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Effect of Different Preservation Methods on Physicochemical Quality of Beef

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ABSTRACT - The study was conducted to evaluate the effect of drying, curing and freezing on the quality of beef. Three types of dried (without salt = T_1, with salt = T_2 and salt + spices = T_3); three types of cured (salt curing = T_4, sugar curing = T_5 and brine curing = T_6) and three types of frozen beef (0°C = T_7, -10°C = T_8 and -20°C = T_9) were analyzed at different time intervals up to the period of 180 d. Parameters studied were protein, fat, ash, color and cooking loss of beef. All the chemical constituents (protein, fat and ash) were decreased gradually up to 120 d. The decreasing trend was observed rapid after 120 d up to 180 d of preservation. Highest protein loss was found in T_7 (11.1%) and the lowest protein loss was found in T_6 (3.85%) in 180 d preservation and significant ($p < 0.01$) differences were observed among the different preservation methods. Highest fat loss was observed in T_6 (7.62%) and the lowest fat loss was observed in T_2 (3.18%) and the differences were also significant ($p < 0.05$) among different methods during the experimental period. Spices dried beef showed a brighter color than others and cured beef showed brown color and the intensity of color was reduced gradually with the increasing of storage period. T_9 showed the lowest cooking loss among 3 treatments of frozen beef and the differences also significant ($p < 0.01$) up to 180 d. It might be stated that sugar curing (T_5) and spices drying (T_3) would be the useful technique of meat preservation in rural areas and freezing (T_9) would be used in large scale preservation at urban areas.

Key words: Drying, Curing, Freezing, Protein, Cooking loss, Beef quality.

Beef is recognized as a highly nutritious food, being an excellent source of high quality protein. Meat can also be regarded as an important source of dietary vitamins and minerals especially iron and contain all essential amino acids which are helpful for human life. Meat is essential to build a healthy nation by providing energy, health and vigor. In Bangladesh, total cattle population was 24.5 million and 23% of total cattle are being slaughtered every year and the annual meat production was 1020.2 thousands metric ton in 2004[1)]. The extent of slaughtering was around 7% on a single occasion, called Eid-ul-Adha and the remaining 16% are slaughtered throughout the year[2)]. The surplus meats that are produced in the special occasion needs to preserve for further use and consumption. Raw meat has a possibility to microbial contamination during their production and handling and may cause of some diseases. So, it is the prime necessity to preserve meat to prevent the growth of spoilage microorganisms and to ensure quality. Producers and consumers of beef have expressed a desire to reduce the use of synthetic chemicals in food preservation. Recently, there has been a considerable interest in spices and aromatic plants characterized by a notable antimicrobial activity. Such substances can be used to delay or inhibit the growth of pathogenic and/or toxin producing microorganisms in foods[3)]. Drying, curing and freezing are the conventional method of meat preservation in our country. The aim of preservation is not only to retard the food spoilage but also to control undesirable changes of wholesomeness, nutritive value, and growth of microorganisms[4)]. Drying is one of the oldest methods of meat preservation. It is based on the principle that all living organisms need water to survive. Drying of meat reduces the availability of water that is stored in the food to a level where microbes can not survive in the meat. Curing is one of the methods of preservation of meat by adding common salt, sugar, spices and/or potassium nitrate. In the beginning, salts were used for lowering the water activity and for the inhibition of growth of spoilage microorganisms. But with the advancement of science, people realized that some salts were preserving better than others. Saltpeter (KNO_3) was recognized as a contaminant

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of the salt which enhances its preserving action and gives a red color to the product. Nitrite added to a raw meat is partially oxidized to nitrate by sequestering oxygen - thus it acts as an antioxidant - a part of nitrite is bound to myoglobin, forming the heat stable NO-myoglobin and other part is bound to proteins or other substances in meat. Nitrate may be reduced to nitrite in raw meat products by microorganisms[5]. Sugar improves the flavor of meat and helps to autolysis of microorganisms by creating a negative osmotic pressure in the microbial cells, and salt adversely affect the growth of microorganisms. Freezing is the only known method by which meat can be preserved in a condition similar to their normal state. Drying, curing and freezing of meat help to increase the shelf life of meat without a mass deterioration of color, flavor, marbling appearance, nutritive content or other factors which are associated with the quality of the product. Of all these attributes are important factors affecting beef palatability and eating quality. A lot of research works have done to observe the quality of meat through drying, smoking, curing or freezing in developed countries, but unfortunately there is no baseline information on the suitable method of meat preservation in Bangladesh. Based on the present need of the country, the current study was conducted to observe the physical and chemical quality changes of beef in different preservation methods and hence to finally identify the suitable method in beef preservation.

Materials and Methods

Sample preparation

Fresh beef from the round of a bull carcass was purchased from the butcher's shop of "Kamal Ranjit Market" of Bangladesh Agricultural University Campus, Mymensingh. All visible fat and connective tissues were trimmed off as far as possible and then fresh muscle was collected to fulfill the purpose of the experiment. Three drying methods (T_1, T_2 and T_3); 3 curing methods (T_4, T_5 and T_6) and 3 freezing methods (T_7, T_8 and T_9) were examined with 3 replications. Experimental design was shown in Fig. 1.

For drying, beef samples with or without salt and spices were wreathed into separate wires and hung in the sunlight from morning to evening for 10 d that were treated as T_1, T_2 and T_3. During drying, the ambient temperature was 20°C and the relative humidity was 70-75%, and the day length was 10 hr. For curing, samples were placed in three different jars after mixing the ingredients. Inter cultural operation such as moving, enclosing and opening the cover, stirring of meat pieces were done every day. Addition of salts and other ingredients with meat samples for drying and curing were shown in Table 1. In case of T_4 and T_5, samples were removed at 10^{th} d but brine cured samples (T_6) were removed at 20^{th} d from jars and wreathed into different wires and hanged under sunshine from morning to evening for 10 d. Environmental condition of drying was same as expressed

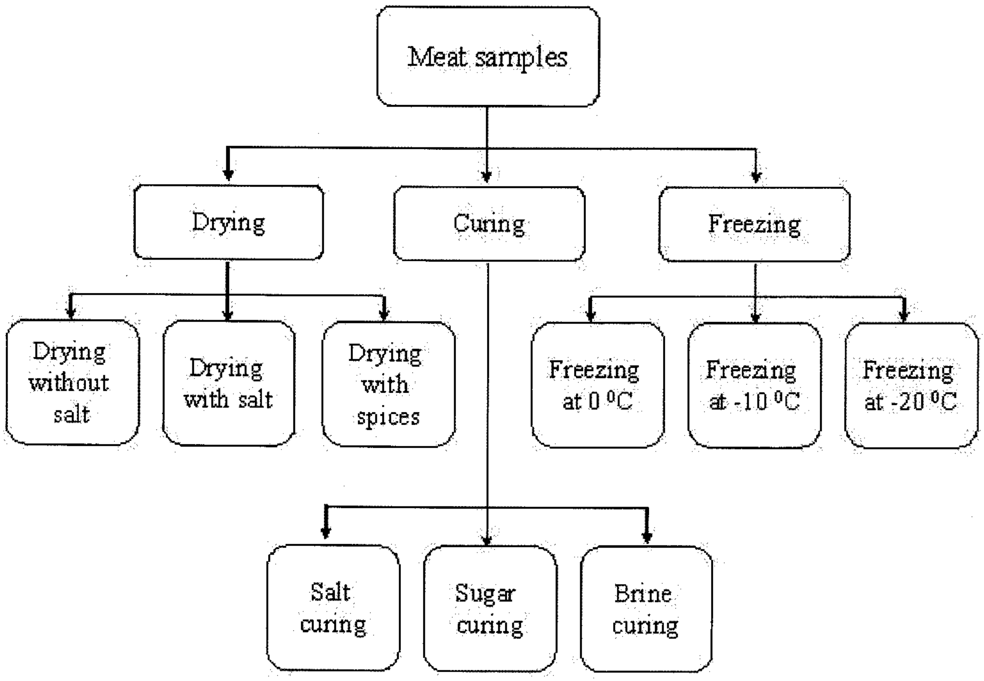

Fig. 1. Flow diagram of the experimental design.

Table 1. Methods of meat preservation and reagent used in the experiment

Methods of preservation		Proportion of meat sample and reagent added
Drying	Without salt (T_1)	250 g meat sample only
	With salt (T_2)	250 g meat + 20 g NaCl
	With salt & spices (T_3)	250 g meat + 20 g salt + 5 g turmeric & 5 g chilly powder.
Curing	Dry salt (T_4)	250 g meat + 20 g NaCl + 312 mg KNO_3
	Dry sugar (T_5)	250 g meat + 20 g NaCl + 5 g sugar + 312 mg KNO_3
	Brine (T_6)	250 g meat + 20 g NaCl + 5 g sugar + 312 mg KNO_3 + 197 ml water
Freezing	At 0°C (T_7)	No ingredients were added, directly preserved at the specific refrigerator after wrapping.
	At -10°C (T_8)	
	At -20°C (T_9)	

before. All dried samples were kept individually in air tight plastic packet. For freezing, beef samples were wrapped with polyethylene paper and preserved in 3 different refrigerators fixed at 0°C (T_7), -10°C (T_8) and -20°C (T_9). The quality of meat was analyzed at 30, 60, 120 and 180 d, during 6 mo preservation period.

Physical characteristics

Among physical characteristics, color, flavor, texture, marbling and cooking loss of fresh beef were observed initially before sampling. Then dried and preserved beef were rehydrated again to judge the physical parameters in different methods in every stage. In case of frozen meat, parameters were studied after thawing the samples. According to Korean Animal Product Grading Service, fresh beef samples were assessed for meat color identification[6]. During preservation period, cooking loss was determined only in the frozen beef, not from dried samples. Beef samples were blotted with blotting paper and weighed accurately just before cooking. After cooking at 80°C for 30 min, the samples were cooled and wiped with blotting paper and weighed immediately[7]. The cooking loss was expressed as a percentage and it was the difference in weights of the sample before and after cooking.

Chemical analysis

Crude protein was determined by the Macro kjeldahl method. Fat content was determined by Soxhlet apparatus using diethylether. For DM determination, fresh meat samples were dried at 80°C for two days. Ash was determined by burning the DM at 600°C for 5 hr. All measurements were done according to the standard method[8]. For pH measurement, 20 g of fresh sample was homogenized with 100 ml distilled water in a blender and the pH was measured using by pH meter (Corning, model-250). Proximate components of fresh meat were identified initially. But for the comparison of different preservation techniques, the preserved and dried meat samples were analyzed.

Statistical analysis

Data were analyzed according to CRD using SPSS statistical computer package program. Duncan's Multiple Range Test (DMRT) values were calculated to rank the means[9].

Results and discussion

The fresh meat samples were bright cherry red (color score: 4) in color with good appearance. The tenderness of fresh meat was soft, fine, and firm. Intramuscular marbling grade ranged from 4 to 5 and firmness observed medium (2)[6]. The natural flavor present in fresh beef and the pH of fresh beef was 5.8. The cooking loss of fresh beef was 40.25%. The dry matter, protein, fat and ash percentage of fresh beef was 29.01, 20.47, 8.54 and 0.98, respectively. The proximate composition of preserved beef samples under different preservation methods and different time intervals are described below.

Protein

Protein content of the preserved beef samples at different preservation methods and different time intervals were presented in Table 2. Initial protein content of fresh beef was 70.56% (according to DM) and this value was gradually reduced at different methods of preservation with the progress of preservation time. Significant differences were observed in protein content among different preservation methods at 30th ($p > 0.01$), 60th ($p > 0.01$), 120th ($p > 0.01$) and 180th ($p > 0.05$) d of preservation period. The highest protein loss was observed in T_7 (10.32%), followed by T_1 (7.38%) and T_2 (6.09%) at 30th d of preservation; and the lowest protein loss was occurred in T_5 (0.50%), followed by T_3 (1.87%) and T_4 (2.88%) at the same period of time. Similar results were found at 60th and 120th d of preservation

Table 2. Changes of chemical properties of preserved beef at different preservation methods

Parameter	Days	Treatment									SEM	Sig.
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9		
Protein (% DM)	0					70.56						
	30	65.35^c	65.26^c	69.24^{ab}	68.53^b	70.21^a	67.18^b	63.28^d	66.71^c	67.28^b	0.624	**
	60	63.49^c	64.44^b	68.79^a	68.49^a	68.23^a	66.10^{ab}	61.86^d	64.65^b	65.80^b	0.690	**
	120	62.04^d	64.22^c	67.32^b	68.48^a	67.46^b	64.72^c	61.45^d	63.49^c	64.61^c	0.619	**
	180	60.59^b	60.87^b	63.07^a	62.31^{ab}	63.32^a	59.58^{bc}	57.34^c	61.14^{ab}	62.33^{ab}	0.550	*
Fat (%DM)	0					29.44						
	30	24.10^c	25.20^{bc}	25.25^{bc}	26.67^b	25.05^{bc}	24.26^c	26.19^b	28.05^{bc}	29.12^a	0.433	*
	60	23.25^c	23.56^c	24.55^{bc}	25.35^b	24.35^{bc}	23.30^c	24.50^{bc}	27.35^{ab}	28.45^a	0.438	*
	120	22.18^c	22.60^c	23.30^{bc}	24.80^b	23.87^{bc}	22.15^c	22.51^c	25.62^{ab}	26.96^a	0.432	*
	180	18.10^c	20.15^b	20.78^b	22.65^a	21.20^{ab}	18.81^c	19.52^{bc}	21.06^c	22.93^a	0.409	*
Ash (%DM)	0					3.38						
	30	3.35	3.58	3.67	3.70	3.54	3.63	3.34	3.35	3.37	0.133	NS
	60	3.34	3.54	3.60	3.67	3.42	3.57	3.33	3.30	3.35	0.101	NS
	120	3.30	3.52	3.53	3.55	3.37	3.40	3.25	3.22	3.28	0.099	NS
	180	2.96^c	3.12^b	3.42^a	3.34^a	3.16^{ab}	3.31^a	2.92^c	3.17^b	3.20^{ab}	0.098	*

Mean with different Superscripts within same row differ significantly
*Significant at 5% level, **Significant at 1% level
NS = Non significant
T_1 = Dried meat (without salt), T_2 = Dried meat (with salt), T_3 = Dried meat (salt + spices), T_4 = Cured meat (salt),
T_5 = cured meat (sugar), T_6 = cured meat (brine),
T_7 = Frozen meat 0°C, T_8 = Frozen meat (-10°C), T_9 = Frozen meat (-20°C)

at different types of cured and frozen beef (Table 2). A significant amount of protein was lost from T_7 (18.74%), T_6 (15.56%) and T_1 (14.13%) after 180 d of preservation, but comparatively lower protein loss was occurred from T_5 (10.26%), T_3 (10.62%), T_9 (11.66%) and T_4 (11.69%) at the same time. A rapid protein loss was occurred within 30 d of preservation except T_5, T_3 and T_4. The result also showed that the protein loss was occurred slowly up to 120 d of preservation, and again a rapid loss was occurred within 120-180 d. It could be concluded that T_5, T_3, T_4 and T_9 might be better than other preservation methods, and the preservation period would not be more than 120 d. Initial higher loss of protein in drying and freezing might be due to denaturation of protein during sun drying and subsequent preservation process. Proteolysis might also be occurred due to presence of some bacteria in dried beef. In case of frozen stored meat, the loss of protein may be related with loss of sarcoplasmic (water soluble protein) protein, probably due to the osmosis and poor water holding capacity. Sarcoplasmic protein might be lost during drying and frozen storage in the form of drip loss[10]. Furthermore, protein content of beef slowly decreased during frozen storage[11]. Therefore, the changes in muscle proteins during freezing depended on freezing rate[12]. They also stated that slow freezing caused a larger loss of drip on thawing; a larger loss of proteins and nucleic acid derivatives and also water-holding capacity of meat, than fast freezing. Slow freezing increased proteolysis and caused a greater decrease in the adenosine-triphosphatase activity of myofibrillar proteins than fast freezing. Due to break down of myofibrillar protein, freezing at 0°C showed the highest protein loss. It has been observed that amount of protein gradually decreased from the frozen preserved beef[13]. On the other hand, raw pork samples that frozen at -10°C for 6 d, thawed and then immediately deep chilled at near cryoscopic temperature (-3°C) may causes some damages in meat structure[14]. Meat structure only slightly damaged within two days of frozen storage, whereas prolonged freezing resulted in increased histological changes. Frozen storage reduced water holding capacity and tenderness of pork loin, but did not affect electrophoretic pattern of myofibrillar proteins.

Fat

Fat content of fresh beef was 29.44% (according to DM) and the amount of fat gradually decreased at different preservation methods with the progress of preservation period. Significant differences ($p > 0.05$) were observed in fat content among different preservation methods at 30th,

Table 3. Cooking loss in frozen preserved beef

Parameter	Days	Treatment			SEM	Significance
		T_7	T_8	T_9		
	0		40.25			
	30	39.20^a	35.98^b	36.29^b	0.5417	**
Cooking loss (%)	60	35.59^a	33.16^b	32.62^b	0.4851	*
	120	30.26^a	28.83^{ab}	27.28^b	0.4703	*
	180	23.02^a	21.15^b	19.67^b	0.5131	**

Mean with different Superscripts within same row differ significantly
*Significant at 5% level,
**Significant at 1% level
T_7 = Frozen meat 0°C, T_8 = Frozen meat (-10°C), T_9 = Frozen meat (-20°C)

60th, 120th and 180th d of preservation period. The highest fat loss was showed in T_1 (18.14%) followed by T_6 (17.60%), and the lowest fat loss was occurred in T_9 (1.08%) followed by T_8 (4.72%) and T_4 (9.41%) after 30 d of preservation. Initially higher fat loss in the dried and cured beef might be occurred due to oxidation of fat during sun drying. Minimum fat loss was occurred at -20°C up to 30 d indicated that it would be a good method to maintain the quality of beef. The results showed that the fat loss was occurred gradually at 60th and 120th d of preservation at different types of cured and frozen beef (Table 2). A significant amount of fat loss was occurred after 120 d of preservation, and the highest fat loss was occurred in T_1 (38.52%), followed by T_6 (35.66%) and T_7 (33.70%) after 180 d of preservation, but comparatively lower fat loss was occurred in T_9 (22.11%), T_4 (23.06%) and T_8 (28.46%) at the same time. Rapid breakdown of fat was occurred within 30 d might be due to oxidation of fat during curing and sun drying. A higher fat loss was also showed after 120 d of preservation. Cryopreservation prevents the oxidation of fat and hence the fat losses were minimal in T_9 and T_8. It might be indicated that turmeric and chilly powder may have lipolytic effect that break down the fat. Less fat loss also occurred in sugar cured beef. With the presence of saltpeter, glucose might be prevented oxidation. It has been known that curing agent nitrite acts as an antioxidant, which prevents the rancidity of fat[5]. Decreasing of fat occurred due to oxidation of fatty acids in fat. Also, enzyme activity and microbial contamination might be influence fat degradation. It is quite natural that some fat from the samples may be released as drip loss. Oxidation of fat deteriorated the quality of preserved meat. In this point of view of fat degradation, dried without spices and sugar cured beef ensures the better quality, followed by freezing at -20°C. It might be stated from the experiment that the preservation period of meat might be kept within 120 d. Lipid oxidation was minimal at -70°C[10]. The oxidation of fats increased linearly during refrigerated storage[15].

Ash

Ash content of the preserved beef samples at different preservation methods and different time intervals are also presented in Table 2. The ash content of fresh beef was 3.38% (DM basis) and the amount of ash was increased in cured beef at 30th d of preservation. Higher ash content was observed in T_2, T_3, T_4, T_5 and T_6 rather than other treatment groups, might be due to addition of NaCl and KNO_3 salts during curing. It was also showed from the result that the amount of ash was gradually decreased with the progress of preservation time. No significant differences of ash were observed at 30th, 60th and 120th d of preservation but there was a significant difference ($p < 0.05$) of ash content at different treatments at 180th d of preservation. The highest ash loss was occurred at T_7 (13.61%), followed by T_1 (12.43%) after 180 d of preservation. Ash loss was occurred might be due to loss of volatile minerals from beef during preservation. From all the chemical composition of preserved beef, it was observed that significant differences were observed in case of protein ($p < 0.01$), fat ($p < 0.05$) and ash ($p < 0.05$) content in different time intervals. The decreasing trends of all of these components were slowly progressed up to 120 d of preservation, but the decreasing trend was faster after 120 d up to 180 d. It might be concluded from this result that, maximum preservation time would be 120 d. Preserved beef can conserve its quality within the acceptable range within 120 d.

Cooking loss

Cooking loss of only frozen preserved beef was estimated during the whole preservation period. Cooking loss of fresh beef was 40.25% and this value was gradually decreased with the increasing of time (Table 3). The rate of decreasing comparatively slower up to 60 d, but a rapid decreasing observed up to 120 d. A drastic reduction of cooking loss observed after 120 of preservation. Cooking loss is one of the important factors of juiciness and palatability of meat

Table 4. Physical assessment of beef in different drying methods

Time period	Drying			
	Without salt (T_1)	With salt (T_2)	With spices (T_3)	Comments
One hour after sampling	· Fresh, full bloom, shining and bright red appearance · Elastic and firm texture	· Light brown with natural flavor · Firm, elastic and bright appearance	· Bright yellow- brown color, natural beef flavor · Elastic and firm texture	All three were excellent
10th day	· Bright red grey color, natural beef flavor · Hard and firm structure	· Brown color, natural beef flavor · Hard and firm structure	· Spices color with bright appearance, natural beef flavor · Hard and firm structure	All three were excellent
30th day	· Pale red color · Slightly beef flavor	· Pale brownish or pinkish color, glossy appearance · Good beef flavor	· Bright color and good flavor of beef · Glossy appearance and fresh looking	T_3 was excellent, T_1 & T_2 were very good
60th day	· Grey color · Poor beef flavor · Not glossy	· Pale brown color · Slightly beef flavor	· Pale yellowish color, good flavor · Fresh looking	T_3 was very good & other two were good
120th day	· Slightly black color · Poor beef flavor	· Pale color · Slightly beef flavor · Not glossy	Spices color and glossy appearance Good flavor	$T_3 > T_2 > T_1$
180th day	· Slightly black color · No beef flavor	· Poor brown color · Poor flavor	· Pale color · Mild rancid flavor · Not glossy	$T_3 > T_2 > T_1$

products. At 30th d of preservation, a reduction of cooking loss was shown and the differences of 3 frozen storage beef were significant ($p < 0.01$). At 60th d of preservation, cooking loss was lowest in T_9 (32.62%) followed by T_8 (33.16%) and T_7 (35.59%) showed the highest cooking loss. Higher cooking loss is due to loss of higher amount of water from these samples and products might be observed less juicy. At 120th d of preservation, significant differences ($p > 0.05$) were observed among three different frozen groups. The lowest cooking loss was observed in T_9 (27.28%), medium in T_8 (28.83%) and the highest in T_7 (30.26%). After 4 months of preservation, a great loss was observed, and approximately 7-8% cooking loss occurred at last 2 months. It was indicated from the experiment that long term preservation (6 months) of beef reduced its juiciness as well as palatability. Also, T_9 showed the lowest cooking loss compared to others at 180th d and the differences were significant at 1% level. From the results of cooking loss of different frozen beef, it was showed that freezing at -20°C (T_9) gave the better performance. On the other hand, T_7 (0°C) gave the worse performance. It could also be stated that preservation time might be within 4 mo for better juiciness and palatability. The cooking loss of dried cured beef ranges between 20.1 to 22.4% compared to uncured beef (26.5%)[16]. Lower cooking loss indicated that meat products increased its ability to bind and retain water during cooking. They also observed comparatively higher color uniformity, juiciness and tenderness in dry cured beef than uncured beef. Cooking loss changes the cooking yields that result in compositional changes in the products and that can affect on palatability[17].

Color and flavor

Comparative study of color and flavor of different dried preserved beef at different time intervals were presented in Table 4. Color score of fresh beef sample was observed 4.0 (bright reddish color). Bright yellow-brown color was showed in T_3 might be due to addition of turmeric and chilly powder combined with salt and brown color in T_2 might be due to addition of only salt, and bright red color in T_1. Colors of all 3 groups gradually decreased with the increasing of storage period. Changing pattern of color was showed rapid after 60 d, and glossiness was disappeared at 60 d in T_1, 120 d in T_2 and 180 d in T_3. It might be indicated that disappearance of glossiness occurred quickly when no salt added and spices help to conserve the glossiness at a longer period. Spices might be having some ability to enhance the meat color. There showed a disappearance in color and mild rancid flavor at 180 d of preservation in dried samples. Continuous evaporation and weight losses during drying was changed the shape of the meat through shrinkage of the muscles and connective tissues. The pieces of beef became smaller, thinner due to moisture loss and wrinkled. The consistency also changed from soft to firm to hard. In addition to these physical changes, there were also certain specific biochemical reactions with a strong impact on the

Table 5. Physical assessment of beef in different curing methods

Time period	Curing			
	Dry salt curing (T_4)	Dry sugar curing (T_5)	Brine curing (T_6)	Comments
One hour after sampling	· Light pink red color · Natural beef flavor · Firm and elastic	· Deep brown color · Bright appearance · Natural beef flavor · Firm elastic texture	· Brown color · Natural beef flavor · Firm and elastic	All three were excellent
10^{th} day	· Brown color · More juicy · Ropiness found · Fermented flavor	· Brown color · More juicy · Ropiness found · Fermented flavor	· Brown color · More juicy · No ropiness · Fermented flavor	All three were excellent
30^{th} day	· Brown color · Hard in structure · Fermented beef flavor	· Pale brown color · Hard in structure · Fermented beef flavor	· Whitish color · Hard structure · Flavor present	$T_4 > T_5 > T_6$, according to appearance
60^{th} day	· Pale brown color · Hard structure · Slightly fermented flavor	· Pale color · Fermented beef flavor	· Whitish color · Hard structure · Poor flavor	$T_5 > T_4 > T_6$, according to appearance & flavor
120^{th} day	· Grey color · No beef flavor	· Grey color · Fermented beef flavor	· Whitish color · No beef flavor	$T_5 > T_4 > T_6$, according to appearance & flavor
180^{th} day	· Whitish color · Slightly rancid flavor	· Whitish color · Slightly fermented flavor	· Whitish color · No beef flavor · Mild rancid flavor	$T_5 > T_4 > T_6$, according to appearance & flavor

organoleptic characteristics of the product during drying preservation[18]. Meat used for drying in Bangladesh is usually derived from unchilled carcasses, and rapid ripening processes occur during the first stage of drying. For that reason the specific flavor of dried meat is completely different from the characteristic flavor of fresh meat. Slight oxidation of the meat fats contributes to the typical flavor of dried meat. In case of curing, the color of meat samples were turned into pinkish red in T_4 and brown in T_5 and in T_6, after adding the curing materials (Table 5). Brown color of the cured beef was turned to disappear quickly in T_6 compared to T_4 and T_5. Comparatively better appearance and flavor was showed in T_5 might be due to addition of sugar. Although, color was disappeared at 120 d of preservation, fermented flavor was existed, but there developed a rancid flavor at 120 d of preservation. Meat color depends on myoglobin pigment, consists of protein and non-protein porphyrin with a central iron atom. Dark purple or bright red color of beef due to oxymyoglobin (oxygenated myoglobin), and brown color develops due to production of metmyoglobin by loosing electron (oxidation) of myoglobin[19]. Addition of KNO_3 in fresh meat enhances the redness and sugar might be responsible for brown color. Addition of sugar enhances lactic acid production during curing that lowers the pH of meat products and acts as preservative and lower pH turns the meat to pale color or brownish[20]. Nitrate compound makes red color complex with heme protein of muscle which helps to make more reddish color at the initial stage of preservation. A series of nitrite reactions developed the color of cured meat and probably also play a strong role in the anti-oxidant function of nitrite in cured meat, because mechanisms for the antioxidant effect of nitrite include reaction with heme proteins and metals, and formation of nitroso- and nitrosyl-compounds that have antioxidant properties[21]. In case of freezing, T_9 showed the better performance regarding color and flavor during the whole preservation period, and the gradual changing pattern was shown in Table 6. Pale red color existed up to 60^{th} d and turns into grey at 120^{th} d and finally whitish color was showed at 180^{th} d. Freezing and thawing had a significant effect on meat quality[22]. In all stages of freezing, the sequence of quality of the treatments were $T_9 > T_8 > T_7$, according to appearance & flavor of the frozen beef. The color of beef can be reduced as much as 50% after 2 week of storage in a vacuum or controlled atmosphere[23]. Color is the most important factor of meat quality that influences consumer's buying decision and affects their perception of the freshness of the product.

Considering all of the physicochemical properties of preserved beef at different preservation methods and different time interval, it might be stated that T_5 (dry sugar curing), T_9 (freezing at -20°C) and T_3 (drying with spices) would be the suitable methods of meat preservation in Bangladesh. Although, protein loss was minimal in T_6, fat loss showed the maximum and it's also difficult to maintain. On the other hand, spices dried beef loosed lower protein and can conserve attractive color and flavor during preservation. In practical perspective of Bangladesh, electricity

Table 6. Physical assessment of beef in different freezing methods

Time period	Frozen meat			Comments
	0°C (T_7)	-10°C (T_8)	-20°C (T_9)	
One hour after sampling	· Reddish color with full bloom · Natural beef flavor · Firm, elastic and bright appearance	· Reddish color with full bloom · Natural beef flavor · Firm, elastic and bright appearance	· Reddish color with full bloom · Natural beef flavor · Firm, elastic and bright appearance	All three were excellent
10th day	· Light red color · Natural beef flavor · Firm and elastic	· Reddish color · Natural beef flavor · Firm and elastic	· Reddish color · Natural beef flavor · Firm, elastic and bright appearance	All three were excellent
30th day	· Pale red color, loss of bloom · Natural beef flavor	· Light red, firm and elastic · Natural beef flavor	· Bright appearance, firm and elastic · Natural beef flavor	$T_9 > T_8 > T_7$, according to appearance & flavor
60th day	· Highly pale color · Less flavor · Less elastic	· Pale red · Beef flavor present · Less elastic	· Pale red · Beef flavor present · Firm and elastic	$T_9 > T_8 > T_7$, according to appearance & flavor
120th day	· Grey color · Less flavor · Less elastic	· Grey color, loss of bloom · Less flavor · Less elastic	· Pale red · Beef flavor present · Firm and elastic	$T_9 > T_8 > T_7$, according to appearance & flavor
180th day	· Whitish color · No beef flavor · Less elastic	· Whitish color · No beef flavor · Less elastic	· Very pale red · Dull appearance, loss of bloom · Less flavor	$T_9 > T_8 > T_7$, according to appearance & flavor

is unavailable in rural areas and there is also a limitation to buy deep freeze for rural people. Considering this point, it might be stated that freezing at -20°C is suitable for urban areas and sugar curing and spices drying is suitable for rural areas. All of these changing characteristics of beef up to a period of 180 d might be recommended to preserve beef up to 120 d without much deterioration of its quality.

요 약

본 연구는 쇠고기의 품질에 있어서 건조, 절임, 냉동의 효과를 평가하기 위해 수행되었다. 건조의 3가지 타입(소금 비처리 $=T_1$, 소금 처리 $=T_2$, 소금 및 향료 처리 $=T_3$), 절임의 3가지 타입(소금 절임 $=T_4$, 설탕 처리 $=T_5$, 소금물 처리 $=T_6$)과 냉동의 3가지 타입(0°C = T7. -10°C = T8, -20°C = T9)으로 180일 동안 시간 간격을 두고 쇠고기의 단백질, 지방, 회분, 색도와 조리 영양손실을 분석하였다. 모든 화학적 구성요소들(단백질, 지방과 회분)은 120일 까지 점차적으로 감소하였으며 감소 경향은 저장 120일이 지난 후 180일까지 빠르게 진행되는 것으로 관찰되었다. 180일 저장 기간 동안 T_7에서 단백질 손실이 11.1%로 가장 높았으며 T_6는 3.85%로 가장 낮은 단백질 손실을 나타냈고 다른 처리구들에서도 유의적 차이($p < 0.01$)가 나타났다. T_6에서 지방 손실이 7.52%로 가장 높았으며 T_2에서 3.18%로 가장 낮았다. 또한 다른 처리구들에서도 서로 유의적인 차이($p < 0.05$)를 나타내었다. 향료가 처리된 건조 쇠고기가 가장 밝은 색을 나타냈으며 절임 쇠고기는 갈색으로 나타났다. 색의 명암은 저장 기간이 증가함에 따라 점차적으로 감소하였다. 3가지 냉동 타입 중 T_9 쇠고기가 가장 낮은 조리 영양손실을 나타냈으며 다른 처리구들 또한 유의적 차이($p < 0.01$)를 나타냈다. 설탕 절임(T_5)과 향료 처리 건조(T_3)방법은 농촌 지역에서 육류 저장기술로 유용할 것이며 냉동(T_9)방법은 도시 지역에서 큰 규모의 저장에 사용되면 좋을것으로 사료된다.

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