and 48 hrs in all the treated groups (Biswas et al., 2007). A lower moisture percentage was observed in the stimulated group (72.8%) in comparison to the non-stimulated control group (74.2%) of beef carcasses (Cross & Tennent, 1980). It might be due to elevation of muscle temperature after stimulation (Bendall, 1980). Increased temperature causes evaporation and reduces ability of the muscle to retain water to a certain extent, resulting in some loss of fluid from muscle. There was a non-significant reduction of protein content in electrically stimulated carabeef (Mckeith et al., 1980). But high voltage (550 and 1100) ES reduced the protein content of carabeef. This might be due to denaturation and hydrolysis of myofibrillar and lysosomal structures. Fat percentage significantly decreased in carabeef cuts after electrical stimulation (Biswas et al., 2007). A clear decrease of raw fat percentage in electrically stimulated beef *Longissimus dorsi* muscle was noted (Cross & Tennent, 1980).

Water holding capacity and pH decreased significantly in carabeef cuts after electrical stimulation (Hwang & Thompson, 2001). Electrical stimulation effectively accelerated post-mortem glycolysis as evidenced by low pH values at 24 and 48 hours post-mortem (Biswas et al, 2007). The condition of low pH and high temperature in post-mortem muscle reduce WHC of the meat, an effect attributed to denaturation of muscle proteins, particularly myosin. Electrical stimulation contributes to low WHC by accelerating pH decline, though the magnitude of effect depends on chilling rate (Strydom et al., 2005).

Fibre diameter is one of the most widely used and reliable indicators of tenderness. Fibre diameter significantly decreased in carabeef cuts following electrical stimulation (Biswas et al., 2007). The decrease of fibre diameter in electrically stimulated carabeef may be due to the occurrence of massive contracture bands created as a result of damage to membrane of sarcoplasmic reticulum and local leaks of calcium ions in electrically stimulated muscles (Will et al., 1980). The measure of sarcomere length is also related to tenderness. Sarcomere length significantly increased in electrically stimulated sides of carabeef carcass (Biswas et al., 2007). This increase in sarcomere length on electrical stimulation might be due to the fact that electrical stimulation causes stretching and tearing of myofibrils preventing occurrence of cold shortening.

The hydroxyproline content significantly decreased in electrically stimulated carabeef cuts (Biswas et al., 2007). This might be due to the diminution of collagen content in electrically stimulated meat. Furthermore, hydroxyproline or collagen is thermolabile and undergoes the process of gelation resulting in increased tenderness. ES increases the muscle temperature as high as 35°C compared to 23°C for similar non-stimulated sides (Bendall, 1976).

Electrical stimulation of buffalo carcasses significantly improved sensory tenderness scores. An average 50% increase in tenderness in electrically stimulated sides compared to non-stimulated sides was observed (Smith, 1985). The tenderness improvement of more than 32% was observed in electrically stimulated carcasses (Biswas et al., 2007). In general, electrical stimulation is desirable as meat becomes tender at an earlier stage. Similar tenderness in non-stimulated muscle may only be reached with prolonged ageing. ES had a deleterious effect on either bacteria themselves or on meat as a growth medium (Biswas et al., 2007). A significant decrease in bacterial number due to ES was observed (Contreras & Harrison, 1981). It was concluded that electrically stimulated carcasses would have slightly longer case-life than retail cuts from non-stimulated carcasses (Smith, 1985).

Antioxidants

Meat becomes rancid and browns more rapidly due to pigment and lipid oxidation. It leads to degradation of lipid and protein along with deterioration of flavour, texture and nutritive values.

Ground buffalo meat containing 500 ppm sodium ascorbate had significantly higher pH, visual colour and odour, lovibond tintometer red colour units and chroma, lower cooking loss, metmyoglobin content and TBARS number (Sahoo & Anjaneyulu, 1997a). TBARS number was highly correlated with metmyoglobin and inversely with odour score; visual colour was negatively correlated with metmyoglobin, aerobic mesophilic count and psychrotrophic plate count. Sodium ascorbate at 500 ppm was found to be optimum level for preblending which extended shelf life of ground buffalo meat from 4 to 8 days under refrigerated storage.

Ground buffalo meat containing 10 ppm tocopherol acetate had significantly extended desired visual colour and odour, higher LTCU 'R' and chroma, lower cooking loss, metmyoglobin content and TBARS. Use of 10 ppm tocopherol acetate for preblending extended the shelf life of ground buffalo meat from 6 to 8 days under refrigerated storage (Sahoo & Anjaneyulu, 1997b).

Buffalo meat samples containing 1.0% and 1.5% carnosine significantly inhibited metmyoglobin formation and brown colour development. Carnosine improved meat pH and water-holding capacity and lowered cooking loss and 2-thiobarbituric acid-reacting substances values. It also improved desired visual colour, odour, higher LTCU 'R' and chroma of meat samples. Use of 1.0% carnosine for preblending extended the shelf life of ground buffalo meat up to 8 days under refrigerated storage (Das, Anjaneyulu & Biswas, 2006).

Enzymes

Antilisterial activity of nisin (Nisaplin), alone at concentrations of 400 and 800 IU/g and in combination with 2% sodium chloride was incorporated in raw buffalo meat mince. Samples of the raw meat mince were inoculated with 10^3 colony forming units (cfu)/g of *L. monocytogenes* and stored at 4°C for 16 days and at 37°C for 36 h. Initial estimates of pH, extract release volume, mesophilic and psychrophilic counts were found to be 5.74, 48 ml, 3.5×10^5 and 1.0×10^5 cfu/g of meat, respectively (Pawar et al., 2000). The growth of *L. monocytogenes* in the treated groups was significantly ($P<0.05$) inhibited compared to the control group. The degree of inhibition increased with increasing concentration of nisin and decreasing storage temperature. Addition of 2% sodium chloride in combination with nisin increased the efficacy of nisin at both storage temperatures. The pH in the treated groups remained significantly lower ($P<0.01$) than in the control groups at both 4 and 37°C.

A method was developed for improving tenderness and overall qualities of tough buffalo meat using plant proteolytic enzymes from *Cucumis trigonus Roxb* (Kachri) and *Zingiber officinale roscoe* (Ginger rhizome). Their tenderizing efficacy was compared with the most popular enzyme papain (Naveena, Mendiratta & Anjaneyulu, 2004). 3 × 3 × 3 cm chunks from *Biceps femoris* muscles of spent Murrah buffaloes (4-5 years age) were marinated with distilled water (control), 2% (w/w)

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powdered cucumis extract, 5% (w/v) ginger extract or 0.2% (w/w) papain for 48 h at 4 °C and subjected to various physicochemical, histological and sensory evaluations. An increase ($p<0.01$) in collagen solubility, sarcoplasmic and myofibrillar protein solubility and reduction ($p<0.01$) in shear force values were observed in all enzyme treated samples compared to control. Electrophoretic pattern of muscle proteins also revealed extensive proteolysis and reduction in number of protein bands in all treated samples. Improvement ($p<0.01$) in flavor, juiciness, tenderness and overall acceptability scores were observed in all enzyme treated samples compared to controls. Ginger extract treated meat samples received better scores for appearance, flavor, tenderness and overall acceptability. From these results, it was shown that ginger and cucumis can be used as an effective alternative to papain.

Food additives

A study was conducted on the effect on certain quality parameters of adding sodium chloride (2·5%) and tetrasodium pyrophosphate (1%) to hot minced buffalo meat (Kondaiah et al., 1985). The effects on buffalo meat were observed in chilled and frozen conditions. These treatments significantly increased pH, water-holding capacity (WHC) and emulsifying capacity (EC) and decreased cooking loss. Chilled and frozen conditions did not affect buffalo meat quality. Salt additions had a greater effect in improving EC of buffalo meat. Significant correlations were observed among quality parameters.

The effects of sodium pyrophosphate (SPP), sodium tripolyphosphate (STPP), sodium hexametaphosphate (SHMP), sodium acid pyrophosphate (SAPP) and their blends at different levels (0·3, 0·5 and 0·7%), along with 2% sodium chloride on certain quality parameters of buffalo meat were evaluated (Anjaneyulu, Sharma & Kondaiah ,1989). The SPP, STPP and phosphate blends significantly increased pH, water holding capacity, emulsifying capacity, extractability of salt soluble proteins and colour of ground meat. Compared to these phosphates, SAPP and SHMP had significantly poorer effects on improving the quality of meat. The order of effectiveness of phosphates was SPP > STPP > SHMP. A phosphate blend consisting of 65% sodium pyrophosphate, 17·5% sodium tripolyphosphate and 17·5% sodium acid pyrophosphate was equally effective as that of sodium pyrophosphate in improving the functionality of hot and chilled buffalo meat and had the advantage of reducing the amount of sodium by 3%.

Silverside of buffalo was cut in 15 equal sized steaks and divided into five groups, each group containing three steaks. The steaks from groups 1, 2, 3 and 4 were treated with 1, 2, 3 and 4% acetic: lactic acid combinations, respectively, and the fifth group was kept as a control. Similar treatments were also given with acetic: propionic acid mixtures. The microbial analysis and changes in colour and odour were noted at 0, 24, 72 and 168 h (Surve et al., 1991). The bacteriostatic and bacteriocidal action of the acid mixtures increased with increasing concentration but the effect was reduced as the time advanced. Both acid mixtures had pronounced antibacterial effect on gram negative organisms than gram positive ones. The 3% acetic: lactic acid combination showed reduction in bacterial numbers without affecting the colour and odour of buffalo meat and is recommended for decontamination and preservation of meat for up to seven days at refrigeration temperature (7 ± 1°C).

Buffalo meat steaks dipped in distilled water (control), lactic acid (LA), LA + clove oil (clove), or LA + clove + vitamin C (Vit C) were displayed at 4 ± 1 °C, illuminated by a standard fluorescent lamp. The pH, 2-thiobarbituric acid reactive substances (TBARS), instrumental colour (CIE L^*, a^*, b^*), aerobic plate counts (APC), psychrotrophic counts (PC), coliform counts and sensory colour and odour were determined up to 12 days of display at 3 days interval (Naveena et al., 2006). Results showed that, all the treatments had significantly ($P < 0.05$) reduced the TBARS values compared to control. Among treatments, use of LA + clove has exhibited significantly ($P < 0.05$) lowest TBARS values throughout display period than others. Buffalo meat steaks treated with either LA + clove or LA + clove + Vit C had significantly ($P < 0.05$) lower APC, PC and coliform counts than control or LA treated samples. LA + clove + Vit C treated samples maintained significantly ($P < 0.05$) higher a^* and b^* values during display as well as the improvement in sensory colour and odour than others. The treatment with either LA + clove or LA + clove + Vit C extended the display life of buffalo meat steaks at 4 ± 1 °C. There was a significant advantage to using LA + clove or LA + clove + Vit C over LA alone.

High pressure treatment

A pressure heat treatment, which disrupts the myofibrillar structure of meat but leaves the connective tissues essentially intact, was used to compare the connective tissue component of toughness in the *Semimembranosus* and *Longissimus dorsi* muscles from nine Brahman cross and nine buffalo steers, 24 to 29 months of age (Robertson et al., 1984). In non pressure heat treated samples, the only breed difference detected was in peak minus initial yield force value, which was significantly lower for the beef *Semimembranosus* muscles. However, for the pressure heat treated samples of muscles, peak force and peak minus initial yield force values were significantly lower for beef than for buffalo. The pressure heat treatment could thus be used to detect differences in the contribution of connective tissue to toughness which would otherwise be obscured by the differences in the myofibrillar toughness.

The effect of broiling and pressure cooking as well as alterations during refrigerated (4°C) and frozen (–10°C) storage on the phospholipids of adult male buffalo muscles viz. *Triceps brachii* (TB), *Longissimus dorsi* (LD) and *Biceps femoris* (BF), i.e. from three different locations were studied (Kesava Rao & Kowale, 1991). Muscles differed significantly in their total lipid and phospholipid content. Cooking methods significantly altered the total phospholipid content and its fractions. Storage period did not show any significant effect on total phospholipids during refrigerated and frozen storage. Whereas certain phospholipid classes viz. lysophosphatidyl choline and lysophosphatidyl ethanolamine + sphingomyelin increased significantly and major phospholipid classes viz. phosphatidyl choline and phosphatidyl ethanolamine decreased significantly. The changes in phospholipid classes were similar both in refrigerated and frozen samples but relatively more pronounced in the former. Palmitic, stearic, oleic and linoleic acids were the four predominant fatty acids in the phospholipids of buffalo meat. Heat processing significantly increased the total saturates in TB and LD muscles while it decreased in BF. The total monounsaturated and total polyunsaturated fatty acids of phospholipids decreased during refrigerated and frozen storage indicated by a significant decrease in oleic, linoleic and arachidonic acids.

Total lipid, cholesterol, free fatty acid, glycolipid and glyceride contents increased significantly during the cooking of meat but did not show any significant changes during either refrigerated or frozen storage except for free fatty acid content which showed an increase (Kesava Rao et al., 1996). The TBA values also increased during storage but not to the extent of indicating rancidity. Cholesterol oxidation products separated by thin layer chromatography were cholestanetriol, 7-α-hydroxycholesterol, 19-hydroxycholesterol, 7-ketocholesterol, cholesterol-α-epoxide, cholesterol-β-epoxide and an unidentified fraction. All these fractions, except for the unidentified fraction, increased on cooking and storage. The cholesterol-β-epoxide fraction was resistant to changes. Changes in broiled meat were more pronounced compared to pressure cooked meat. Frozen storage did not prevent the development of cholesterol oxidation products in buffalo meat.

Muscle LD had significantly higher total lipid content than TB and BF (Kesava Rao et al., 1992). Muscles differed significantly in their esterified cholesterol contents. Heat processing increased total lipids, cholesterol, Monoglycerides (MG), Diglycerides (DG) and Triglycerides (TG) contents of all the buffalo muscles studied. Total cholesterol contents remained unchanged during refrigerated and frozen storage. However, EC, MG, DG and TG contents declined during storage. The influence of anatomical locations on fatty acid composition of neutral lipids was observed. The ratio of unsaturated to saturated fatty acids increased due to cooking.

Packaging

Storage life of chilled product is increased through the use of systems that provide an oxygen free environment within the package. Both vacuum and carbon dioxide packaging systems demand packaging materials with high oxygen and carbon dioxide barrier properties. Under anoxic conditions meat becomes purple red which is unattractive to most retail consumers. Consequently retail display packaging systems must provide an aerobic environment to allow the meat to bloom.

The effect of modified atmosphere packaging of buffalo meat on the structural parameters viz., fibre diameter, sarcomere length and myofibrillar fragmentation index and physical parameters viz., pH, drip loss and colour scores were studied (Sekar et al., 2006). The buffalo meat was packed under aerobic, vacuum and modified atmosphere (80% oxygen + 20% carbon dioxide) and stored at 4 ± 1 °C up to 21 days. The results revealed that vacuum packed buffalo meat had the lowest fibre diameter and myofibrillar fragmentation index and the highest sarcomere length, vacuum thus appear to enhance ageing. Buffalo meat packed in modified atmosphere had a low drip loss and a desirable colour. The modified atmosphere packed and vacuum packed buffalo meat was acceptable for up to 14 days at 4 ± 1 °C.

Radiation

Ionizing radiation has the ability to penetrate into the depth of meat. Through physical effects, they interact with the atoms and molecules that make up the meat and also those of meat contaminants such as bacteria, molds, yeast and insects causing chemical and biological consequences that can be utilized in beneficial ways. Although ionizing radiation frequently is referred to as high energy radiation, the total quantity of energy needed to secure the beneficial effects with muscle foods is relatively small and changes in meat or food that could affect its acceptability usually do not occur. Most importantly, there are no residues remaining after the process is complete.

The effect of low dose irradiation on the microbiological, chemical and sensory qualities of fresh buffalo meat stored at 0-3°C was studied (Naik et al., 1994). Meat slices packed in polyethylene bags subjected to 2·5 kGy dose had a shelf life of 4 weeks with acceptable sensory score, low total volatile basic nitrogen values and remarkable improvement in microbiological quality. Irradiated meat was completely free of *Pseudomonas* spp. and *Enterobacteriaceae* throughout storage. In contrast, the non irradiated control meat spoiled within 2 weeks.

Conclusions

Many of the technologies have been highly successful at the experimental level producing improved buffalo meat quality. The application of these inno-

vations in the meat industry has a great consequence improving buffalo meat safety and quality which can enhance revenue generation from this trade. Conservation of post harvest losses of buffalo meat and proper utilization for the development of meat products will be a prudent measure to contain the ominous nutritional insecurity in the world.

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Inovativne tehnlogoije u poboljšavanju kvalitete bivoljeg mesa

Sažetak

Bivolje meso ima veliki potencijal u osiguravanju nutritivne sigurnosti značajnom dijelu svjetske populacije. Glavne karakteristike bivoljeg mesa ga čine prikladnijim za preradu u mesne proizvode. Tehnologije omekšavanja bivoljeg mesa će biti od veće koristi potrošačima. Čuvanje u hladnjaku i zamrzavanje značajno poboljšavaju teksturu, sočnost i aromu bivoljeg mesa. Visokovoltažna stimulacija značajno povećava miofibrilarnu fragmentaciju. Dodavanje antioksidanata pri miješanju produžuje vijek trajanja mljevenog bivoljeg mesa. Vakuumsko pakiranje je dobro pri promjenama vezanim uz starenje miofibrila. Nizin značajno sprječava rast bakterije Listeria monocytogenes. Đumbir i krastavac poboljšavaju mekoću. NaCl i tetra sodium pyrophosphate značajno povećavaju emulzijski kapacitet i smanjuju gubitke tijekom kuhanja. Acetični: kombinacija mliječne kiseline se može koristiti kao dekontaminant i konzervans. Iradijacija sprječava razvoj bakterija Pseudomonas i Enterobacteriaceae. Obrada visokim tlakom smanjuje doprinos vezivnog tkiva na žilavost. Ove inovacije će uvelike povećati kvalitetu bivoljeg mesa za održivu proizvodnju i iskoristivost.

Ključne riječi: *bivolje meso, kvaliteta, hlađenje, zamrzavanje, električna stimulacija, antioksidansi, enzimi, aditivi, visoki tlak, pakiranje, iradijacija*

Innovative Technologien bei der Qualitätsverbesserung von Büffelfleisch

Zusammenfassung

Büffelfleisch hat einen großen Potential bei der Versicherung der nutritiven Sicherheit für einen bedeutenden Teil der Weltpopulation. Die Hauptcharakteristiken des Büffelfleisches machen es geeignet für die Verarbeitung zu Fleischerzeugnissen. Die Technologie des Büffelfleischerweichens wird zu Nutzen der Verbraucher sein. Das Aufbewahren im Kühlschrank und das Einfrieren verbessern bedeutend Textur, Saftigkeit und Aroma des Büffelfleisches. Die Hochvoltstimulation vergrößert bedeutend die myofibrillare Fragmentation. Durch die Zugabe von Antioxydanten bei der Mischung wird die Dauerzeit des gehackten Büffelfleisches verlängert. Die Vakuumverpackung ist gut bei der Veränderungen gebunden mit dem Altern von Myofbrill. Nisin verhindert bedeutend den Wuchs von Bakterie Listeria monocytogenes. Ingwer und Gurken verbessern die Weichheit. NaCl und Tetra sodium pyrophosphate vergrößern bedeuend die Emulsionskapazität und vermindern die Verluste während des Kochens. Acetisch: die Kombination der Milchsäure kann als Dekontaminant und Konservans benutzt werden. Iradiation verhindert die Entwicklung der Bakerie Pseudomonas und Enterobacteriaceae. Die Behandlung mit Hochdruck vermindert den Beitrag des Bindegewebes zur Zähigkeit. Diese Innovationen werden sehr die Qualität des Büffelfleisches für die Erhaltung der Herstellung und Nutzbarkeit vergrößern.

Schlüsselwörter: B*üffelfleisch, Qualität, Kühlung, Einfrieren, elektrische Simulation, Antioxydante, Enzime, Aditive, Hochdruck, Verpackung, Iradiation*

Tecnologie innovative nel miglioramento della carna di bufala

Sommario

La carne di bufala ha una prospettiva promettente nell'assicurare la sicurezza nutritiva alla percentuale significante della popolazione mondiale. Le caratteristiche principali della carne di bufala la rendono molto adatta alla lavorazione nei prodotti di carne. Le tecnologie di ammorbidimento della carne di bufala saranno molto utili ai consumatori. Se la carne di bufala viene conservata nel frigorifero o congelata, migliorano evidentemente la sua struttura, l'aroma e la percentuale d'acqua nella carne che diventa più saporita. La stimolazione ad alto voltaggio aumenta notevolmente la frammentazione di miofibrille. La durata di conservazione viene prolungata se al contempo si aggiungono degli antiossidanti e si mescola la carne di bufala. È utile confezionarla sottovuoto se ci sono degli cambi legati alla maturazione di miofibrille. La nisina in gran parte impedisce la crescita del batterio Listeria monocytogenes. Lo zenzero e il cetriolo danno la morbidezza. Il NaCl e il pirofosfato tetrasodico aumentano notevolmente la capacità emulsiva e causano una minore perdita durante la cottura. Acetici: la combinazione dell'acido lattico può essere usata come decontaminante, ma anche come conservante. L'irradiazione impedisce lo sviluppo dei batteri tipo Pseudomonas ed Enterobacteriaceae. Sottoposta alla pressione alta, diminuisce il contributo del tessuto connettivo alla persistenza fibrosa. Queste innovazioni miglioreranno la qualità della carne di bufala con lo scopo di produrla ed usufruirl

Parole chiave: *carne di bufala, qualità, refrigerazione, congelamento, stimolazione elettrica, antiossidanti, enzimi, additive, pressione alta, confezionamento, irradiazione*

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