EFFECT OF HIGH PRESSURE TREATMENT AND SUBSEQUENT STORAGE ON THE COLOUR OF A BEEF PUREE

Bruce Moss, Donald E Johnston, William D Graham & Eileen M Stewart

Food Chemistry Branch, Agriculture, Food & Environmental Science Division, Department of Agriculture & Rural Development (DARD) for Northern Ireland, Newforge Lane Belfast BT9 5PX, UK.

Background

The effects of high pressure on meat have been reviewed by Cheftel and Culioli (1997) and include changes in muscle ultra structure, denaturation of proteins, inactivation of microorganisms and extension of shelf-life. The colour of meat depends on the amount and type of heme pigment, and the scattering properties of the meat (MacDougall 1983). High-pressure treatment of myoglobin solutions has been shown to result in partial denaturation with later renaturation (Defaye *et al* 1995). The effect of high-pressure treatment on myoglobin solutions depends on the temperature at which pressure treatment occurs. Zipp and Kauzmann (1973) did not observe denaturation of myoglobin below 225 MPa at 20°C, and Ooi (1994) did not observe denaturation until 500 MPa at 10°C. Carlez *et al* (1995) found increases in L* values and decreases in a* values when minced beef was pressure treated above 350 MPa at 10°C. High-pressure treatment is undertaken on vacuum packed meat and it is well established that when vacuum packs are opened the myoglobin oxygenates to oxymyoglobin. Thus given the partial denaturation reported by Defaye *et al* (1995) it is important to standardise colour measurement at a set time after opening of the vacuum pack of pressure treated meat.

Objectives

The purpose of this study was to compare the effects of high-pressure treatment at different temperatures followed by storage on the CIELAB colour values of vacuum packaged beef puree samples.

Materials and methods

Fresh minced beef was purchased from a local supplier in Belfast. The beef was mixed thoroughly to give a homogenous sample. A total 180 beef puree samples, each weighing approximately 100 g and formed into 5 cm sided cubes, were prepared after which each sample was placed in a sterile polyethylene/polyamide vacuum pouch, vacuum packed and stored overnight at 1ºC prior to high pressure treatment.

Samples were pressure treated in a Stansted Foodlab 900 high pressure isostat capable of operating at 900 MPa (Stansted Fluid Power Ltd., Stansted, UK). The pressure transmission fluid was a 10% vegetable oil in water emulsion. A submerged thermocouple was used to monitor the temperature of the pressurisation fluid during treatment. The pressure come-up time using this system was approximately 300 MPa per min and the pressure release time was 4.5 s per 100 MPa. The temperature increase due to adiabatic heating was approximately 2.5°C per 100 MPa. The puree samples were given pressure treatments of 100, 300 and 600 MPa or left untreated to serve as controls. Pressure treatment was carried out at temperatures of 5, 20 or 40ºC. Samples were treated at each pressure/temperature combination for 15 min. For each pressure treatment, 15 samples were treated at each temperature to give a total of 45 samples. Following treatment, colour measurements were carried out on three samples from each pressure/temperature combination. The reflectance spectra of the vacuum packs were measured immediately after opening and again at 45 min post-opening using a Monolight spectrophotometer and CIELAB values calculated (Moss *et al* 2000).

Results and discussion

High-pressure treatment had a statistically significant effect on all CIELAB colour parameters both on initial opening and after 45 min post-opening. In general, changes in CIELAB values were not observed until pressure treatment was applied at 300 MPa and above (Tables 1 & 2). These results are similar to those of Carlez *et al* (1995) who observed increases in L* from above 200 MPa and decreases in a* particularly above 400 MPa when minced beef was treated. Carlez *et al* (1995) observed little change in b* values with increasing pressure treatment, whereas in the present experiment b* values on initial opening increased with pressure treatment above 300 MPa, whereas after 45 min opening only the b* values at 300 MPa were significantly different. Carlez *et al* (1995) undertook colour measurements 10 min post-opening with pressure treatment carried out at 10°C which could explain some of the differences observed, although in the current studies the temperature at which the meat was pressure treated had little effect on CIELAB unless at 40°C (Fig 1). O'Connor (2001) studied the effects of combination pressure/temperature treatments on both colour and microbiological shelf-life and showed that, in general, combination of high pressure with higher temperature resulted in greater inactivation of microorganisms.

The main effect of storage was an increase in L* values and decrease in a* values with storage time on both the initial opening and 45 min later. The major effect was seen between 0 and 2 weeks storage. The statistically significant interaction between pressure treatment and storage (Tables 1 and 2) shows that for a* values, in particular, the decrease between 0 and 2 weeks storage was greater for the 300 and 600 MPa treatments than for the control and 100 MPa treatments (Fig 1).

The effect of storage of beef in vacuum packs on colour values has been studied extensively. In the current studies the potential for the meat puree to oxygenate ('bloom') is evident at all storage times as indicated by the higher a* values in the packs 45 min post-opening (Fig 1). Studies on myoglobin solutions have shown denaturation occurs at 500 MPa at 10°C (Ooi 1994) and 350 MPa at 30°C (Taniguchi *et al* 1994). It has been suggested that the effect of pressure on myoglobin was similar to denaturation by heat, with spectral changes indicating the 6th co-ordination position (water for myoglobin) was replaced by imidazole group of histidine (Zipp & Kauzmann 1973).

In intact meat systems the contribution of the meat matrix to colour must be considered, particularly denaturation of myofibrillar proteins, sarcoplasmic proteins and consequently influences on enzyme activity (Govindarajan *et al* 1977). Studies on the effect of high-pressure individual proteins have shown a number of changes including aggregation of myosin (O'Shea *et al* 1976) and disaggregation of actomyosin (Ikkai and Ooi 1969). Changes in a number sarcoplasmic proteins and enzyme activity have also been observed (Cheftel and Culioli 1997). The paler appearance and higher L* values of PSE pork are due to an increase in the scattering coefficient (McDougall 1983).

In these studies the $^k/_s$ ratio at 730 nm decreased due to high-pressure treatment from 0.41 and 0.48 at 0 and 100 MPa to 0.15 at both 300 and 600 MPa. This decrease indicates general denaturation of the meat protein matrix and consequent increase in scattering coefficient, since at 730 nm absorption due to myoglobin is low (Millar *et al* 1996). The $^k/_s$ ratio at 525 nm shows a similar trend (3.2, 3.7, 1.4 and 1.4 at 0, 100, 300 and 600 MPa, respectively). Since 525 nm is generally considered to be the isobestic form of the myoglobin, oxymyoglobin and metmyoglobin (Millar *et al* 1996), any denaturation of myoglobin should have little effect on the absorption coefficient. Thus, the increased $^k/_s$ ratio at 525 nm is also indicative of a general increase in scattering coefficient. The colour of meat depends on oxygen penetration into the meat and the formation of oxymyoglobin in bloomed meat. The darker appearance of DFD meat and greater contribution of myoglobin to the observed colour is due in part to the lower scattering coefficient of high pH meat. Thus conversely, an increased scattering coefficient due to high pressure would result in a greater contribution of the outer surface to the observed appearance/measured surface reflectance. It might be expected that high pressure treated spectra show a more oxymyoglobin type spectra. Further detailed evaluation of the reflectance spectra at the meat surface and at depths through the meat is required to evaluate this.

Conclusions

High-pressure treatment of beef puree results in changes in CIELAB colour values. Increased L*, decreased a* were found at 300 MPa and above, but were not evident at 100 MPa. The results indicate that the myoglobin is not completely denatured and the beef puree has the potential to 'bloom' when the vacuum packs are exposed to air. The temperature at which high pressure treatment is undertaken also has an effect on CIELAB colour parameters with higher L* and lower a* values when pressure treated at 40°C. Decreases in a* values with storage are dependent on the pressure treatment used.

References

Carlez, A., Veciana-Nogues, T. and Cheftel, J.C. 1995. Changes in colour and myoglobin of minced beef meat due to high pressure processing. Lebensm.-Wiss. u.-Technol. 28: 528-538.

Cheftel, J.C. and Culioli, J. 1997. Effects of high pressure on meat: A review. Meat Sci. 46: 211-236.

O'Connor, D. 2001. Effects of high hydrostatic presssure on the microbiological and sensory quality of poultry meat. MPhil Thesis, Queen's University Belfast, UK.

Defaye, A., Ledward, D.A., MacDougall, D.B. and Tester, R.F. 1995. Renaturation of metmyoglobin subjected to high isostatic pressure. Food Chem. 52: 19-22.

Govindarajan, S., Hultin, I. And Kotula, A. 1977. Myoglobin oxdiation in ground beef: mechanistic studies. J. Food Sci. 42: 571-577.

Ikkai, T. and Ooi, T. 1969. The effects of pressure on actomyosin systems. Biochem. 8: 2615-2622.

MacDougall, D.R. 1983. Instrumental assessment of the appearance of foods. In: Sensory Quality in Foods and Beverages (Williams, A.A. and Atkin, R.K., Eds.). Ellis Horwood Ltd., Chicester, pp.121-139.

Millar, S.J., Moss, B.W. and Stevenson, M.H. (1996). Some observations on the absorption spectra of various myoglobin derivatives found in meat. Meat Sci. 42: 277-289.

Moss, B.W., Millar, S.J. and Kilpatrick, D.J. 2000. The use of discriminant analysis for the interpretation of the reflectance spectra of irradiated porcine M. longissimus dorsi. Meat Sci. 55: 337-348.

Ooi, T. 1994. Effects of pressure on thermal denaturation of proteins. In: High Pressure Liquids and Solutions (Taniguchi, Y., Senoo, M. and Hara, K., Eds.). Elsevier Science B.V., pp. 16-24.

O'Shea, J.M., Horgan, D.J. and MacFarlane, J.J. 1976. Austr. J. Biol. Sci. 29: 197.

Taniguchi, Y., Takeda, N. and Kato, M. 1984. Pressure denaturation mechanism for proteins. In: High Pressure Liquids and Solutions (Taniguchi, Y., Senoo, M. and Hara, K., Eds.). Elsevier Science B.V., pp. 107-117.

Zipp, A. and Kauzmann, W. 1973. Pressure denaturation of metmyoglobin. Biochem. 12: 4217-4228.

Table 1: Effect of high pressure treatment on the colour of vacuum packaged beef puree samples. Measurements taken upon initial opening of pack.

	L*	a*	b*	hue	Metric Chroma
Effect of pressure (MPa)					
0	45.32	10.74	14.66	53.82	18.22
100	44.59	10.16	14.49	55.02	17.75
300	56.28	4.47	15.96	74.63	16.68
600	58.14	4.24	16.64	75.82	17.27
Significance of effect	***	***	***	***	***
SEM (n = 45)	0.334	0.133	0.131	0.399	0.141
Effect of temperature (ºC)					
5	50.30	7.69	15.22	63.77	17.40
20	50.52	7.51	15.48	64.62	17.40
40	52.43	7.01	15.61	66.07	17.44
Significance of effect	***	***	*	***	NS
SEM (n = 60)	0.289	0.116	0.113	0.345	0.122
Effect of storage (weeks at <4ºC)					
0	49.75	9.77	15.46	57.88	18.32
2	50.93	7.32	14.91	64.59	16.98
4	51.03	6.59	15.23	66.69	16.95
6	51.39	6.59	15.40	67.00	17.14
8	52.31	6.73	16.21	67.95	17.88
Significance of effect	***	***	***	***	***
SEM (n = 36)	0.373	0.149	0.146	0.446	0.153
Significance of interaction					
P x T	NS	NS	**	*	**
P x S	*	***	***	***	***
T x S	NS	***	NS	*	NS
P x T x S	NS	NS	***	*	***

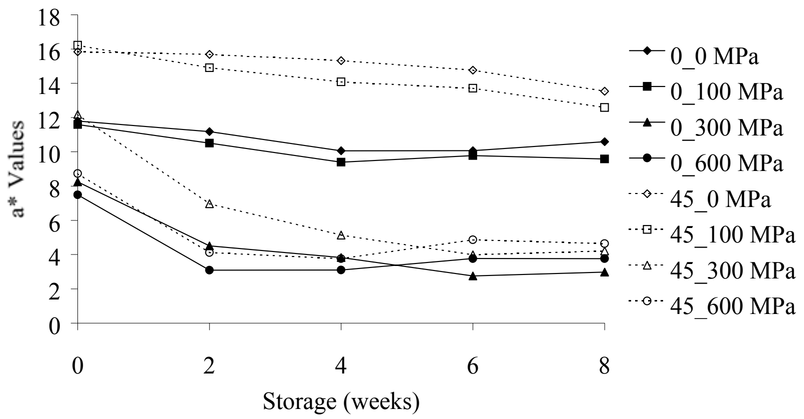
SEM = standard error of mean; *** = p<0.001; ** = p<0.01; * = p<0.05; NS (not significant) = p>0.05

Table 2: Effect of high pressure treatment on the colour of vacuum packaged beef puree samples. Measurements taken 45 min after initial opening of pack.

	L*	a*	b*	hue	Metric Chroma
Effect of pressure (MPa)					
0	44.28	15.03	17.08	48.78	22.78
100	44.67	14.30	17.04	50.25	22.30
300	55.37	6.49	16.05	68.86	17.49
600	56.58	5.22	17.03	73.10	17.92
Significance of effect	***	***	***	***	***
SEM (n = 45)	0.380	0.179	0.152	0.353	0.197
Effect of temperature (ºC)					
5	49.25	10.65	16.75	59.24	20.24
20	49.53	10.62	16.81	59.52	20.34
40	51.89	9.52	16.85	61.98	19.79
Significance of effect	***	***	NS	***	‡NS
SEM (n = 60)	0.329	0.155	0.132	0.306	0.171
Effect of storage (weeks at <4ºC)					
0	48.95	13.24	17.64	53.71	22.20
2	49.34	10.42	16.38	59.40	19.85
4	50.50	9.58	16.52	61.87	19.60
6	50.53	9.34	16.69	62.50	19.61
8	51.80	8.74	16.78	63.76	19.35
Significance of effect	***	***	***	***	***
SEM (n = 36)	0.425	0.200	0.170	0.395	0.220
Significance of interaction					
P x T	NS	*	*	**	**
P x S	*	***	***	***	***
T x S	NS	NS	NS	*	NS
P x T x S	NS	*	NS	***	NS

SEM = standard error of mean; *** = p<0.001; ** = p<0.01; * = p<0.05; NS (not significant) = p>0.05; ‡p = 0.056

Figure 1: Effect of high pressure processing and storage on the a* values of beef puree samples



CONSUMER PREFERENCES OF PORK CHOPS: RESULTS OF AN INTERNATIONAL CROSS-CULTURAL COMPARISON.

Ngapo, T.M.[1], Martin, J.F. and Dransfield, E.

Propriétés Sensorielles et Préférences, Station de Recherches sur la Viande,
INRA, Theix, 63122 St-Genès-Champanelle, France.
[1]Current address: Agriculture and Agri-Food Canada, Food Research and Development Centre,
Saint-Hyacinthe, Quebec, J2S 8E3, Canada.

Background

The pork industry is competitive at both international and national levels and is responding to consumers' demands and expectations for safe, nutritious products, which conform to their life-styles. With increasing international trade, the industry needs to be aware of different consumer preferences for meat according to their different cultures and traditions. This will be increasingly important for the pork market.

Consumer preferences of pork are based on expectations of enjoyment within a given context. Expectations are perhaps different when the pork is for oneself, others or for a particular meal or event. These contextual differences play a role in the selection of pork and the type of pork to be bought. At the point of purchase, the choice is based on an expectation of good eating quality, an expectation that the pork will be tender and juicy. These expectations are based on information and previous experiences. Choice is therefore based on expectations, price and the appeal of the pork, where appeal is strongly expressed as a preference for the appearance characteristics.

Appearance characteristics of the pork are thought to be the main factors governing choice and comprise the main characteristics: colour, amount of fat cover, marbling and drip. Preferences for pork characteristics have been determined separately in different countries in several local studies but the practical limitations, imposed by the short display-life of meats, make it inevitable that the people in different localities have assessed different meats. The meats also will have differed simultaneously in several of those characteristics and the relative importance of those characteristics is uncertain. The conclusions from such studies are therefore limited when considering the cultural and international dimensions.

These limitations, particularly so when surveying large numbers of people in different countries, have been overcome by using photographs varying systematically in four appearance characteristics. This is the first time a large-scale systematic study has been conducted on meat appearance and consumer preference.

Objectives

- To identify the most important characteristics of fresh pork which determine preference
- To show any variations in preferences among people from different countries

Materials and methods

The methodology and chop characteristics are described in detail in Ngapo *et al.* (2004). Briefly, photographs of 16 pork chops were computer-modified to give two levels of each of the characteristics: fat cover, colour, marbling and drip. The pork chops were purchased at local supermarkets and butcher shops. The resulting 256 (2x2x2x2x16) images have been published as a book (Dransfield *et al.*, 2001), which can be used as a tool for analysing the importance of those factors in consumer choice. The book is comprised of 6 series of which series 1+2, 3+4, and 5+6 each contain all 256 images. A series constitutes 16 (A4) pages or 8 double-pages. Every double-page contains the 16 different chop shapes and each chop represents one of the combinations of the four characteristics studied. Therefore every double-page contains a complete set of all 16 combinations of the 2 levels of each of the four characteristics. Both the order of representation of the characteristics with respect to the chop shape and the position of the chops in a double-page are randomised. It is important to note that the chop shape was not a factor studied, but can be considered a distraction and a means to realistically present a range of characteristics to the consumer.

Consumers, older than fifteen years of age and who eat pork, were chosen at random and asked to select their preferred chop from each double-page. The selection was repeated 8 times completing one series. The consumers then completed a short questionnaire (translated by the research group undertaking the survey into the language of that country) asking basic socio-demographic and purchase- and eating-behaviour information (Table 1). Each new consumer was given a series in the order 1 to 6 so that all series were used approximately equally throughout a survey period. Consumers were surveyed at a range of sites, including agricultural shows, supermarkets and at their workplaces. The surveys were undertaken by 28 research groups in 26 countries and coordinated by the French group. These countries and the number of consumers surveyed in each were Argentina (505), Australia (498), Belgium (353), Brazil (710), Canada (Alberta and Quebec; 1053), China (544), Denmark (200), Estonia (248), Finland (305), France (573), Germany (143), Greece (412), Ireland (300), Japan (645), Korea (1014), Mexico (751), New Zealand (327), Poland (480), South Africa (562), Spain (358), Sweden (200), Taiwan (716), The Netherlands (873), United Kingdom (290), USA (Iowa and Texas; 732) and Yugoslavia (488).

Detailed analyses of the French results have been reported earlier (Ngapo *et al.*, 2002; Ngapo *et al.*, 2004) and, more briefly, the results of the Korean (Cho, *et al.*, 2003) and Brazilian (Cipolli *et al.*, 2003) surveys.

Results

The characteristics of the images of the pork chops used in these surveys are given in Table 1. Visual differences in colour were mainly due to average differences of 8.6 units in lightness (L*) and 5.4 units in redness (a*). Subcutaneous fat cover of the fat chops was, on average, twice that of the lean chops. Drip was either absent or represented almost 6% of the surface area in the samples modified to show drip. Bone and loin muscle area were similar across appearance variables.

Table 1. Mean composition of the 256 pork chop images.

	Light	Dark
Colour L*	64.3	55.7
Colour a*	18.3	23.7
Colour b*	20.8	18.8
(% chop surface area)	Fat	Lean
Cover fat	16.9	7.9
Drip	5.4	5.7
Bone	15.7	16.1
Loin muscle	39.2	43.9

From the results of the 8 replicates given by each person, the frequency of choice for the 4 main characteristics was calculated. For each of the 2 levels of each characteristic, the choice was classed as consistent when the same level was chosen at least 6 times from the 8 replicates, otherwise the choice was deemed inconsistent. Three classes were then produced for each characteristic: with the percentage of people choosing level 1 (for example for colour, light red), level 2 (dark red) and inconsistent (with <6 of the replicates the same choice) for each of the 26 countries.

This frequency of choice was then subjected to a correspondence analysis (SAS, 1999) to determine the relationships among countries of choice for each of the 12 classes (3 frequency classes for 4 appearance characteristics). The first 2 dimensions of the correspondence analysis accounted for 80% of the total variation and are shown graphically in Figure 1. The positions of the countries are given relative to 8 of the choice options (the 4 inconsistent options are not given for clarity, but are included in the analyses). Countries shown close to a given choice have a greater percentage of their people who chose consistently that characteristic as its preferred appearance. Conversely, large distances from a choice characteristic usually denote preference for the other option of the characteristic. Inconsistent choices tend to be found in the central region of Figure 1.

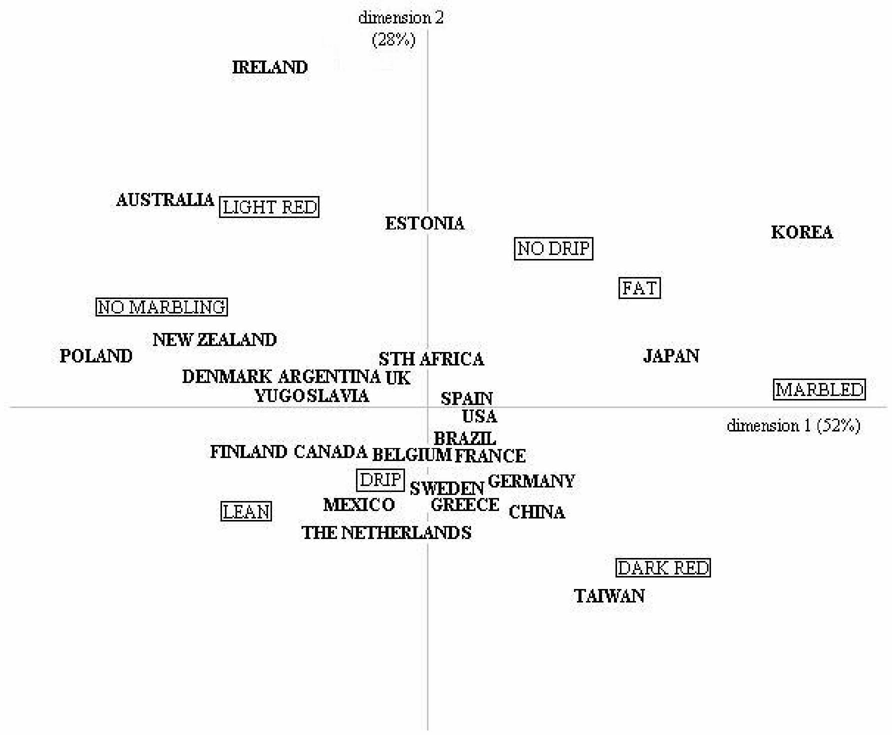


Figure 1. Preferences for 4 pork characteristics from surveys conducted in 26 countries.

Large differences in preferences were found between individuals, groups of people and between countries. Compared to the other consumers, more of the Polish, Australian and Irish consumers preferred non-marbled, light red pork, that is, they are positioned in the upper left quadrant. Those in Estonia preferred light red pork without drip. On the contrary, more people from Korea and Japan tended to prefer the fat and marbled options and are positioned in the upper right quadrant of Figure 1. More people in Taiwan preferred the dark red pork whilst the Dutch and Finnish preferred lean meat with little overall preference for colour. Most countries tended to group close to the 'centre' of Figure 1 showing that preferences for colour, marbling and drip were not strongly in favour of any one option but they were more consistent in their choice of the leaner option.

France, USA and Canada conducted surveys in different regions, and estimates can be made of the within and between country variation. In France, 3 regions were studied (Ngapo *et al*., 2004), which showed differences in preferences between the regions composed of about 200 consumers each.

Discussion

This unique study of preferences for appearance characteristics, in which consumers in 26 countries viewed exactly the same appearance characteristics, has shown that choice of pork is influenced by its colour, fatness, marbling and drip and that preferences differed considerably between countries. The range of characteristics chosen for the study was not exceptional and can be found in the market within Europe.

Using replicate choices, the study was able to show those characteristics which were consistently chosen and those which were not. This is a unique consumer study conducted with replication, but without the consumers knowing it. Consistency is interpreted as a measure of importance to the individual, who presumably paid more attention to those characteristics to be able to give a consistent choice. So it was shown that, overall, colour and fatness were the most important appearance characteristics and marbling and drip were less important.

Using groups of people from different regions within the same country has also enabled the variation within country to be established which was found to be much less than that between countries.

Conclusions

- Significant differences were found for consumer choice of pork chops based on 4 appearance characteristics. The greatest differences were for external fat cover with preferences for both fat and lean chops differing among countries. The second criterion for selection was for colour where both dark and light red chops were preferred by different people.
- Differences in preference between regions within country were generally smaller than those between many of the countries surveyed.
- Significant market segmentation exists in preferences on a global scale.
- Pork producers should be aware and prepared to respond to such market opportunities.

Acknowledgements

For organising the surveys in different countries, thanks are expressed to: Dr F. Carduza, ITA-INTA Castelar, Buenos Aires, Argentina; Dr C. Russell, University of Ballarat, Ballarat, Victoria, Australia; Dr W. Verbeke, Ghent University, Gent, Belgium; Dr E.T.F. Silveira, ITA, Campinas, Sao Paulo, Brazil; J. Fortin, Agriculture and Agri-Food Canada, St-Hyacinthe, Quebec, Canada; Dr J. Aalhus, Agriculture and Agri-Food Canada, Lacombe, Alberta, Canada; Dr G.H. Zhou, Nanjing Agricultural University, Nanjing, China; L. Bredahl, MAPP, Aarhus, Denmark; Prof M. Rei, Estonian Agricultural University, Tartu, Estonia; Prof E. Puolanne, University of Helsinki, Helsinki, Finland; Dr M. Bruhn, University of Kiel, Kiel, Germany; Dr P. Fortomaris, Aristotle University of Thessaloniki, Thessaloniki, Greece; Dr S. O'Reilly, University College Cork, Cork City, Ireland; Prof K. Samejima, Rakuno Gakeun University, Hokkaido, Japan; Dr S. Cho, National Livestock Research Institute, Suwon, Korea; Dr A. Alarcon-Rojo, Universidad Autónoma de Chihuahua, Chihuahua, Mexico; P. Fenwick, New Zealand Pork Industry Board, Wellington, New Zealand; Prof N. Barylko-Pikielna, Szkoła Główna Gospodarstwa Wiejskiego, Warsaw, Poland; Dr H. de Kock, University of Pretoria, Pretoria, South Africa; Dr C. Sanudo, University of Zaragoza, Zaragoza, Spain; Dr M. Magnusson, Uppsala University, Uppsala, Sweden Dr M.-T. Chen, Da-Yeh University, Chung Hwa, Taiwan; Dr S. Hillebrand, ID-Lelystad, Lelystad, The Netherlands; G. Nute, Bristol University, Bristol, United Kingdom; Dr S. Lonergan, Iowa State University, Ames, Iowa, USA; Dr R. Miller, Texas A & M University, College Station, Texas, USA; Dr L. Turubatović, Laboratorija Instituta za Higijenu i Tehnologiju Mesa, Belgrade, Yugoslavia

References

Cho, S., Ngapo, T.M., Dransfield, E., Park, B., Kim, J., Yoo, Y., Yun, S., & Lee, J. (2003). Criteria influencing choice of pork chops by Korean consumers. *The 49th International Congress of Meat Science and Technology* (pp247-248). 31 August – 5 September 2003, Campinas, Brazil.

Cipolli, K.M.V.A., Silveira, E.T.F., Ngapo, T.M., & Dransfield, E. (2003). Consumer preferences of pork chops – the Brazilian survey. *The 5th Pangborn Sensory Science Symposium. A Sensory Revolution.* (pp187). 20-24 July 2003, Boston, USA.

Dransfield, E., Martin, J.-F., Miramont, J., & Ngapo, T.M. (2001). Meat Appearance: Pork Chops. A tool for surveying consumer preferences. INRA, France, ISBN 2-7380-0976-X.

Ngapo, T.M., Martin, J.-F., & Dransfield, E. (2002). Consumer preferences of pork chops: an international cross-cultural comparison. Proceedings of the 48th International Congress of Meat Science and *Technology (Vol. 1, pp150-151). 25-30 August 2002, Rome, Italy.*

Ngapo, T.M., Martin, J.-F., & Dransfield, E. (2004). Consumer choices of pork chops: results from three panels in France. *Food Quality and Preference*, **15**(4), 349-359.

SAS. (1999) SAS Users Guide: Statistics. Version 8.1. Cary: SAS Institute Inc.