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THE EFFECTS OF CURING AND DRYING ON THE MUSCLE FIBER, SARCOMERE AND TENDERNESS OF REHYDRATED AND COOKED CHEVON

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Introduction

Any process, be it physical or chemical applied to meat cause changes in the ultrastructural characteristics of the meat tissues. These changes affect meat characteristics, which subsequently influence water-binding capacity, protein solubility and tenderness of meat. In processed meat products, the total effect depends on the kind and degree of muscle structure damage and on the method this damage was inflicted on the structure. Tenderness of the final meat product is influenced by several factors with which the meat has been exposed to. For dehydrated meat, the degree of tenderness is affected by the behavior or response of the contractile and connective tissues to the processing method. The importance of their relative contribution depends on circumstances such as the degree of contraction of the myofibrils, the type of muscle, amount and type of connective tissue and the cooking temperatures (Lawrie, 1998; Purchas, 1989).

To determine the degree of muscle fiber shrinkage and destruction and its corresponding effect on the tenderness of rehydrated chevon (goat meat) products, fiber diameter and sarcomere length of fresh, dried and rehydrated meat samples were determined. Tenderness was evaluated objectively by measuring the shear force required to cut the cooked meat pieces.

Objectives

The general objective was to evaluate the degree of muscle fiber shrinkage and destruction in dried and rehydrated chevon. Specifically,

1. To measure the muscle fiber diameter and sarcomere length of dried-cured and rehydrated chevon.
2. To determine the rehydration potential of dried-cured chevon.
3. To measure the tenderness of dried-cured, rehydrated and cooked chevon thru the shear force values

Methodology

Meat preparation. The *longgisimus dorsi* muscles from six male goats of mixed breeds with slaughter weights ranging from 18–28 kg were used for this research. Meat pieces were sliced into approximately 5-10 mm thickness across the grain, mixed properly and divided into three lots corresponding to the two curing treatments: %14 salt solution, 14% salt solution with nitrite and the control (fresh meat). The cured meat pieces were either sundried or smoked/oven-dried to reduce moisture to 15-20%.

Fiber diameter. Pieces of fresh dried and rehydrated muscle samples taken from the *longgisimus dorsi* were placed in 20% HNO_3 solution. After 24 hours the muscle samples were transferred to test tubes of distilled water and shaken vigorously. Then samples were transferred to saturated solution of aluminum potassium sulfate, and several muscle fibers were placed in slides and measured in a compound microscope fitted with ocular micrometer. Twenty fibers from each treatment were randomly selected for fiber diameter measurement. Each fiber was measured in three points: on the two ends and in the middle section of the fiber. The values were averaged to get the diameter of one fiber. Measurement of the fiber length was not possible due to curling and fragmentation of almost all of the dried and rehydrated samples.

Sarcomere length. Small pieces of fresh, dried and rehydrated samples were likewise taken from the *longgisimus dorsi* of the same animals. The muscle pieces were teased while soaked in 3% glutaraldehyde as fixative solution. Several muscle fibers were separated and transferred to airtight plastic test tubes containing 3% glutaraldehyde and submitted to the National Institute of Molecular Biology and Biotechnology (Biotech) Electron Microscopy Service Laboratory for processing, viewing and measurement in the transmission electron microscope (TEM, Hitachi H-300 model). Suitable images were subsequently photographed and printed.

Rehydration. Sample meat pieces from the different dried products were rehydrated by soaking in warm water (50°C) for 2 hrs. The rehydrated meat pieces were then weighed and the rehydration yield computed following Ibarra et. al., (1988).

Tenderness. Rehydrated samples were cooked into a local recipe called *caldereta*. Tenderness of the cooked meat samples was evaluated using the Warner Bratzler Shear Machine. Thin strips of cooked samples were layered and rolled and fitted in a ½ inch diameter metal bore. Three readings per meat sample were taken.

Statistical analysis. Data on the effects of curing and drying on the rehydration and tenderness characteristics were analyzed using Analysis of Variance (ANOVA) under 2x2 factorial in Randomized Complete Block Design (RCBD) with the animals as blocks, curing solution as factor A and drying method as factor B. On the other hand, simple ANOVA in RCBD was done to determine the effect of treatment on the fiber diameter. Comparison of means was done using Duncan's Multiple Range Test (DMRT).

Results And Discussion

Muscle Fiber Diameter

Table 1 presents the mean muscle fiber diameter of cured-dried (CD) and cured-dried-rehydrated (CDR) chevon. For unhydrated CD meat samples, fiber diameter of

sundried samples (T_2 and T_4) were comparable with the control (T_5) regardless of the curing brine used ($P > 0.05$). On the other hand, samples, which were smoke-oven dried, (T_1 and T_3) have significantly smaller fiber diameter ($P < 0.05$). Smoke-oven dried meat pieces were subjected to increasing temperature of up to 80^oC during drying which denaturatured the sarcoplasmic and myofibrillar proteins and part of the connective tissues, causing the decrease in muscle fiber diameter. Hamm (1966) established that the coagulation of myofibrillar proteins begins between $30^\circ C$ and $40^\circ C$ and is almost complete at $55^\circ C$. At $62^\circ C$, most of the sarcoplasmic proteins are denatured (Bendall, 1964 as cited by Hamm, 1966) and at $80^\circ C$ they all become insoluble (Hashimoto and Yasui, 1957 as cited by Hamm, 1966). This then results in the stiffening of the structure of the muscle fibers. Shrinkage of collagen at $60^\circ C$ also contributed to the subsequent shrinking of the muscles.

On the other hand, sundried meat samples were exposed to below $50^\circ C$ drying temperature. A large part of the globular muscle protein is not yet coagulated at temperature below $50^\circ C$ and therefore minimized the structural changes that occurred in the cells.

Table 1 also shows the mean fiber diameter of rehydrated meat pieces. There were no significant variations in the diameter among the treated samples ($P > 0.05$). T_2 and T_3 were the most comparable with the control ($P > 0.05$). There was an observed increase in the diameter of the smoke-oven dried samples over their dried counterparts. Surprisingly however, fiber diameter of sundried samples, decreased and yielded measurements smaller than the dried samples despite the higher percent rehydration. One possible explanation is the non-uniform swelling of muscle fiber in rehydrated sundried samples. The study of Knight, et al (1989), demonstrated that the non-uniform swelling of muscle fiber is due to the destruction of cell membrane and a sheath of endomysial connective tissue surrounding the fiber. Non-uniform breakdown of these layers, he added, could be a cause of variable behavior of muscle fiber. Wilding et al (1986) as cited by Knight et al (1989) showed that greater swelling occur at the broken endomysium and he further showed that fibers lacking endomysium on prolonged immersion in 0.25 m KI shrink after swelling whereas smaller swelling fibers with intact endomysium is maintained.

In this experiment, sundried meat samples underwent less heat denaturation, thus, there was less stiffening of the endomysium which made them softer over those that were smoke-oven dried. With vigorous shaking in distilled water to separate muscle fibers, more cells were damaged. Observations also showed that there were more fragmented and damaged fibers in these samples. Some fibers may have retained their endomysial sheath while others were stripped either partially or fully creating breaks and becoming vulnerable to excessive but unstable swelling. On the other hand, smoke-oven dried muscle bundles were more difficult to separate into individual fibers possibly due to more stiffening of the fiber structure. However, individual fibers in this treatment were observed to have more uniform measurements along its entire length probably due to a more intact and stable endomysial sheath acting as restraint.

The 2-hour rehydration time and higher temperature could have been more than enough to cause excessive swelling and subsequent collapse of muscles with damaged endomysium resulting to smaller fiber measurements.

Sarcomere Length

Longitudinal cuts of muscle fibers from fresh, dried and rehydrated samples were prepared for viewing in the transmission electron microscope (TEM) to determine the length of the sarcomeres. Figure 1 shows the micrographs of the sarcomeres of fresh goat meat showing distinct A-bands (→), I-bands (—•), and Z – lines (→). These sarcomeres have an average length of 1.16 µm (n=20). In salt-cured samples (Figure 2), there is obvious contraction of contractile structures. Z-lines are no longer recognizable while A-bands are much closer to each other. There was crimping of the sarcomeres. When these treatment samples were rehydrated (Figures 3 and 4) structures are not distinguishable anymore. Black aggregate substances were prominent which are probably denatured proteins separated/broken from each other during hydration. These observations show that upon drying, the A and I filaments are meshed together irreversibly. According to Purchas (1989), the myosin of the A filament is the most heat sensitive. He described further that adjacent A filaments begin to coalesce from about 55°C and continues up to 60-70°C. At the latter temperature I filaments of actin begin to disintegrate. At 70 – 80°C these filaments lose their identity. All that remains according to the same author is a coagulum of actomyosin in which very fine "through-running" filaments can be perceived. This, he suggested are the T-filaments which survive even after 4 hours of 100°C. These T filaments could be the remaining thin and straight running structures along the length of the fibers as in Figure 4 (arrow) and embedded in a coagulum derived from the wreckage of the filaments (Purchas, 1989).

Rehydration

Percent rehydration (Table 1) shows no significant differences among treatments. Drying and curing did not affect significantly the rehydration capacity of the processed meat. Slight variations could be attributed to the differences in temperature with which the samples were exposed during processing. The higher the temperature the more proteins are denatured that would result to lowered capability of meat tissues to reabsorb water. Percent rehydration in this study was negatively correlated with shear value at - 0.21. The relationship, however, is statistically not significant.

Tenderness

Table 1 likewise, contains the tenderness evaluation of treated cooked chevon as measured by the shear value (SV). Shear value measures the shear force required to cut right through the sample and follows that it increases with toughness of meat (Lawrie, 1998). The control (T_5) is shown to have significantly lower shear value than all the dehydrated samples. As has been shown in Figure 1, sarcomeres of T_5 are intact and relaxed. Smulders et al (1990) showed the relationship between sarcomere length and tenderness in their study on beef tenderness and sarcomere length. They found out that longer sarcomeres were clearly associated with greater tenderness. The average sarcomere length of the fresh goat meat in this study is 1.16 µm, shorter than those of the mature sheep (2.3 µm)(Ockerman, 1980). All treated samples have similar shear value ($P > 0.05$) but are significantly tougher than the control ($P < 0.05$).

Although collagen content and solubility were not measured in this study, its effect could be predicted based on its established response to heat. Research by Mutungi et al (1995) showed increased strength of perimysium with cooking temperature until 50°C. However at higher temperature and prolonged cooking, collagen is transformed into water-soluble gelatin, which is responsible for the softening and disintegration of tissues. When meat samples in this study were subjected to prolonged cooking, connective tissues were gelatinized which contributed to the relatively tender cooked meat product (maximum 2.5 kgF). Devine et al (1990) as cited by Swan et al (1998) claims that meat is considered acceptably tender if the mean shear force value is less than 8.0 kgF.

Conclusions

When unhydrated, muscle fiber diameter of sundried samples, regardless of the curing brine used, were comparable with the fiber diameter of the fresh chevon. On the other hand, those smoke-oven dried have significantly smaller fiber diameter. When rehydrated, all cured-dried samples had significantly smaller fiber diameter than the fresh samples.

The sarcomere lengths of the treated samples were not measured due to contraction and crimping of the contractile structures. The Z–lines and other structures were no longer recognizable and A-bands were much closer to each other. Rehydrated samples showed indistinguishable, disorganized and swollen structures. This shows that upon drying, A and I filaments are meshed together irreversibly and rehydration did not restore the structures.

Percent rehydration were similar among the treated samples.

The cured-dried chevon had similar tenderness values. However, they were all significantly tougher than the control (fresh). The shear force values nonetheless, are still within the tender range since maximum value considered to be acceptably tender is 8.0 kgF (Swan et. al. 1998).

Drying and curing, to some degree, damaged the contractile structures of the muscle cell, diminishing the cell's ability to reabsorb water during rehydration and consequently reducing the tenderness of the product.

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Tables and Figures

Table 1. Fiber diameter, percent rehydration and shear value of rehydrated cooked chevon.

Treatment	Fiber Diameter, µm		% Rehydration	Shear Value (KgF/cm^2)
	Dried	Rehydrated		
T1	2.82 b	3.48 b	19.15	2.0 a
T2	3.98 a	3.65 b	24.42	2.1 a
T3	3.29 b	3.71 b	20.61	2.5 a
T4	3.94 a	3.38 b	26.00	2.0 a
T5	4.16 a	4.16 a		1.0 b

[1]Means in the same column without or have a common letter in their superscript do not differ (P>0.05).

[2]T1 = Nitrite-cured/Smoke-oven dried; T2 = Nitrite-cured/Sun dried; T3 = Brine-cured/Smoke-oven dried; T4 = Brine-cured/Sun dried; T5 = Fresh

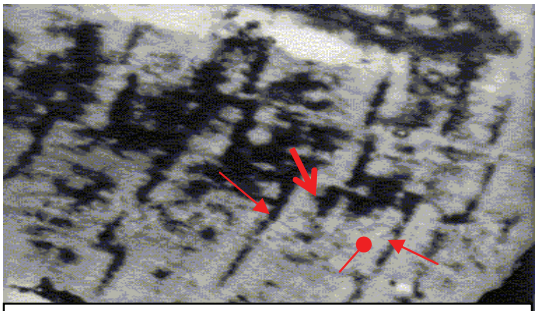

Figure 1. Electron micrograph of a longitudinal section fresh chevon muscle fiber showing contractile structures: Z-line (—►); A-bands (→) and I-bands (—●) ; x 15,000. Bar = 1 *u*m

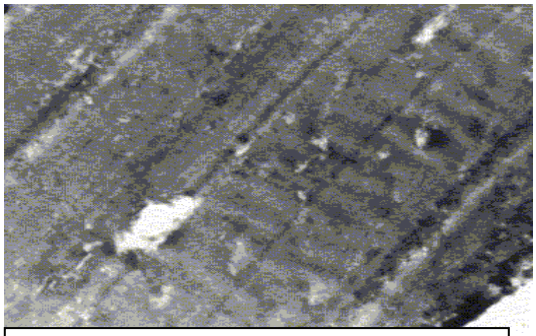

Figure 2. Electron micrograph of salt–cured/sundried chevon: contraction of sarcomeres ; x 15,000. Bar = 1 *u*m

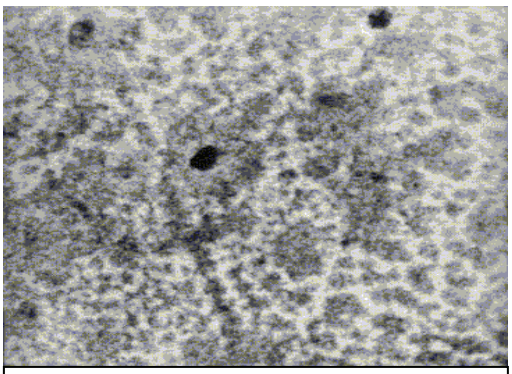

Figure 3. Micrographs of rehydrated chevon (salt-cured/ smoke-oven dried) showing disorganized and disfigured ultrastructures; x10, 000. Bar = 1*u*m

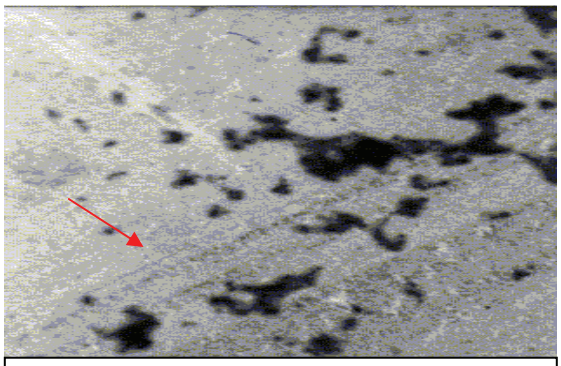

Figure 4. Longitudinal micrographs of rehydrated chevon (salt-cured/sundried): structures are no longer distinguishable, regions are devoid of contractile materials and organelles, black aggregate substances are probably denatured protein and organelles. Arrow points to possible T-filaments, x5, 000. Bar = 1 *u*m.