MEAT CHANGES DURING CHEWING IN YOUNG AND ELDERLY SUBJECTS.

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Key words : chewing, bolus formation, elderly, meat

Background :

Acceptability of meat during consumption is mainly driven by texture perception (Harris, 1972). This perception is elaborated during chewing (Mathevon *et al.*, 1995; Mathonière *et al.*, 2000). With aging, chewing behaviour and efficiency evolve, which can influence the formation of the bolus and, as a consequence, meat acceptability. Indeed, when chewing problems occur, often associated with age, meat is usually found among the most rejected foods (Veyrune and Mioche, 2000).

A better understanding of the mechanisms underlying texture perception requires to identify the relationship between meat texture before chewing and the properties of the food bolus ready to be swallowed. During chewing, meat sample is mashed under compression, tension and shear bite forces whilst saliva is incorporated. The resulting mixture is shaped into a cohesive bolus by agglomeration of small particles, the characteristics of this bolus triggering a swallow. The influence of texture on various aspects of the masticatory process has been shown by several workers (Plesh *et al.*, 1986 ; Hiiemae *et al.*, 1996 ; Agrawal *et al.*, 1998 ; Mioche *et al.*, 1999) and mastication process during meat chewing has been documented (Mioche *et al.*; 2002). However, the relationship between the texture of the food and the characteristics of the bolus at swallow are unknown. Models of bolus formation were developed using brittle foods (Lucas and Luke, 1983 ; Prinz and Lucas, 1997) but bolus properties with cohesive food like meat are only sparely documented (Lillford, 1991).

Objectives :

This study aims to investigate 1) the relationship between the structure and mechanical properties of meat and the corresponding characteristics of the bolus at the time of swallowing and 2) the influence of aging in chewing behaviour and its consequence in bolus formation.

Methods :

Subjects:

Twenty five healthy young human subjects (11 female, 14 male, age range 25-30) and 20 healthy elderly persons (11 female, 9 male, range age 68-73) participated in this study. A full dental examination was performed and all had at least 6 pairs of natural post-canines teeth. All subjects gave informed consent and the protocol was approved by the Regional Ethic Committee.

Samples :

Two different textures (1 and 2) of beef meat were obtained from the same muscle (*Semimembranosus*) obtained by combining different aging times and cooking temperatures ad modem (Mathevon *et al.*, 1995). One half of the muscle was aged 2 days at 4°C and then cooked at 80°C (Texture 1). The other half was aged 14 days at 4°C and then cooked at 65°C (Texture 2). After cooking, meat was vacuum-packed, placed at -20°C (maximal storage 3 month) and then cut into cubes (4.7g ± 0.5). Just before use, the samples were thawed by immersing the packs in a 15°C water-bath for 1h.

Data acquisition :

Subjects were asked to chew normally cold meat samples without swallowing and then to spit out the bolus when swallowing would normally have been triggered. Without prior warning subjects were told, in some experiments, to stop after a short chewing time (7 s.) : this produced bolus formed during a standard chewing period for all subjects. Deglutition was monitored with a necklace strain gauge and trials presenting unexpected swallows were discarded.

Texture order and chewing conditions were randomised among subjects and two replicates were performed for each condition thereby giving eight bolus per subject.

Food bolus analysis :

The meat samples were weighed before and after chewing to appreciate saliva impregnation. Bolus with a decrease in weight after chewing were discarded.

The mechanical properties of the food bolus were measured by applying a shear test (Salé, 1970). After thawing at room temperature, individual bolus were gently placed into a U-shape mould (70 x 10 x 10 mm). Samples then had a section of 10 x 10 mm with a length depending on the bolus size. After removal from the mould, they were sheared using a double-bladed cell with a displacement rate of 60 mm/min. Several measurements were performed on the same bolus, 5 mm apart from each other, without any interference from one measure to another one. The maximum shear force was calculated from the force-distance curves and expressed as stress relative to the initial bolus section area. Three to five replicates per bolus were performed to get information about structure homogeneity.

Mastication recordings and analysis :

The left and right superficial *masseter* and *anterior temporalis* muscles of each subject were recorded. The EMG signals were filtered (0-10 kHz) and amplified (x 500). Five variables were determined from each of the 4 recorded muscles and then pooled : Chewing time (only when sequence lasted up to the swallowing time), Number of bursts (closing and occlusal phase of the chewing cycles), Mean voltage of bursts, Muscle work per chew and Total muscle work (sum of the integrated areas of all individual bursts of the sequence expressed in mV.s).

Statistical Analysis :

The SAS General Linear Model procedure was used to study the effect of meat texture on EMG variables. When the F ratio was significant, Student-Newman and Keuls test was used to compare the differences of the means. Samples were designed to have the same weight, but they showed slight differences in weight (4.7 ± 0.5 g). To avoid any bias due to the samples weight, this variable was introduced as a co-variable in the GLM model. Texture effect was tested using subjects nested by sex as an error term.

Results and Discussion

During chewing, meat mechanical resistance rapidly decreased, especially for the young subjects (Figure 1). For these subjects, the shear stress difference between the two meat samples remains significant until swallowing, the toughest meat giving the toughest bolus. In contrast, for the elderly subjects the shear stress difference became no longer significant after a 7s chewing period. However, the mechanical resistance of the bolus was always higher for the elderly than for the young subjects.

Variations in meat sample weight during chewing did not allow to identify specifically meat juice loss and saliva incorporation. Therefore, saliva intake during bolus formation was probably underestimated. The amount of saliva incorporated into the bolus was the highest for the tougher meat but this effect was significant only for young adults (Table 1). In contrast, no age effect was found on the amount of saliva incorporated in the bolus at the time of swallowing. This could be explained by the lengthening of the chewing duration observed for the elderly group. Indeed, a significant age effect was found on chewing behaviour : Elderly subjects chewed with less force (muscle work/chew) but they applied a greater number of chewing cycles and finally developed a larger total muscle work than young subjects. However, the elderly chewing was less efficient to comminute a meat bolus than that of young subjects. In addition, texture had a significant effect on all chewing variables for the young subjects, whereas only a slight significant texture effect was observed on the number of chews and the total muscle work for the elderly subjects.

Figure 1: Variations with chewing time in the shear resistance of meat bolus.

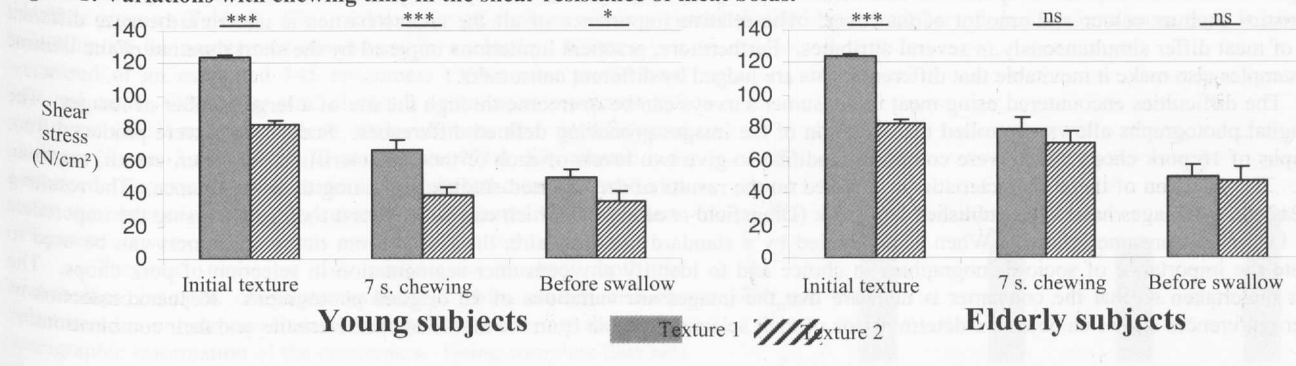

Table 1: Influence of meat texture on salivation, bolus mechanical resistance and EMG variables.

Texture Effect		*Young Subjects*				*Elderly Subjects*				*Age effect*			
		F	p	T1	T2	F	p	T1	T2	F	p	Young	Elderly
Salivation	Weight bolus increase (g)	**11.47**	**	**1.92**	**1.47**	1.37	ns	1.75	1.57	3.76	ns	1.69	1.6
Food bolus	Shear Stress (N/cm²)	**6.03**	*	**39.49**	**32.26**	0.74	ns	49.9	49.0	**40**	***	**37.5**	**39.5**
Chewing	Number of chews	**13.78**	**	**45.12**	**36.02**	**3.6**	*	**57.13**	**47.66**	**60.85**	***	**40.52**	**52.86**
	Muscle Work / chew	**14.64**	***	**0.17**	**0.14**	1.29	ns	0.16	0.15	**13.61**	***	**0.17**	**0.15**
	Total muscle work	**13.41**	**	**7.96**	**5.31**	**4.16**	*	**8.73**	**7.36**	**16.90**	***	**6.62**	**8.11**

In conclusion, meat undergoes important structural changes during chewing (breakdown of fibres and saliva incorporation). These changes depend on chewing behaviour which is modified during aging. The properties of the meat bolus can then be influenced by the age of the subject, which can explain the variations in meat acceptability and could impair protein digestibility.

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Acknowledgement

This work was part of the Healthsense Project supported by the European Commission Quality of Life and Management of Resources Fifth Framework Program QLK1-CT-1999-00010.