PE7.15 Effect of heating on the transverse adhesion of collagen fibers 167.00

J. Lepetit (1) phyllis.shand@usask.ca, P. J. Shand(2), ,
(1)National Institute for Agricultural Research, Canada
(2)University of Saskatchewan, Canada

***Abstract*—The mechanical properties of a composite fibrous material depend on the properties of the fibers, of the matrix and of the interactions between them. The purpose of this work was to investigate the evolution of the adhesion between collagen fibers and the extracellular matrix when the tissue is heated. A peel test was applied on small samples of bovine *longissimus* epimysium to measure the transverse adhesion. The energy of peeling per surface is calculated. After 30 min of heating at 55°C, the energy of peeling was approximately the same as for the tissue in the raw state. It decreased by half between 60 and 65°C. After heating at 75°C, 25% of this energy still remained. These results show the destruction of the adhesive elements of the matrix with aqueous heating.**

J. Lepetit is with the National Institute for Agricultural Research. Unit Quality of Animal Products, 63122 Saint Genès Champanelle, France. e-mail: Jacques.Lepetit@clermont.inra.fr
P. J. Shand is Professor of Meat Science at the Department of Food and Bioproduct Sciences, University of Saskatchewan, Saskatoon, Saskatchewan, Canada. S7N 5A8 email: Phyllis.shand@usask.ca

***Index Terms*— epimysium, extracellular matrix, collagen, peel test.**

I. INTRODUCTION

THE extracellular matrix plays an important role in the mechanical properties of raw connective tissues. It is made of proteoglycans, glycoproteins and of other molecules with adhesive properties. There are several types of proteoglycans which vary in amount among muscles [1]. During storage there is a decrease in the quantity of proteoglycans and consequently a decrease in raw perimysium strength [2]. In a study using eight pork muscles, a positive correlation of 0.49 was found between proteoglycan quantity and the shear force of raw meat [3]. A decrease in the strength of the perimysium of *semitendinosus* muscle from heifers during conditioning was observed for raw meat and in meat cooked at 50° C for 1hr, but not in meat cooked at higher temperatures [4].

For a better understanding of the sources of variations in meat tenderness, it is necessary to know accurately what happens to the matrix compounds during heating. Very little is known about their thermal stability [4]. The denaturation of these compounds during heating will affect the force of adhesion between the extracellular matrix and collagen fibers. The purpose of this work was to quantify changes in adhesion between collagen fibers and the matrix as a result of aqueous heating.

II. MATERIALS AND METHODS

Epimysium sheets were removed at 48 hr postmortem from the *longissimus dorsi* of 2 cows (6 and 7 years old) and were frozen at -20°C. Before use they were thawed at room temperature. Samples of approximate dimensions, length=100 mm, depth=15 mm and thickness=5 mm, were cut, with the longest dimension in the direction of collagen fibers, i.e., along the longitudinal axis of the *longissimus dorsi*.

Samples were selected randomly and subjected to thermal treatments (30 min in a water bath at temperatures of 55, 60, 65, or 75°C). During heating samples were free to contract and swell and the final dimensions of the samples after heating were measured with a micrometer. All the mean values presented were obtained from 7 to 10 samples.

In preparation for the peel test, a cut of 20 mm length was done at one end of the sample giving a Y shape. The two parts on either sides of the cut are used to grip the samples (Figure 1). The samples were extended using a TMS Pro texture system (Food Technology Corp., Sterling, Virginia, USA) at a rate of 200 mm/ min until complete separation.

From the force–distance curves (Figure 2) the breaking energy was calculated. The first part of the diagram is due to the extension of the fibers and is removed from the calculation of the energy. Using the thickness and length of the sample after heating the energy is expressed in mJ/mm^2 and corresponds to the energy per unit of surface area created during the test.

III. RESULTS AND DISCUSSION

The peel test has been used by various food and non-food industries to measure the interfacial adhesion between various materials. This work illustrates its utility during the tearing of bovine connective tissue to document changes in adhesive force following aqueous heating.

At the beginning of the peel test there is a phase where collagen fibers are progressively stretched producing a continuous increase in stress without a break in the fibers (Figure 2, at displacements below 8 mm). The amplitude of this phase increases with temperature because collagen fibers become more elastic. Then at a certain level of stress the samples begin to break, and show successive breaks (Figure 2, region between the dotted lines).

As shown in Figure 3, the peeling energy does not significantly change between raw samples and those heated at 55°C for 30 min. At heating temperatures above 55°C, the peeling energy deceases rapidly. Following 75°C heating, about 25% of the initial energy remains.

The peeling energy represents the energy necessary to create two surfaces, i.e., to separate the sample in two. There are several compounds involved in adhesion of the matrix to collagen fibers which have their own temperatures of denaturation and kinetics. Figure 3 shows that these compounds become progressively weaker with temperature but are still present at 80°C.

The breakage of molecules of adhesion in the tissue due to thermal treatment may be explained either as a simple denaturation process or as a mechanical stress. As a matter of fact, a stress-induced breakage of molecules of adhesion during heating must be considered as epimysium tissue swells and contracts with heating which modifies the distance between collagen fibers both in the longitudinal and transverse directions.

IV. CONCLUSION

In a tissue with well oriented fibers such as epimysium, the adhesion between fibers can be easily quantified by a peel test. This work has shown that matrix modifications occur above 55°C and continue until 75°C. For rapidly cooked meat for which the core temperature is around 60°C, the contribution of the extracellular matrix to texture must be considered.

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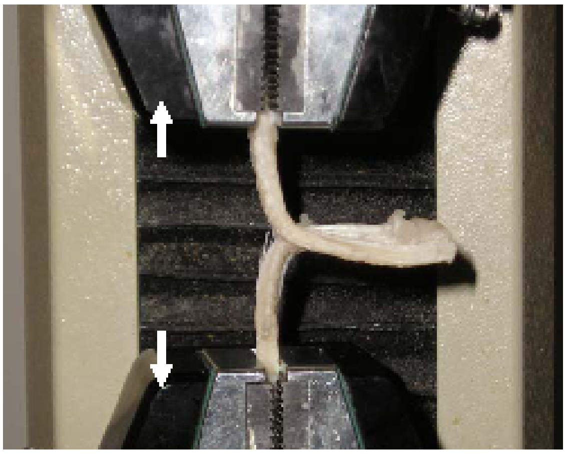

Figure 1: Epimysium sample during the peel test.

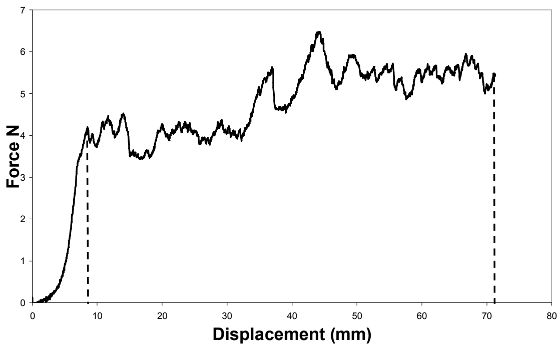

Figure 2: Force displacement curves from the peel test of an epimysium sheet. The peeling energy is calculated as the area under the curve and between the two dotted lines.

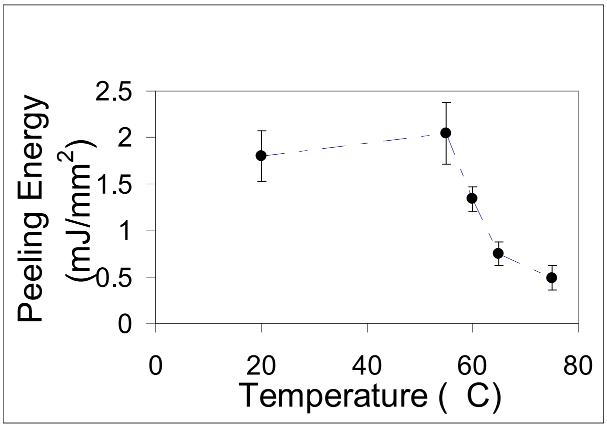

Figure 3: Variation of the peeling energy with temperature following heating in a water bath for 30 min.