Studies on Indonesian-style Experimental Dried Beef

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An Indonesian-style dried beef was prepared experimentally and changes in physical and chemical properties of the product during processing were studied. The moisture content of beef decreased to about 20% by weight after drying at 40°, 50°, and 60°C for 12, 9, and 6 h, respectively. The water activity after drying at 40°C for 12 h was about 0.6 and the hardness of the beef dried at 40°C for 12 h was about 2/3 of that dried for 24 h. The addition of 200 ppm of NaNO₂ to the soaking solution gave a significant positive effect on the redness of the dried beef ($p < 0.01$). The redness was developed well by drying at 40°C for 12 h. Residual nitrite content in beef dried at 40°C for 12 h decreased to about 30% of that added to the soaking solution. The moisture content, water activity, hardness, and redness of experimental dried beef containing 20% moisture were reversible when samples were kept under 100% humidity for 48 h. There were not appreciable differences in main myofibrillar proteins during preparation. These results are suggestive for developing new dried meat products.

Probably the earliest method of preserving meat was drying in the wind and sun. Lowering the moisture content (dehydration) to prevent foods from spoilage is a well-known method. Such dried meat products are known as *biltong* in South Africa, *charqui* (jerky) in South America, *carne secca* in Brazil, *pemmican* in North America, *tassajo* in Uruguay, and *dendeng* in Indonesia^{1)~3)}.

Dendeng may be prepared from beef, chicken, pork, or goat meat, but dried beef, *dendeng sapi*, is the most commonly found in Indonesia. Briefly, the preparation of the *dendeng sapi* is as follows: Beef is sliced lengthwise along muscle fibers to about 2 mm in thickness and then soaked for 1 to 6 h in a soaking solution containing palm sugar, cooking salt, and additives such as coriander, caraway seeds, garlic, onion, nitrate and nitrite, cane sugar, or dried cassava. The proportion of ingredients used is variable but the sugar content in the products is about 40–50%. The treated meat slices are then dried under sunlight.

Recently, unrefrigerated meat products gained interest in some parts of European countries since they save energy and costs during distribution and storage. Thus unrefrigerated meat products, especially traditional products, such as *dendeng* deserve to be studied in detail. Generally, dried foods will absorb moisture when these are kept in an environment with high humidity. Studies on the transfer of moisture from the surroundings to dried meat products are important for storage or quality control of the products. In this work, we prepared the Indonesian-style dried beef and studied the changes in moisture content, water activity, hardness, and changes in myofibrillar proteins during drying (or humidifying), and the effect of nitrites on the properties of the product.

Materials and Methods

Materials

The frozen beef was purchased from some markets or sampled at The Experimental Farm

of Hokkaido University.

Methods

Preparation of experimental dried Beef : A cut of top rump or top side beef was used. The beef was cut into slices about 2 mm in thickness along muscle fibers after removing the fat. The sliced beef was soaked in a solution containing 30% (w/w) suger, 5% (w/w) cooking salt, and NaNO_2 at 4°C for 2 days. The weight of the soaking solution, which was boiled and cooled immediately before use, was the same as that of the sliced beef. The soaked beef was then dried in an oven with an air blower at selected temperatures.

Humidifying of experimental dried beef : A container with 100% humidity was used for humidifying. Samples dried at 40°C for 12 h were kept in the container at room temperature.

Measurement of nitrite content : Sample were cut to about 1 mm³ and homogenized by a blender at 10 000 rpm for 45 s to extract nitrite residues. Concentration of nitrite was measured colorimetrically by the AOAC method⁴⁾ with slight modifications as suggested by HARADA⁵⁾.

Color measurements : The color of experimental dried beef was measured as described by HUNTER⁶⁾ with a color difference meter, Nippon Denshoku Kogyo Z-1001 DP. The surface color of several different samples was measured and color parameters were calculated by the L.a.b color system.

Water activity (a_w) : The water activity of each sample was measured by the method of TROLLER *et al.*⁷⁾ with a Rotronic Hygroscope, model DT.

Measurement of hardness : The hardness of experimental dried beef was measured as the force to perforate the sample by a shear-force meter, Dynagraph DYN-1250 of IIO Electric Co., Ltd. A blunt needle 1.5 mm in diameter was used as a perforate device.

SDS-polyacrylamide gel electrophoresis of myofibrillar proteins : Dried beef sample was homogenized with 0.1 M KCl, 5 mM EDTA, and 39 mM borate buffer (pH 7.1) at 4°C.

Myofibrils were obtained as a sediment after repeated suspension and centrifugation as described by PERRY and CORSI⁸⁾. Polyacrylamide slab gel electrophoresis with sodium dodecyl sulfate (SDS) was done by the method of LAEMMLI⁹⁾ and WEEDS¹⁰⁾. The samples (2 mg/ml) were boiled for 5 min in the presence of 2 % (w/v) SDS, 20% (v/v) glycerol, 0.004 % (w/v) bromophenol blue, 5% (v/v) 2-mercaptoethanol, and 0.0625 M Tris-HCl (pH 6.8). The final concentrations in the separation gel were 10% (w/v) acrylamide, 0.1% (w/v) SDS, 0.2% (v/v) tetramethylethylenediamine (TEMED), 0.08% (w/v) peroxydisulfate, and 0.1 M Tris-Bicine (pH 8.2) and those in the stacking gel were 4% (w/v) acrylamide, 1% (w/v) SDS, 0.15% (v/v) TEMED, 0.08% (w/v) peroxydisulfate, and 0.125 M Tris-HCl (pH 6.8). The electrode buffer contained 0.1 M Tris-Bicine (pH 8.2) and 0.1% (w/v) SDS.

Results

Drying characteristics

Table 1 shows the thickness and weight of beef at various stages of drying. The thickness and weight of samples dried at 40°C for 12 h decreased to about 80% and 65% of those of the control beef, respectively. Fig. 1 shows the changes of moisture content of beef during drying at 40°, 50° and 60°C. The decreasing rate of moisture content was high till 6 h and then became low until 12 h. The degree of dryness was the almost constant after 12 h. The moisture content of samples was nearly 20 % (w/w) after drying for 12, 9, and 6 h at 40°, 50°, and 60°C, respectively. When the dried beef was kept in 100% humidity, the moisture content increased to about 50% (w/w) after 48 h.

Changes in water activity (a_w)

The water activity of beef during drying changed from 0.97 to about 0.5 (Fig. 2). At all different temperatures used, a_w decreased rapidly in the early drying time and then slowly. The a_w values of the dried beef containing about 20% (w/w) moisture were less than 0.70. During humidifying, a_w of the product dried at 40° for 12 h increased from

Table 1 Thickness and weight of experimental dried beef at each preparation stage¹⁾

Samples	Thickness (mm)	Weight (%)
Control beef	2.2±0.2	100
After soaking	2.4±0.3	145.8±1
After drying at 40°C		
for 3 h	—	72.0±4.5
6	1.9±0.3	64.3±4.0
12	1.8±0.1	63.7±2.3
18	1.7±0.1	62.8±3.0
24	1.5±0.2	51.1±3.3

¹⁾ Results are means of five experiments

Fig. 1 Changes in moisture content of dried beef during drying and humidifying

Sample was dried at 40°C (○), 50°C (△), and 60°C (□). Sample dried at 40°C for 12 h was humidified at room temperature under 100% humidity (●).

0.62 to 0.88. After humidifying for 48 h, a_w was the almost same as that of samples in the early stage of drying (1 ~ 3 h).

Nitrite content in dried beef

Remaining concentrations of nitrite in beef are shown in Table 2. The concentration decreased during drying and that in a product dried at 40°C for 12 h was about 30% of that added to the soaking solution.

Changes in redness of beef

Fig. 2 Changes in water activity of dried beef during drying and humidifying
Conditions were the same as Fig. 1

Fig. 3 shows the changes of redness (a -value) of beef with or without NaNO_2 during drying at 40°C. The a -value of samples increased rapidly in early drying period and then remained at a certain value depending on the nitrite concentrations. The a -value of dried beef without NaNO_2 was the smallest as expected. High a -value was found when more than 200 ppm of NaNO_2 was added to the soaking solution. Maximum redness was developed after drying for about 12 h in all samples. On the other hand, a -value decreased from 8.0 to 5.2 after humidifying for 48 h and it was the almost same as that of sample before drying.

Table 2 Residual nitrites in experimental dried beef¹⁾

Added nitrites to the soaking solution (ppm)	Residual nitrites ²⁾ (ppm)			
	6 h	12 h	18 h	24 h
100	37.8±1.3	32.6±1.5	26.1±3.2	23.9±1.1
200	65.6±2.2	55.5±2.6	46.3±1.8	43.1±3.7
300	106.4±2.1	94.6±1.4	88.2±0.9	65.7±1.8
500	182.0±2.2	168.4±1.2	142.4±1.3	124.8±2.2

¹⁾ Dried at 40°C²⁾ Calculated as NaNO₂

Fig. 3 Changes in a-value of dried beef during drying and humidifying

Sample was dried after soaking in a solution containing 30% sugar, 5% cooking salt, and 0 ppm (○), 200 ppm (△), or 300 ppm (□) of NaNO₂. Sample dried at 40°C for 12 h after soaking in a solution containing 200 ppm of NaNO₂ was humidified at room temperature under 100% humidity (▲).

Effect of nitrites on a-value (redness) of dried beef

The relationship between NaNO₂ added and a-value in experimental dried beef is shown in Fig. 4. An average value of a-value did not increase by adding up to 100 ppm of NaNO₂ but did increase by the addition of more than 100 ppm. The addition of more than 300 ppm of NaNO₂ failed to increase in a-value further, although a sharp increase of residual nitrite content was observed (Table 2).

Changes in hardness of beef

Fig. 5 shows the changes of hardness of beef during drying at 40°C. The hardness increased between 6 h and 12 h of drying followed by further increase. The hardness of sample dried for 12 h was about 2/3 of that of sample dried for 24 h. The hardness decreased without a lag phase during early humidifying. After humidifying for 48 h, hardness was about 0.2 kg, which was the same as that of the beef before drying.

Changes in myofibrillar proteins during processing

Changes in myofibrillar proteins prepared from the dried beef at various stages were examined by polyacrylamide gel electrophoresis with SDS (Fig. 6). There were no wide characteristic differences in the main myofibrillar proteins among raw beef and the beef after soaking at 4°C for 48 h and drying at 40°C for 6 and 12 h.

Discussion

Nitrites are commonly employed as curing agents for meat products. Sodium and potassium nitrites are used to improve the color¹¹⁾⁻¹³⁾ and flavor of products¹²⁾¹⁴⁾¹⁵⁾. It is also known that nitrites can inhibit the growth of *Clostridium botulinum* in certain cured meat products¹²⁾¹⁷⁾. However, nitrites have received negative publicity over the last several years, because they have toxic properties and because they can form nitrosamines which are known as potent carcinogens¹⁸⁾¹⁹⁾.

The nitrite content in all samples, prepared with various concentrations of NaNO₂, decreased to about 30% of that added to the soaking solution after drying at 40°C for 12 h

Fig. 4 Relationship between a-value of dried beef and NaNO_2 concentrations in the soaking solution
Sample was dried at 40°C for 12 h

Fig. 5 Changes in hardness of dried beef during drying and humidifying
Sample was dried at 40°C. Conditions for humidifying were the same as in Fig. 1

Fig. 6 SDS-polyacrylamide gel electrophoresis of myofibrillar proteins of beef

1, raw beef; 2, after soaking at 4°C for 48 h; 3, after drying at 40°C for 6 h; 4, after drying at 40°C for 12 h. MHC, myosin heavy chain; A, actin

as shown in Table 2. It has been established that the amount of nitrite in foods decreases considerably during processing or storage due to various mechanisms. Nitrites change by oxidation to nitric oxide and nitrate, by reduction to nitric or nitrous oxides, or by reaction

with phenols, amines, or thiols, etc.²⁰⁾ POULANNE reported that by adding 50 ppm of NaNO_2 to dry sausage emulsions, the residual nitrite content was at the level of 10~15 ppm.²¹⁾ On the basis of these facts, the residual nitrite content in the beef in this work is a reasonable concentration.

The experimental dried beef prepared by adding 200 ppm of NaNO_2 became appreciably redder (Fig. 3). The addition of more than 200 ppm of NaNO_2 failed to improve the color (Fig. 4). An analysis of variance was applied to differences in color with the change of treatments²²⁾. There was no significant difference between the dried beef with 100 ppm of NaNO_2 and the control ($p > 0.05$). The color became significantly redder ($p < 0.01$) than that of the controlled beef by adding NaNO_2 at 200 ppm. The a-values of the experimental dried beefs with 200, 300, and 500 ppm of NaNO_2 were almost the same statistically ($p > 0.05$). The a-value increased from early drying time and then maintained a certain value. The fixed redness was reached after drying for 12 h (Fig. 3). This suggests that the color developed more speedily in the drying process as reported by FUJIMAKI *et al.*²³⁾ They have reported that

nitrosomyoglobin formation accelerated mostly not in the curing period but in the cooking stage.

The a_w values of Chinese dried meat products were in the range from 0.54 to 0.68²⁴⁾. An average value of a_w of our dried beef was 0.6 (Fig. 2). An a_w value below 0.69 was essential for the microbiological stability of Chinese dried meat products, which contained about 4 ~ 5% salt, 20 ~ 35% sugar, and 15 ~ 20% water²⁴⁾. Our experimental dried beef prepared at 40°C for 12 h was stable microbiologically for several months when refrigerated²⁵⁾.

The hardness of over-dried meat products (24 h) became 1.5 fold that of those products heated for 12 h (Fig. 5). Control of the hardness seems to be of consequence because it is an important problem in countries where dried meats are eaten without cooking. The transfer rate of moisture between foods and the surroundings is affected by physical characteristics of the food's environment²⁶⁾. The moisture content of the experimental dried beef increased when the products were humidified at 100% humidity for 48 h (Fig. 1). These data suggest that water absorption by the dried beef can be easily forced by humidifying. Water activity (Fig. 2), a -value (Fig. 3), and hardness (Fig. 5) of dried beef were reversible at 100% humidity. The reversibility of these characteristics poses problems to be solved concerning storage conditions at various humidity levels.

Sucrose is effective in protecting myosin from denaturation due to freeze drying²⁷⁾ and inhibit denaturation of myosin by high or low pH, freezing, thawing, lyophilization, or high temperature²⁸⁾. NAKANO and YASUI²⁹⁾ reported that the minimum concentration of sucrose was 0.05 M for complete inhibition of the inactivation of myofibrillar ATPase activity due to dehydration. The changes of myofibrillar proteins prepared from beef at the various processing stages were examined by SDS-polyacrylamide gel electrophoresis. Much changes in main myofibrillar protein bands were not observed among the samples after thawing, after soaking in the curing solution, and after drying at 40°C for 6 h and 12 h

(Fig. 6). Large amounts of sugar in the experimental dried beef protected myofibrillar proteins from denaturation prior to proteolysis.

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インドネシア-スタイル乾燥牛肉に関する研究

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インドネシア風乾燥牛肉製品を実験的に調製し、乾燥工程における牛肉の物理的、化学的性質の変化を調べた。牛肉の水分量は、40、50、60℃における乾燥によって、それぞれ12、9、6時間後に、およそ20%に減少した。40℃で12時間乾燥した牛肉の水分活性は、およそ0.6で、その時の硬さは、24時間乾燥したものの硬さの2/3であった。浸漬液へ200ppmの亜硝酸ソーダを添加すると、乾燥肉は、有意に好ましい赤色を呈した ($p < 0.01$)。40℃、12時間の乾燥によって、牛肉は十分に発色した。40℃で12時間乾燥した時、製品中の残留亜硝酸の量は、浸漬液へ加えた量のおよそ30%であった。20%の水分を含む乾燥牛肉製品の水分含量、水分活性、硬さ、および色は、製品を飽和水蒸気圧のもとに、室温で48時間放置することによって、乾燥前のそれらの近くまで戻った。浸漬および40℃における乾燥処理中に、筋原繊維蛋白質の主成分には、大きな変化が認められなかった。以上の結果は、新しい乾燥肉製品を開発するに際して、示唆に富むものである。