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Sensory capability of young, middle-aged and elderly Irish assessors to identify beef steaks of varying texture

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1. Abstract

This study assessed the capability of various Irish assessor age cohorts to identify beef steaks of varying texture. Varying steak textures Moderately Tough (M_{TH}), Moderately Tender (M_{TR}) and Tender (T_R) were achieved by aging beef longissimus thoracis et lumborum (LTL) muscle for 2, 7 and 21 days respectively. Warner Bratzler Shear Force (WBSF) was measured to standardise the samples. Sensory evaluation was carried using 428 participants; 18-30 yrs (years) (n=143), 31-60 yrs (n=80), 61-75yrs (n=99) and 76-85 yrs old (n=106).

Within 6 age cohort categories (18-70), significant positive and negative correlations were observed for T_R and M_{TH} tenderness categories respectively. Poor identification of tenderness classification was found in the 71-85 age cohort groupings. Consequently more research is required in this area so that guidelines could be presented for industrial uptake

This study supports the hypothesis that changes in textural perception occur with age in humans.

Keywords

Texture; elderly; sensory decline; meat avoidance.

2. Introduction

The term 'elderly' has been defined as a chronological age of 65 years old or older, while those aged between 65 to 74 years old are referred to as 'early elderly' and those over 75 years old are termed 'late elderly'(Orimo et al., 2006)**.**

Older persons aged 65 and over accounted for 18.9% of the European Union (EU) population in 2010. This was an increase of 0.4% from the previous year and the previous ten years of 2.3%. It is expected that those aged 65 years and over will account for 28.7% of the EU population by 2080 (Giannakouris, 2008).

In the 2011 Irish census, there were 535,393 people in Ireland over the age of 65. This was a 70% increase from the previous census carried out in 2006. The aged population is predicted to increase further by 2041; the number of people aged 75 and over in Ireland is estimated to reach almost 1 million. The number of Irish 85+ year olds is predicted to increase from the 2006 figure of 74,000 to 356,000 by 2041 (CSO, 2012). With this forthcoming increase in the elderly population, great economic challenges are anticipated, in addition to the enormous pressures that will be exerted on healthcare facilities and associated services.

High protein diets continue to gain scientific interest in their ability to preserve lean mass, promote weight loss, prevent weight regain following weight loss or to maintain a healthy weight throughout the lifespan (Paddon-Jones & Leidy, 2014). A collection of data from muscle protein anabolism, appetite regulation and satiety studies suggests meeting a protein threshold of approximately 30g/meal. This represents a strategy for middle-aged and older adults concerned with sustaining muscle mass while controlling body fat (Paddon-Jones & Rasmussen, 2010; Arciero et al., 2013). Currently in Ireland, 37% of the population's protein intake is obtained from meat and meat products (IUNA, 2001). Thus, it is in the Irish beef industries best interest to ensure all of the populations textural preferences are catered for.

Evaluation of texture is a complex and dynamic process that includes visual perception of the surface of the product, product behaviour in response to previous handling and integration of in-mouth sensations experienced during mastication and further swallowing. Texture evaluation should be carried out by a sensory panellist, as it determines the sensation perceived by the panellist when consuming the product. As we chew and swallow, texture-related sensations are perceived, along with the sensory aspects of taste and flavour (Stokes, Boehm, & Baier, 2013). For the elderly who are unable to swallow due to dysphagia, declining sensory perception and saliva production, a decrease in food pleasantness may be perceived (Finkelstein & Schiffman, 1999). Unfortunately, an indifference to consuming meat, and indeed other food products, will result in various malnutrition forms which will subsequently lead to various life-limiting diseases.

Beef is a muscle food whereby texture plays an important sensory characteristic. Meat quality is a complex term involving many attributes including; colour, texture and flavour. Tenderness is viewed as the most important characteristic associated with beef palatability (Smith, Tatum, Belk, & Scanga, 2008; Jaramillo, 1994; Miller, Carr, Ramsey, Crockett, & Hoover, 2001). While this is understood, little is known with regard to how the meat quality parameter is defined in respect to consumer classification. What is known is that by improving tenderness, consumer's acceptance for muscle foods increase (Campo et al., 2000). Many studies examining the relationships between muscle aging on instrumental texture and sensory assessments have been highlighted in a review carried out by Muchenje et al. (2009). The review demonstrates the ranges of sensory scores for some meat quality characteristics (aged for 2-21 days) as reported in the literature. It was found that sensory values for tenderness tend to be high as the aging times increase. Muchenje et al. (2009) reported that the important meat quality characteristics are indeed tenderness, flavour and colour and they concluded that factors affecting meat eating quality include improving the body condition of animals before slaughter, reducing pre-slaughter stress, ageing meat correctly, and developing appropriate feeding management strategies.

There are many studies comparing sensory characteristics between elderly and younger consumers, whereby deterioration in the senses was noted as humans aged. Mojet (2003) studied various taste perceptions and their effects on human ageing. NaCl, KCl, sucrose, aspartame, acetic acid, citric acid, caffeine, quinine, hydrochloric acid (HCl), monosodium glutamate (MSG) and inosine 5' monophosphate (IMP) were dissolved in water and food products. Participants ranged in age from 19-75 years (n=42). It was found that the intensity rating decreased with age for all tastants in water, but only for the salty and sweet tastants in products.

Yoshinaka et al. (2015) investigated three age groups for taste sensitivity. The ages ranged from 24-71 years (n=2015). Recognition thresholds for the four basic tastes were measured using a whole mouth gustatory test. The authors concluded that there are age differences in sensitivity between various age groups.

To date, most research has focused on the flavour differences in foods as perceived by different age cohorts. Oral perception decline, olfactory perception decline, badly fitting dentures, medications, social and socio – economic factors all play a role in meat avoidance in the elderly. However, relatively little is known about the effects that consumer aging has on meat textural preferences.

The main objectives of this study are as follows:

1) Determine the influence texture has on sensory properties of steak

2) Study the perception of tenderness in different age populations

3) Determine if differences in liking could affect beef consumption habits of the elderly in Ireland.

3. Materials and Methods

3.1 Sample Preparation

Beef longissimus thoracis et lumborum (LTL) muscle was purchased from a local abattoir; Ballyburden Meats, Ballincollig, Co Cork. The animals all featured the following euro grades; E, R, 3. All animals were the same breed; Limousin, the same age at slaughter; 2 years old and the same sex; female. Six primals (striploin) were purchased from three animals. The six primals were dry aged in the abattoir at a constant humidity of (80%) prior to delivery. All primals were subsequently cut into sub-primal pieces (steaks) (25.4mm x 25.4mm). All steaks were pooled and randomly analysed to one of the three wet aging periods; 2, 7, or 21 days (M_{TH}, M_{TR}, $T_{R)}$ respectively. The steaks were aged in sealed vacuum bags (Vacuum pouch PA/PE 90 Niederwiser ($O_{2:}$ 50 cm^3/m^2/24h/bar, N_2: 10 cm^3/m^2/24h/bar, $CO_{2:}$ M150 cm^3/m^2/24h/bar) at 4°C. The steaks were then placed into laminated pouches (as described above), labelled and vacuum packed. These packs were then blast frozen (Foster, Mod BF35, Norfolk, UK) and stored at -18°C until the steaks were required. Upon requirement, steaks were defrosted at 4°C for 24 hr prior to cooking. Triplicate measurements were carried out on the three individual steaks at each aging time. All steaks used for sensory assessment were also analysed for physical and chemical analysis. All analyses (proximate and physiochemical) was carried out three times on triplicate steaks from each treatment: M_{TH}, M_{TR}, T_R.

3.2 Cooking

Oven cooking of the steaks was chosen as the cooking method as it was deemed to be a relatively easy cooking approach, provided consistent results and was easily replicated. All steak samples were wrapped in aluminium foil, labelled and dry-cooked at 150°C in a Zanussi convection oven (C. Batassi, Conegliano, Italy) for 20 minutes to an internal temperature of 73°C, as measured by a temperature probe (Testo 110, Lenzkirch. Germany).

3.3 Proximate Compositional Analysis

Protein Content

The Kjeldahl method, with slight modifications was used to determine the protein in steak samples (Suhre, Corrao, Glover, & Malanoski, 1982), and percentage protein was calculated using a nitrogen conversion factor of 6.25. This method was in accordance with the work outlined by Tobin, O'Sullivan, Hamill, & Kerry (2013).

Ash Content

The ash content of was determined gravimetrically using a furnace at 550°C (Nabertherm GmbH, Lilienthal, Germany). (AOAC, 1996) method 920.153.

Moisture & Fat Content

A SMART Trac system (CEM GmbH, Kamp-Lintfort, Germany) was used to measure the percentage moisture and fat. Approximately 1.0 g of each of the homogenised vacuum packed steak samples were measured in accordance with the methods used by Bostian, Fish & Webb (1985).

Carbohydrates

Total carbohydrates was determined by difference: A hundred grams minus the addition of protein, fat, water and ash in grams, expressed as a percentage.

3.4 Sensory Analysis

Recruitment

Panellists of varying age cohorts were recruited for this study. Panellists were chosen in compliance with the following criteria; community dwelling, healthy, not on a pre-described diet, did not have a food allergy, did not have any difficulties swallowing, and were regular consumers of beef steak. The subjects were recruited from University College Cork and from active retirement groups based around the Cork region. The assessor cohorts were derived from various socio-economic backgrounds and were gender balanced. The panellists completed a questionnaire prior to participating in the sensory evaluation. They included their annual income by ticking a box from the following options; ≤ €20,000, €20,000 - €50,000 or ≥ €50,000. The elderly participants completed a questionnaire indicating if they had a medical card or not. Recruitment was divided equally around these socio-economic factors. All participants indicated their gender in the questionnaire. They also signed a declaration indicating they did not have any difficulties swallowing food.

Sensory Evaluation

Sensory analysis was carried out on 428 participants. Ages ranged from 18-85 years and categories ranged as follows; 18-30 (n=143), 31-60 (n=80), 61-75 (n=99), 76-85 (n=106). The age categories were subdivided into 9 age cohorts; 18-30, 31-40, 41-50, 51-60, 61-65, 66-70, 71-75, 76-80 & 81-85.

Sensory analysis was carried out in the sensory kitchen in University College Cork. The kitchen features sensory booths and conforms to (ISO, 1998) standards. The samples were assigned random three digit codes. Sensory analysis was also carried out on triplicate batches presented to the panellists in duplicate. Assessors were asked to rinse their mouths with water in between each sample. The panellists were asked to rate the coded and randomised order samples using an hedonic eight-point scale (AMSA, 1995). The following attributes were assessed: tenderness, overall flavour, overall firmness, overall texture and overall acceptability (AMSA, 1995).

3.5 Physical Analysis

Texture Analysis

Texture profile analysis (TPA) was used to determine the texture of the samples instrumentally. All samples (cooked) were analysed in triplicate, using a Texture Analyser 16 TA-XT2i (Stable Micro Systems, Godalming, U.K). Three individual (10mm x 10mm) cylindrical slices (cores) of steak were taken from each sample and a duplicate sample. The steak cores then underwent a two–cycle compression test using a 25kg load cell. The samples were compressed using a 35mm diameter cylindrical probe (SMSP/35 Compression plate). A cross–head speed of 1.5 mm/s was employed. The deformation percentage employed for this experiment was 50%.

The texture profile descriptors measured included the following:

Hardness (N) - represents the maximum force required to compress the steak at the first bite, springiness (mm) – represents the ability of the sample to return to its original state after deformation, adhesiveness (N x mm) – represents the part under abscissa, post initial compression, chewiness (N) – represents the work required to masticate the steak to a state that can be swallowed, resilience (dimensionless) – represents the ratio of work carried out between the negative and positive force input during the first compression and cohesiveness - (dimensionless) represents the ratio of work carried out between compressions.

Warner–Bratzler Shear Force

Shear force was measured according to the methods of Shackelford, Morgan, Cross & Savell, (1991). Each steak was placed in an individual plastic bag and sealed. It was then placed in a water bath (Model B21, Fisher Scientific GmnH, Schwerte, Germany). Steaks were cooked to an internal temperature of 75°C and refrigerated overnight at a temperature of 4.4°C. Ten core samples were obtained from each steak. Three steaks from each treatment were analysed. They were cored (n=10) parallel to the muscle fibre direction. Warner-Bratzler Shear force (WBSF) was measured using a T Analyser Stable Micro Systems testing machine with a Warner Bratzler V-shaped shearing device (Stable Micro Systems, England). The crosshead speed was 4 mm/s. Results were expressed as maximum shearing force/kg diameter core. The six closest samples to the mean were utilised as recommended by the experimental procedure. WBSF was used to standardise the samples prior to sensory testing.

Differences were noted between the three treatments as can be observed in Table 2. As a results of the difference derived from the Warner Bratzler texture analysis the samples were coded as follows; Moderately Tough (M_{TH}), Moderately Tender (M_{TR}) and Tender (T_R).

Cooking loss analysis

The samples were placed on aluminium plates and their initial weight was recorded. After cooking the samples were allowed to cool down at room temperate for approximately 20 minutes and then reweighed. Cooking loss was determined as the difference between cooked and raw weights expressed as a percentage of the raw weight.

3.6 Statistical Analysis

Triplicate measurements were carried out on the three individual steaks at each aging time. All analyses (proximate and physiochemical) was carried out three times on triplicate steaks from each treatment: (M_{TH}) (M_{TR}) and (T_R). One-way ANOVA was used to examine the data from instrumental analysis and compositional analysis. Tukey's post-hoc test was used to adjust for multiple comparisons between treatment means using SPSS statistics 20 software (IBM, Armonk, NY, USA. Data was presented as mean values ± standard deviation. Sensory was also carried out on triplicate batches presented to the panellists in duplicate. The data obtained from the sensory trials and the data obtained from the instrumental analysis was analysed using Unscrambler software version 10.3. (CAMO ASA, Trondheim, Norway). Data was processed using ANOVA–Partial Least Squares Regression (APLSR). The X-matrix was designed as different age categories and treatments. The Y–matrix were the sensory and instrumental variables. The optimal number of constituents in the APLSR models presented was concluded to be PC1 vs PC2. The APLSR model can be seen in Figure 1.

4. Results and Discussion

The range of values for compositional analysis can be seen in Table 1 and they are as follows: Protein 28.8 - 29.0%, fat 6.6 - 7.0%, moisture 62.2 - 62.7%, ash 1.3 - 1.4%, carbohydrates 0.3 - 0.6%, and cook loss 24.5 - 24.6%. There were no significant differences observed in the proximal compositional analysis of the steaks. These results were as expected as the composition of the beef steaks were not altered.

Results obtained for WBSF testing differed and the results are presented in Table 2. Values obtained for the varying treatments were as follows: sample M_{TH} (6.6 ± 0.14), M_{TR} (5.0 ± 0.48) and T_R (4.2 ± 0.19). Similar observations were noted previously by other researchers (Lorenzen, Neely, Miller & Tatum, 1999) and (Boleman et al., 1997), where aging of striploins improved WBSF results.

The TPA values are also presented in Table 2. Hardness (N), Springiness (mm), Chewiness (N), Resilience (dimensionless) all featured varying significant results between the three treatment groups. As hardness is the main factor deciding the commercial value of meat (Chambers & Bowers, 1993), it was important that hardness varied in the samples to assess the varying age cohort's value of commercial appeal and worth of the steak samples.

Results from assessor sensory evaluations are presented in the APLSR plot (Figure 1). The corresponding *P* values for regression co-efficients are presented in Table 3. The attributes associated with overall acceptability were flavour, tenderness, and texture. Firmness may have had a lesser part to play in overall acceptability. The results presented above showed six age cohorts categories aged between 18-60 years old, were capable of detecting at least one attribute difference in steak samples from either the 21 day (M_{TH}) or the 2 day ageing treatment (T_R) treatment group employed in this study.

The **18-30** age cohort were significantly ($P \leq 0.05$) negatively correlated to the 2-day ageing treatment (T_R) for overall acceptability. It was also significantly ($P \leq 0.001$) negatively correlated for flavour. This age category also significantly ($P \leq 0.01$) negatively correlated the 7 day (M_{TR}) aging treatment for flavour. The **31-40** age cohort were significantly ($P \leq 0.001$) positively correlated for the 21 day (M_{TH}) aging treatment for overall acceptability. This sample was significantly and positively correlated for tenderness ($P \leq 0.001$), flavour ($P \leq 0.001$), firmness ($P \leq 0.05$) and texture ($P \leq 0.001$). This age category also significantly ($P \leq 0.05$) negatively correlated sample T_R for overall flavour. The **41-50** age cohort significantly ($P \leq 0.05$) negatively scored overall acceptability for sample T_R. This age category also significantly ($P \leq 0.05$) negatively scored this sample for tenderness, flavour and texture. The **51-60** age cohort significantly ($P \leq 0.05$) positively scored sample M_{TH} for overall acceptability. This age category also significantly ($P \leq 0.01$) positively scored this sample for tenderness.

The **61-65** age cohort significantly ($P \leq 0.05$) positively correlated sample M_{TH} to overall acceptability. This sample was also significantly ($P \leq 0.05$) and ($P \leq 0.01$) positively correlated for texture and tenderness, respectively. Age-related textural differences were observed in younger assessors compared to that of the elderly cohort in this study. This has been previously shown by other authors for non-meat food products. For example, textural changes were shown to have a higher degree of pleasantness for elderly assessors when compared to younger test subjects when muesli products were evaluated (Kälviäinen, Salovaara, & Tuorila, 2002). Pleasantness was rated as lower by elderly subjects, compared to younger assessors, when both were presented with texturally-modified yoghurts (Kälviäinen, Roininen, & Tuorila, 2003). Age-related textural differences were identified in soups and it was shown that elderly and younger panel subjects differed in their texture–flavour interaction effects when soups were prepared with or without potato starch, with or without mushroom flavour and with water or with milk (Kremer, 2005). In another study examining the various textural preferences for carrots, it was determined that the young adults liked difficult textures such as rough, crispy, crunchy and hard to a far greater degree than the elderly respondents, but interestingly, the softer textures were not liked by either age group (Roininen, Fillion, Laurence Kilcast, & Lahteenmaki, 2003).

The **66-70** age cohort significantly ($P \leq 0.01$) negatively correlated T_R samples for overall acceptability. It was significantly and negatively correlated for tenderness ($P \leq 0.05$), flavour ($P \leq 0.01$), firmness ($P \leq 0.001$) and texture ($P \leq 0.05$). Figure 1 also displays the correlations of unacceptability for T_R samples by most assessors contained across all age categories. This can be observed in the left quadrant of Figure 1.

Booth, Conner, & Gibson (1989) suggested that older persons may adjust eating patterns and food preferences to account for diminishing sense of taste and smell. Engelen & Van Der Bilt, (2008) found that the physiological process taking part in the buccal cavity, such as salivation (saliva flow, rate and composition) tongue movements and temperate exchanges between food and oral cavity play a vital role in the perception of texture. It was also found that mastication and ability to swallow play a vital role in the perception of food texture. For example, in this study, the 66-70 age assessor category negatively correlated sample T_R for tenderness, whereas the 71-75 age assessor category positively correlated this sample for tenderness. This may be attributed to a diminished perception of texture.

Textural recognition by assessors became unclear in the **71-75** age cohort, as panellists failed to identify textural differences in steak samples along treatment lines and accepted tender and tough meat to the same degree. The 71-75 age cohort significantly ($P \leq 0.05$) positively correlated the T_R sample to overall acceptability. This was the only age category to do so. The M_{TH} sample was significantly ($P \leq 0.05$) positively correlated for tenderness and texture. The **76-80** age cohort and the **81-85** age cohort were not able to differentiate the different textures and aging times significantly. In another study, differences between two different age cohorts in relation to the texture and flavour perception of sweet and savoury waffles were examined. It was determined that poor textural sensitivity was not related to perception of sensory attributes (Kremer, Mojet, & Kroeze, 2007). Thus, changing preferences for texture as aging occurs, seems to be dependent on the food product being investigated.

Texture is defined as a dynamic interaction with time between a foods physical proportion and the senses of touch, sight and hearing (Engelen & Van Der Bilt, 2008). It could be hypothesised that this loss of textural acuity in meats may be due to poor dentition (Roininen et al., 2003), sensory decline as the aging process occurs (Morley, 2001), social factors, medications, physical and physiological issues (Donini, 2003). There are many factors which may be attributed to a changing preference for texture as the human aging process occurs and numerous studies are required to fully understand what these factors are, and how they impact and interact to affect textural perception.

Figure 1 displays the age groups over 61 years old dispersed all over the quadrants of the plot, when sample T_R is assessed. The M_{TR} samples can be seen on Figure 1 on the upper half of the hemisphere, with the exception of the 66-70 age category. The M_{TR} samples are illustrated on the left-hand side of the hemisphere in Figure 1, with the exception of the 76-80 age category. No significant differences were observed for the more senior participants involved in these trials.

As can be seen, steak aged from 2-21 days is not sufficient for the textural preferences of our elderly consumers. Consequently, this may result in a decrease in meat consumption by this age cohort. Therefore, the meat industry needs to adopt new practices, or amend current practices, in an attempt to modify meat texture to address the needs of this potentially significant consumer market.

5. Conclusions

In summary, this paper provides evidence for a difference in textural preference in various age cohorts. Those aged between 18 and 70 years old successfully identified the attribute differences between the meat sample groups of Moderately Tough (M_{TH}) and Tender (T_R) steak samples employed in the study. Attribute blindness was observed in sensory subjects aged from 71 years old. The over 75 age categories (late elderly) failed to recognise any eating quality difference between steak treatments. Currently, there is very limited information in the literature to support this finding and more research in this area is required, particularly as aging populations present a growing consumer market within which meat could play an important and necessary role. From this research it could be suggested that the elderly may not purchase beef due to its current tenderisation treatments. It can be concluded that while certain age groups could detect differences in tenderness between steak samples as consumers aged, they became less sensitive to tenderness, and in some cases, unable to detect differences at all. Consequently, it may be necessary to define tenderness values that would be detectable and acceptable to these consumer groupings. Therefore more research is required in this area so that guidelines could be presented for industrial uptake.

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7. Acknowledgement

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Table 1: Proximal compositional analysis and cook loss values for beef longissimus thoracis et lumborum (LTL) muscle wet aged for 2 days (Moderately Tough, M_{TH}), 7 days (Moderately Tender, M_{TR}) and 21 days (Tender, T_R) at 4ºC.

Sample	Protein (%)	Fat (%)	Moisture (%)	Ash (%)	Carbohydrates (%)	Cook Loss (%)
M_{TH}	29.0 ± 0.42^a	6.6 ± 0.32^a	62.7 ± 0.99^a	1.3 ± 0.25^a	0.3 ± 0.44^a	24.5 ± 0.34^a
M_{TR}	28.9 ± 0.13^a	7.0 ± 0.21^a	62.2 ± 0.66^a	1.4 ± 0.24^a	0.5 ± 0.59^a	24.5 ± 0.31^a
T_R	28.8 ± 0.45^a	6.6 ± 0.58^a	62.2 ± 1.30^a	1.4 ± 0.33^a	0.6 ± 0.38^a	24.6 ± 0.20^a

[a] = non-significant $P > 0.05$

Table 2: Warner-bratzler shear force (WBSF) and texture profile analysis (TPA) values for beef longissimus thoracis et lumborum (LTL) muscle wet aged for 2 days (Moderately Tough, M_{TH}), 7 days (Moderately Tender, M_{TR}) and 21days (Tender, T_R) days at 4ºC.

		TPA				
Sample	**WBSF (kg)**	**Hardness (N)**	**Springiness (mm)**	**Adhesiveness (Nxmm)**	**Chewiness (N)**	**Resilience (n/a)** ♦
M_{TH}	6.6 ± 0.14^a	140.13 ± 0.22^a	0.5 ± 0.02^a	-0.4 ± 0.1^a	57.5 ± 0.40^a	0.2 ± 0.02^a
M_{TR}	5.0 ± 0.48^b	122.18 ± 0.23^b	0.6 ± 0.03^b	-1.40 ± 0.3^b	46.0 ± 0.56^b	0.1 ± 0.01^b
T_R	4.2 ± 0.19^c	98.7 ± 0.52^c	0.7 ± 0.04^c	-0.02 ± 0.02^a	36.6 ± 0.34^c	0.2 ± 0.01^c

^{abc}Mean values (± standard deviation) in the same column bearing different superscripts are significantly different, $P < 0.05$

♦ (n/a) resilience measurement is dimensionless

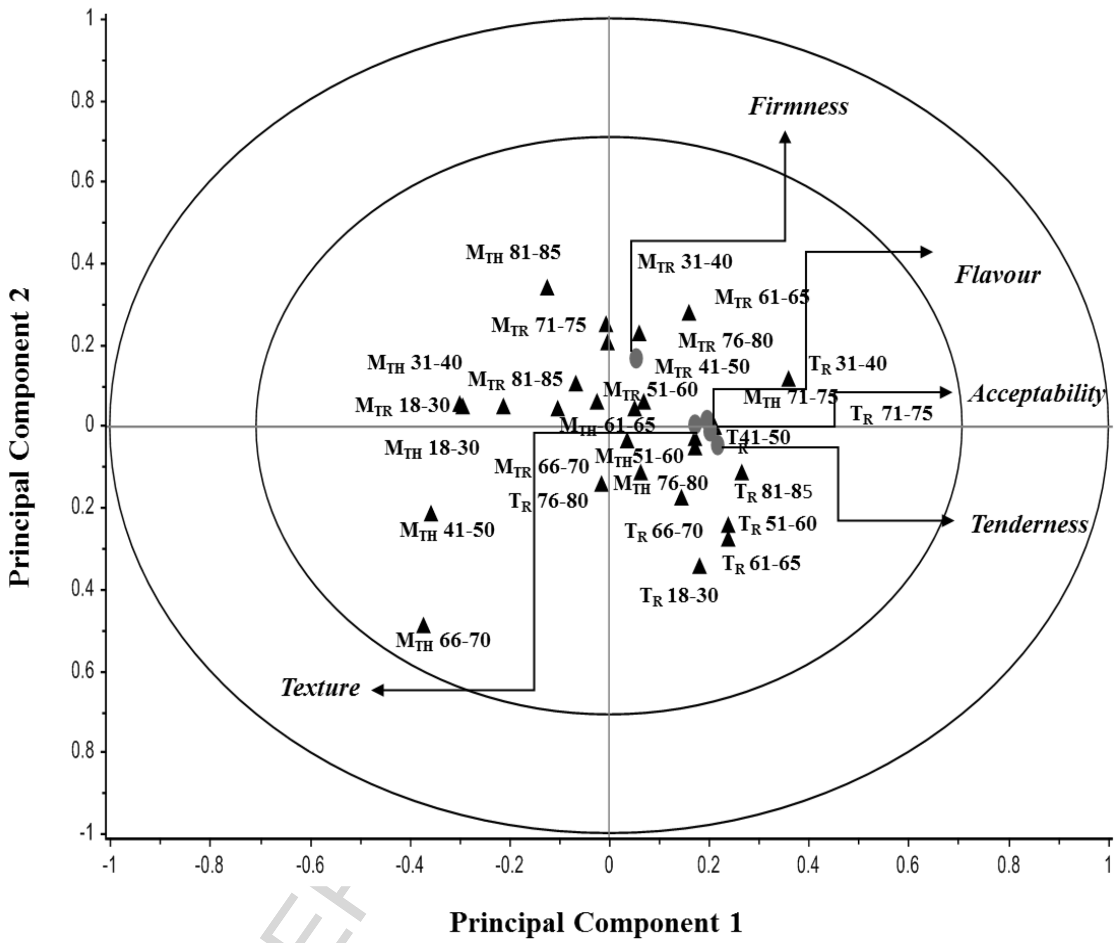

Figure 1: ANOVA - partial least squares regression (APLSR) correlation loading plot for each individual treatment, age category and sensory descriptor.

An overview of the loadings of the X and Y variables for the first two PCs for the individual treatments and age categories V's sensory descriptors

Treatment: Moderately Tough (M_{TH}) Moderately Tender (M_{TR}) and Tender (T_R)

and age categories: 18-30, 31-40, 41-50, 51-60, 61-65, 66-70, 71-75, 76-80, 81-85 yrs old ▲

Sensory descriptors ●

Table 3: Significance of estimated regression coefficients (ANOVA values) for the relationship of sensory terms as derived by Jack – knife uncertainty tests for varying textures in different age cohorts.

Sample	Age Cohort (yrs old)	Tenderness [1]	Flavour [1]	Firmness [1]	Texture [1]	Acceptability [1]
T_R [4]	**18-30** [5]	- [2] 0.09 ns [3]	-0.00***	-0.66 ns	-0.14 ns	-0.04*
M_{TR}	**18-30**	-0.10 ns	-0.01**	-0.68 ns	-0.20 ns	-0.07 ns
M_{TH}	**18-30**	0.06 ns	0.23 ns	0.09 ns	0.29 ns	0.15 ns
T_R	**31-40**	-0.21 ns	-0.04*	-0.85 ns	-0.22 ns	-0.13 ns
M_{TR}	**31-40**	0.72 ns	0.88 ns	0.09 ns	0.89 ns	0.88 ns
M_{TH}	**31-40**	0.00***	0.00***	0.04*	0.00***	0.00***
T_R	**41-50**	-0.02*	-0.02*	-0.13 ns	-0.02*	-0.02*
M_{TR}	**41-50**	0.71 ns	0.15 ns	0.83 ns	0.64 ns	0.45 ns
M_{TH}	**41-50**	0.08 ns	0.28 ns	0.95 ns	0.10 ns	0.09 ns
T_R	**51-60**	0.32 ns	0.33 ns	0.32 ns	0.33 ns	0.32 ns
M_{TR}	**51-60**	0.49 ns	0.97 ns	0.80 ns	0.50 ns	0.54 ns
M_{TH}	**51-60**	0.01**	0.50 ns	0.31 ns	0.07 ns	0.04*
T_R	**61-65**	0.90 ns	0.57 ns	0.81 ns	0.97 ns	0.85 ns
M_{TR}	**61-65**	0.48 ns	0.10 ns	0.06 ns	0.28 ns	0.28 ns
M_{TH}	**61-65**	0.01**	0.21 ns	0.10 ns	0.04*	0.02*
T_R	**66-70**	-0.05*	-0.01**	-0.00***	-0.02*	-0.01**
M_{TR}	**66-70**	0.93 ns	0.58 ns	0.84 ns	0.86 ns	1.00 ns
M_{TH}	**66-70**	0.07 ns	0.35 ns	0.24 ns	0.15 ns	0.11 ns
T_R	**71-75**	0.03*	0.02*	0.59 ns	0.08 ns	0.04*
M_{TR}	**71-75**	0.65 ns	0.25 ns	0.21 ns	0.51 ns	0.73 ns
M_{TH}	**71-75**	0.02*	0.29 ns	0.79 ns	0.03*	0.03*
T_R	**76-80**	-0.35 ns	-0.77 ns	0.78 ns	-0.45 ns	-0.46 ns
M_{TR}	**76-80**	0.77 ns	0.64 ns	0.11 ns	0.43 ns	0.58 ns
M_{TH}	**76-80**	0.79 ns	0.83 ns	0.30 ns	0.96 ns	0.96 ns
T_R	**81-85**	-0.09 ns	-0.51 ns	-0.08 ns	-0.26 ns	-0.17 ns
M_{TR}	**81-85**	-0.10 ns	-0.52 ns	0.75 ns	-0.18 ns	-0.21 ns
M_{TH}	**81-85**	0.15 ns	0.16 ns	0.84 ns	0.18 ns	0.14 ns

[1] Sensory and hedonic terms

[2] Estimated regression coefficients from ANOVA-Partial Least Squares Regression (APLSR) (ANOVA values). The sign dictates whether the correlation is positively or negatively correlated

[3] *P* values: ns = not significant; $*P \leq 0.05$, $**P \leq 0.01$, $***P \leq 0.001$

[4] Ageing treatments: Moderately Tough (M_{TH}) = 2 days, Moderately Tender (M_{TR}) = 7 days and Tender (T_R) = 21 days

[5] Age groups