Ultrahydrostatisches Unter-Druck-Setzen der Muskeln vor Eintritt der Starre und seine Auswirkung auf Zartheit und andere wirtschaftlich bedeutende Eigenschaften

W.H. KENNICK, ELGASIM ALI ELGASIM, Z.A. HOLMES and E.F. BARRETT

Oregon State University, Corvallis, Oregon 97331, U.S.A.

Zartheit ist eine unerlässliche Fleischeigenschaft, wenn es auf vielen Märkten akzeptiert werden soll. Dies könnte zu einem ernsthafteren Problem werden, wenn man, infolge von weltweitem Getreidemangel aufhören würde, besonders Rindvieh mit Futter mit hohem Energiegehalt zu füttern.

Es ist gezeigt worden (Farland, 1973), dass das Unter-Druck-Setzen kleiner Proben von Schaf- und Ochsenmuskeln vor Starreeintritt eine deutliche Erhöhung der Zartheit der gekochten Muskeln bewirkte. Das hier beschriebene Experiment wurde durchgeführt um festzustellen, ob das gleiche Resultat mit grösseren Muskelproben, bis zu 1,5 kg, erzielt werden könnte.

Gleich nach dem Aufbereiten und Reinigen wurden die Muskeln vom Rumpf entfernt, von allen äusseren Fett- und Bindegeweben befreit und in Plastikbeutel getan. Alle Luft wurde herausgesaugt, worauf die Proben in eine vorgeheizte (35C) Kammer gelegt und 2 Minuten lang einem Druck von 103,5 Meganewton/M^2 ausgesetzt wurden.

Nach Entfernung von der Kammer fühlten sich die Proben fest an und waren auf nur 48% ihrer ursprünglichen Länge am Rumpf zusammengeschrumpft. Muskellängenmessungen zeigten ein 9,38%iges Schrumpfen und ausgedehnte Faserrisse. Der pH-Wert unmittelbar nach der Behandlung war 5,81, bedeutend niedriger als Kontrollwerte. Nach 24 Stunden war jedoch kein Unterschied mehr festzustellen. Die Wasserbindefähigkeit der behandelten Proben war bedeutend niedriger und der Feuchtigkeitsverlust bedeutend höher als bei Kontrollproben. Kochverluste der behandelten Proben waren jedoch geringer, so dass der Totalverlust bei Kontrollproben und behandelten Proben der gleiche war.

W.B. Shearprüfungen sowie Geschmacksausschussbeurteilungen wiesen auf bedeutende Erhöhung der Zartheit hin. Rasterelektronenmikrographen zeigen weitgehendes Zerreissen der sarcolemma, und grosse Mengen globularen Materials, unter Phasenkontrast gesehen, zeigen ausgedehntes Zerreissen der Muskelfasern.

The effect of ultrahydrostatic pressurization of pre-rigor muscle on tenderness and other characteristics of economic importance

W.H. KENNICK, ELGASIM ALI ELGASIM, Z.A. HOLMES and E.F. BARRETT

Oregon State University, Corvallis, Oregon 97331, U.S.A.

Tenderness is an indispensable quality in meat if it is to be accepted in many markets. This could become a more critical problem if the practice of feeding high energy feed, especially to cattle, were to cease as a result of world wide grain shortages.

It has been demonstrated (MacFarland, 1973) that pre-rigor pressurization of small samples of sheep and ox muscles caused a marked tenderizing of the cooked muscles. This experiment was conducted to determine if the same results would be obtained on larger muscle samples, up to 1.5 kg.

Muscles were removed from the carcass immediately after dressing and washing, trimmed of all external fat and connective tissue, put in plastic bags, all air was evacuated following which the samples were put into a pre-heated (35C) chamber and subjected to 103.5 meganewtons/M^2 of pressure for two minutes.

The samples were very firm to the touch when removed from the chamber and had contracted to as little as 48% of their on carcass length. Sarcomere length measurements indicated a 9.38% contraction and that there had been extensive fiber disruption. Immediate post-treatment pH was 5.81, significantly lower than controls, however, there was no significant difference at 24 hours. Water binding capacity of the treated samples was significantly less and purge loss significantly higher than the controls. However, cooking losses for the treated samples were less, resulting in an over all loss which was not different between the controls and treated samples.

W.B. shear tests and taste panel evaluations both indicated a highly significant improvement in tenderness. Scanning electron micrographs show an extensive disruption of the sarcolemma and large masses of globular material seen under phase contrast indicate an extensive disruption of fibular material of the muscle.

E 12:2

Effets de l'ultrapression hydrostatique du muscle avant la rigidité cadavérique sur la tendreté et d'autres caractéristiques ayant une importance économique

W.H. KENNICK, ELGASIM ALI ELGASIM, Z.A. HOLMES et E.F. BARRETT

Oregon State University, Corvallis, Oregon 97331, U.S.A.

Ia tendreté est une qualité indispensable à l'acceptation de la viande sur bien des marchés. Ce problème deviendrait plus critique si l'alimentation en nourriture à haute valeur énergétique venait à cesser en raison de crises mondiales des céréales, particulièrement pour le cheptel.
Il a été établi (MacFarland, 1973) que la pression avant la rigidité cadavérique de petits échantillons de muscle de boeuf et de mouton avait pour résultat une nette amélioration de la tendreté des muscles après cuisson. Le but de notre expérience fut de déterminer si les mêmes résultats pouvaient être obtenus pour de plus grand échantillons de muscle, jusqu'à 1,5 kg.
Les muscles furent détachés de la carcasse immédiatement après l'abattage et le lavage, débarassés de toute graisse externe et tissu conjonctif, mis dans des sacs en plastique dont l'air fut chassé, à la suite de quoi les échantillons furent placés dans une chambre préchauffée (35° C), et soumis à une pression de 103,5 méganewtons/m^2 pour une durée de deux minutes.
Au sortir de la chambre, les échantillons étaient très fermes au toucher, et contractés jusqu'à 48% de leur longueur sur carcasse. Nos mesures de la longueur des segments de fibrille musculaire entre deux cloisonnements indiquèrent une contraction de 9,38% et une dislocation considérable des fibres. Immédiatement après le traitement, le pH était de 5,81, sensiblement en-dessous de celui des échantillons de contrôle; toutefois, aucune différence sensible ne fut enregistrée après 24 heures. La capacité de rétention d'eau des échantillons traités était sensiblement moindre que celle des échantillons de contrôle, et leur perte en eau sensiblement plus élevée. Toutefois, la réduction à la cuisson des échantillons traités fut moindre, d'où une perte globale identique pour les échantillons de contrôle et les échantillons traités.
Et les tests de tranchage W.B. et les évaluations d'un groupe de goûteurs indiquèrent une très nette amélioration de la tendreté. Les microphotographies électroniques révèlent une dislocation considérable du sarcolemme, et les grandes masses globuleuses qui apparaissent par l'effet du déphasage indiquent une dislocation considérable de la matière fibreuse du muscle.

Влияние ультрагидростатического приготовления предригорного мускула в герметической кастрюле на мягкость и другие аспекты экономического значения

В.Г.КЕННИК, Е.А.ЕЛЬГАСИМ,З.А.ГОЛЬМЕС,Е.Ф.БАРРЕТ
Орегонский штатный университет, Корваллис, Орегон 97331

Мягкость необходимое качество мяса, чтобы быть принятым на многих рынках. Это может стать даже более серьёзной проблемой, если бы стало невозмжным продолжать кормление скота кормом высокой энергии в результате нехватки зерна в мировом масштабе.

Доказано, что приготовление мускулов овец и рогатого скота в герметической кастрюле вызывает значительную мягкость варёных мускулов.(МакФарланд, 1973). Этот опыт был проведён, чтобы определить, можно ли достичь тех же результатов с более крупными образцами мускула, до 1,5 кг.

Мускулы были удалены с туши сразу после разделывания и мытья. Весь внешний жир и соединительная ткань тоже были удалены и положены в пластический мешок. Весь воздух высосался. Тогда образцы были положены в предварительно нагретую (35 Ц) камеру и подвергнуты давлению 103,5 меганьютонов в течение двух минут.

Образцы были очень твёрдыми после удаления с камеры. Они сократились на 48 % длины туши. Измерения длины мускула показали сокращение на 9,38 % и значительное разрушение фибр. Непосредственно после обработки pH , 5,81, была значительно ниже контрольных опытов, но через сутки не было значительной разницы. Способность обработанных образцов связывать воду была значительно меньше и потеря влажности значительно выше контрольных опытов. Потери за счёт варения были значительно меньше в случае обработанных образцов. Не было разницы в общей потере между контрольными и обработанными образцами.

В.Б. опыты и оценка вкуса указали на значительное улучшение мягкости. Разлагающие электронные микрографы показывают значительное нарушение сарколеммы. Большие массы шаровидного материала, рассмотренные под контрастом фазы, показывают значительное нарушение фиброзного материала мускула.

The effect of ultrahydrostatic pressurization of pre-rigor muscle on tenderness and other characteristics of economic importance

W. H. KENNICK, ELGASIM ALI ELGASIM, Z. A. HOLMES and E. F. BARRETT

Oregon State University, Corvallis, Oregon 97331, U.S.A.

Introduction

Tenderness is an indispensable quality in meat if it is to be accepted in many markets. This could become a more critical problem if the practice of feeding high energy feeds, especially to cattle, were to cease as a result of world-wide grain shortages.

Three remarkable papers (Locker, 1959, Locker, 1960 and Locker and Hagyard, 1963) concerning the influence of degree of muscle shortening on meat tenderness and the influence of cold temperature on muscle shortening opened up a new area of meat science and muscle biology research.

It is generally accepted today that the degree of muscle contraction at the time it goes into rigor has a major affect on the tenderness of cooked meat from both lamb and beef. Marsh and Leet (1966) demonstrated that there are three critical areas in degree of shortening: shortening up to about 20% caused little or no toughening; additional shortening from 20% to 40% caused a severalfold increase in toughness; shortening beyond 40% resulted in a rapid increase in tenderness until at 60% shortened it returned to approximately the same tenderness as unshortened meat. Marsh (1977) has stated that, "With further shortening, major internal rupturing of the structures takes place because some of the sarcomeres supercontract (occasionally by 80% of initial length), this produces complete fractures in nearby areas. The rupturing certainly causes very appreciable tenderizing, but is of only academic interest for a number of reasons: it can only be produced in small samples capable of very rapid cooling, it causes massive drip loss, and the end product is so distorted as to be entirely inacceptable to the consumer."

Numerous methods of preventing muscle shortening have been investigated with varying degrees of success but only MacFarlane (1973) has reported a serious attempt to take advantage of the tenderizing effect of super-contraction. Previous workers (Johnson et al 1954; Brown 1957; Johnson and Eyring 1970) had reported that hydrostatic pressure influenced the development of tension in muscles, increasing or decreasing tension depending upon the temperature at which the muscle was pressurized. MacFarlane (1973) reported the effects of various hydrostatic pressures at different temperatures on small (the sample size was not given but the largest vessel used was 7.62 cm in diameter and 23.76 cm long) samples of sheep and ox muscles. His work indicated that pressures of 103 to 138 Meganewtons/m^2 (MNm^{-2}) at 30 to 35°C resulted in shortening greater than chill shortening and that the cooked muscles were more tender than normally handled controls and very much more tender than corresponding muscles from the same carcasses which were chill shortened. The only exception reported was the semitendinosus muscle from sheep. A very rapid drop in pH was also reported, indicating that post-mortem glycolysis had been greatly accelerated by pressurization.

The current study was undertaken to confirm these results and to determine if the same results could be obtained on larger muscle samples since Marsh (1977) had stated that super contraction as a result of cold shortening could be obtained only with very small samples.

Materials and Methods

Muscle samples for this experiment were obtained from sheep and cattle slaughtered at the Oregon State University Meat Science Laboratory using normal commercial procedures. Muscles to be subjected to pressure treatment were excised immediately after carcass wash (<35 min.), vacuum sealed in Cryo-o-vac bags and placed in a water bath at 30 to 35°C. All pressure treatments were completed in less than one hour past exsanguination. All treatment samples were removed from one half of the carcass with the matching muscles from the other half serving as controls. Control samples were removed after the control side had been chilled for 48 hours at 1± 1°C. Treatment consisted of placing the vacuum packed muscle in a pre-heated (35°C) chamber (10.16 cm in diameter and 30.48 cm long) filled with water and applying 103.5 MNm^{-2} of pressure for two minutes.

pH was measured immediately after pressure treatment and at 1,2,4,6 and 24 hours post mortem using a probe-type combined electrode.

Gross shortening of the semitendinosus muscle was measured by placing two marker strings, 20 cm. apart, through the muscle prior to its removal from the carcass.

Sarcomere lengths of uncooked samples were measured three days post mortem. Approximately 5 gm. samples of muscle were minced with a knife and blended in 40 ml. of 0.25 M physiological sucrose solution in a Waring blender at slow speed. Measurements were taken immediately after blending using a phase contrast microscope equipped with a filarmicrometer (500 X magnification).

Purge loss was determined by weighing the packaged samples after seven days of storage at 1±1°C, removing the samples, blotting them of excess moisture and weighing. All packing material for each sample was air dried and weighed and the difference between the sum of the latter two weights and the weight of the packaged sample was considered purge loss.

Shear forces were taken seven days post mortem. Samples were removed from the cooler, trimmed to approximately

equal weight, placed in plastic cooking bags and cooked in a water bath at 80±1°C for 40 min. to an internal temperature of 70±1°C. After the samples had cooled to approximately 45°C, rectangular pieces 1.25 X .8 cm running parallel to the fibers were removed and sheared in a Warner-Bratzler shear. Samples cooked as for shear test and by pan broiling were evaluated for tenderness by taste panels.

Water holding capacity was determined by a modified Grau and Hamm (1953) procedure. Approximately 3 g of lean tissue was placed on filter paper, covered by acetate film and subjected to 351.5 Kg/cm^2 of pressure for four minutes in a Carver laboratory press. Immediately after removal from the press the moisture and meat areas were traced on the acetate paper for later measurement by planimeter.

Scanning electron micrographs (400X) were prepared for control and pressure treated samples.

Data were analyzed by analysis of variance with significance of differences between treatments tested by F test.

Results and Discussion

The pH changes in L.D. and S.M. in sheep and S.T. muscles in beef followed a very similar pattern to that reported by MacFarlane (1973). The one hour pH of treated muscles was 5.80 to 5.82 while the controls were 6.48 to 6.63. This difference gradually narrowed as the pH of the control muscles decreased much more rapidly than the pressure treated samples until at 24 hr post mortem there was no significant difference between the pH of control and treated muscles. The one hour pH of treated samples indicates that glycolysis was almost complete in the treated samples at the end of pressure treatment.

Upon removal from the pressure chamber muscle samples were very firm to the touch and it was obvious that they had contracted substantially. The semitendinosus muscle has the most linear orientation of muscle fibers to muscle length of all those treated and was therefore used to determine the gross contraction from on carcass length to post treatment length. This contraction varied from 50 to 52% of the on carcass length. Sarcomere length measurements indicated a highly significant ($P<.01$) 9.38% difference in sarcomere length between the controls and treated samples which does not approach the level of gross muscle contraction. Observations under the phase contrast microscope revealed large quantities of globular material which would agree with the findings of Marsh et al (1974) who reported massive disruption of myofibrillar material under extreme cold shortening and MacFarlane's (1973) suggestion that an F-G transformation accounted for the tenderizing effect from pressure induced shortening. Under these circumstances it is quite likely that the myofibrillar fractions which were measured for sarcomere length in the treated samples were those which had not contracted sufficiently to cause disruption. It should be pointed out that we do not know what the degree of contraction was while the muscle was under pressure. Marsh (1977) in discussing super cold shortened meat stated, "The end product is so distorted as to be entirely inacceptable to the consumer." We did not find this to be the case with the muscle we treated. However, distortion could be a problem with large multi-muscled commercial cuts.

Table 1. EFFECT OF PRESSURE ON W-B SHEAR FORCE VALUES OF TWO MUSCLES FROM SHEEP AND FOUR MUSCLES FROM CATTLE.

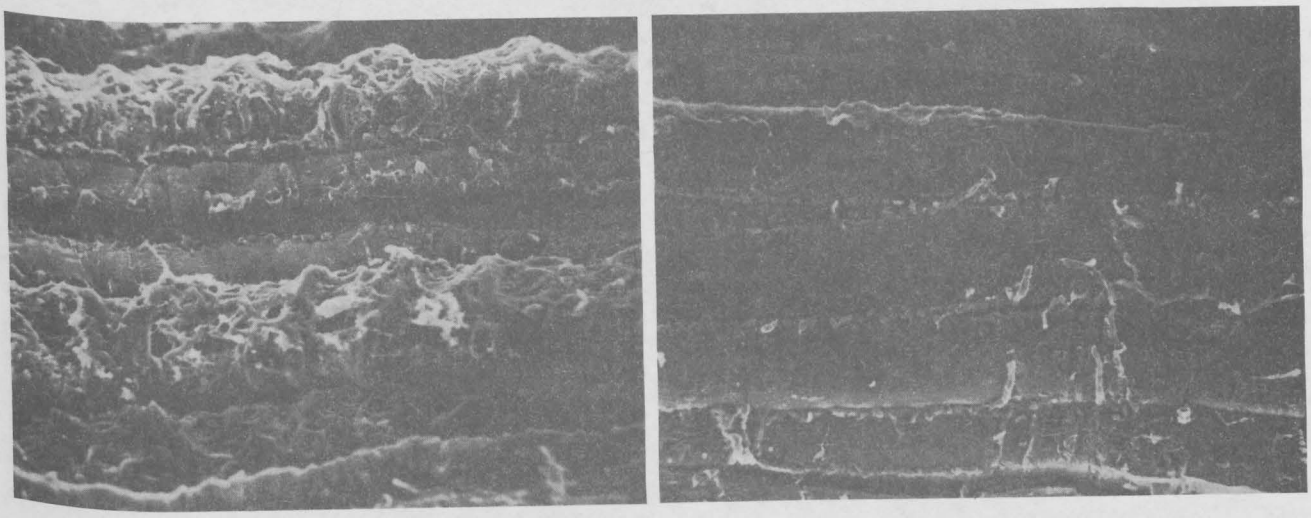
Muscle	Treatment	Shear force values Kgcm^{-2}	S.E.
(Sheep)			
Longissimus dorsi	C	5.74^a	0.68
	P	1.85^a	0.54
Semimembranosus	C	6.26^b	0.89
	P	2.30^b	0.49
(Cattle)			
Longissimus dorsi	C	8.39^c	0.37
	P	2.99^c	0.27
Semitendinosus	C	6.17^d	0.25
	P	4.51^d	0.15
Supraspinatus	C	7.13^e	0.69
	P	4.35^e	0.53
Sternomandibularis	C	14.97^f	0.64
	P	5.80^f	0.89

C = control
P = pressure treated
S.E. = standard error
a,b,c,d,e,f Values bearing the same superscript are significantly different ($P<.01$).

The percentage of purge loss was significantly higher ($P<.05$) for the treated samples (5.34) than for the controls (3.80). The water binding capacity, as measured by the filter paper press method was lower ($P<.05$) for all treated muscle samples (35.38) of beef and sheep than for the controls (40.16). However, cooking losses were less so that the percentage of the initial excised samples represented by the cooked meat did not differ significantly between controls and treated samples.

As shown in table 1 pressure treatment had a highly significant ($P<.01$) tenderizing affect on sheep (L.D. and S.M.) and cattle (L.D., S.T., S.S. and S.M.) muscles. Taste panels were not used as extensively in this study as was the shear test. In tests of two beef muscles (S.T. and S.S.) tenderness ratings were improved from a rating of slightly tender to very tender.

The results reported in this paper agree very closely with those reported by MacFarlane (1973).



A B

Figure 1. Scanning electron micrographs of treated A. (103.5 MNm^{-2}) and control supraspinatus muscle (400X).

Early attempts (Marsh and Carse 1974) to explain the length-tenderness relationship based only on myofibrillar contractile state may now be in doubt (Rove, 1974) and Danfield and Rhodes (1976) have suggested an interaction between contractile filaments and connective tissue. If a muscle fiber contracts beyond the ability of the changing angle (Bendall, 1973) of the inextensible collagen fiber of the endomysium to compensate for the increased diameter of the muscle fiber, some physical breakdown of the collagen fibers seems inevitable.

Figure 1 presents electron micrographs of pressure treated (A) and control (B) samples of S.S. muscle (L.D. and S.T. showed similar results). A close inspection of figure 1A reveals that the sarcolemma of some muscle fibers is extensively and regularly convoluted, suggesting that there is an interaction between the contractile filaments and the connective tissue. Other fibers are extensively frayed and this fraying was even more evident in other samples. It appears from this evidence that contraction caused by pressure treatment reduces the connective tissue or "background" toughness.

Summary

Muscles were removed from the carcass immediately after dressing and washing, trimmed of all external fat and connective tissue, put in plastic bags, all air was evacuated following which the samples were put into a pre-heated (35°C) chamber and subjected to 103.5 meganewtons/M^2 of pressure for two minutes.

The samples were very firm to the touch when removed from the chamber and had contracted to as little as 48% of their own carcass length. Sarcomere length measurements indicated a 9.38% contraction and that there had been extensive fiber disruption. Immediate post-treatment pH was 5.81, significantly lower than controls, however, there was no significant difference at 24 hours. Water binding capacity of the treated samples was significantly less and purge loss significantly higher than the controls. However, cooking losses for the treated samples were less, resulting in an over all loss which was not different between the controls and treated samples.

W.B. shear tests and taste panel evaluations both indicated a highly significant improvement in tenderness. Scanning electron micrographs show an extensive disruption of the sarcolemma and large masses of globular material seen under phase contrast microscope indicate an extensive disruption of fibrilar material of the muscle.

Literature Cited

Bendall, J.R. Geometrical restraints on the connective-tissue of muscle during shortening and lengthening. Meat Res. Inst. Meno. No. 20. Meat Res. Inst., Langford, Bristol. 1973.

Brown, D.E.S. Temperature-pressure relations in muscle contraction, In "Influence of Temperature on Biological Systems," ed. Johnson, F.H., p 83. American Physiological Society, Washington, D.C. 1957.

Grau, R., R. Hamm and A. Bauman. Water binding capacity of mamalian muscle. The influence of pH values on water-binding of ground beef muscle. Biochem. 325:1. 1953.

Johnson, F.H., H. Eyring and M.J. Polissar. "The Kinetic Basis of Molecular Biology," p 286. J. Wiley & Sons, Inc., New York. 1954.

Johnson, F.H. and H. Eyring. The kinetic basis of pressure effects in biology and chemistry. In "High Pressure Effects on Cellular Processes," Ed. Zimmerman, A.M., p 2. Academic Press, New York. 1970.

Locker, R.H. Striated patterns of ox muscle in rigor mortis, J. Biophys. Biochem.Cytal. 6:419. 1959.

Locker, R.H. Degree of musclular contraction as a factor in tenderness of beef. Food Res. 25:304. 1960.

Locker, R.H. and C.J. Hagyard. A cold shortening effect in beef muscle. J. Sci. Fd. Agric. 14:787. 1963.

MacFarlane, J.J. Pre-rigor pressurization of muscle: effects on pH, shear value and taste panel assessment. J. Food Sci. 38:294-298. 1973.

Marsh, B.B. and M.G. Leet. Studies in meat tenderness. 111. The effect of cold shortening on tenderness. J. Food Sci. 31:450. 1966.

Marsh, B.B. The nature of tenderness. Proc. of the 30th R.M.C. of the Am. Meat Sci. Assn. In print. 1977.
Marsh, B.B., N.G. Leet and M.R. Dickson. The ultrastructure and tenderness of highly cold-shortened muscle. J. Fd. Technol. 9:141-147. 1974.

Oregon Agricultural Experiment Station Technical Paper Number 4840.