Asian-Aust. J. Anim. Sci.
Vol. 20, No. 8 : 1272 - 1277
August 2007
www.ajas.info

Comparison of Sensory Traits and Preferences between Food Co-product Fermented Liquid (FCFL)-fed and Formula-fed Pork Loin

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ABSTRACT : Sensory traits and preferences regarding food co-product fermented liquid (FCFL)-fed pork loin were compared with those of formula-fed pork. The FCFL-fed pork was expected to have improved fat meltability. Thirty-nine laboratory panelists took part in a sensory test. The fat meat and the lean meat of FCFL-fed pig were judged more meltable and tender, respectively, than the corresponding meat from the formula-fed pig. These sensory traits agreed closely with the results of a mechanical investigation of fat melting patterns and with Warner-Bratzlar shear force values. However, the overall preference was not significantly associated with sensory fat meltability and meat tenderness, as assessed by chi-square and correspondence analyses, but it was significantly related to the whole fat preference and the fat texture preference. The fat texture preference, however, did not correlate with sensory fat meltability. These results indicated that FCFL feeding altered sensory fat meltability in pork loin, but the preference for such meltable fat differed among individual panelists. (**Key Words :** Pork, Fat, Tenderness, Correspondence Analysis, Food Co-products Fermented Liquid Feeding)

INTRODUCTION

The quality of fat is an important factor affecting the classification, processibility, sensory characteristics, and consumer preference for meat and meat products. In Japan, physical properties such as the firmness and stickiness (in Japanese, "*shimari*" and "*nebari*," respectively) of fat are used for grading pork carcasses, and soft fat is a critical characteristic causing a decrease in carcass grade. Although soft fat has been avoided in the processing of pork carcasses, fat meltability is generally considered to be associated with a positive mouth feeling in consumers (O'Brien, 1998).

The Law for the Promotion of the Utilization of Recyclable Food Resources was instituted in 2001 in Japan. Under this law, the use of food co-products as animal feed has been promoted. As a part of this activity, a system for feeding food co-products fermented liquid (FCFL) was developed (Kawashima, 2004). It has been reported that fermented liquid feed affects the fatty acid profiles, the contents of relevant lipid volatiles, and the odors in pork *longissimus* muscle (Hansen et al., 2000). Kim et al. (2006) reported that dietary supplementation of fermented persimmon shell, by-product of persimmon processing, improved sensory tenderness, juiciness, and flavor in pork *longissimus* muscle. However, the effect of FCFL feeding on the texture of pork fat has not been investigated.

In the present study, we investigated the relationship between the fatty acid composition, melting profiles, sensory properties and preferences for pork fat and lean meat, especially in regard to fat texture, by using FCFL-fed pork loin samples that are actually retailed in the Japanese market. The additional purpose of this study was to clarify the sensory traits and consumer preferences for FCFL-fed pork in regard to the practical use of food co-products as animal feed.

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Received October 21, 2006; Accepted February 20, 2007

MATERIALS AND METHODS

Sampling procedure

Pork (Landrace×Large White×Duroc) loin samples were

Table 1. Feed composition of the pork used in the present study

	Formula	FCFL[1]
Dry matter (%)	86.2	18.8
Ash (%, dry basis)	4.4	8.4
Crude protein (%, dry basis)	17.1	20.6
Crude fat (%, dry basis)	2.5	14.2
Neutral detergent fiber (%, dry basis)	10.2	9.6
Non-fiber carbohydrate (%, dry basis)	65.8	47.2

[1] Food co-products fermented liquid.

obtained from Kasai-Chikusan Co., Fujinomiya, Shizuoka, Japan. The loin samples were taken from pigs fed on FCFL and on formulated feed by farmers around Fujinomiya city, which is located in central Japan. FCFL was supplied by the Food Ecology System Co. (Yokohama, Japan). For preparation of the FCFL, feed co-products and wastes (such as cooked rice, breads, vegetables, etc.) were collected from food processing factories, supermarkets, hotels, and restaurants located in Tokyo, Chiba, and Kanagawa prefectures. These materials underwent lactic fermentation and were then supplied to the farmers. FCFL and formula feed were sampled by the farmers; the feeds' compositions are shown in Table 1.

Pork loin blocks from ten carcasses were sampled from each treatment group at the meat packing facility. These samples were vacuum-packed and stored at -50°C before the experiments. From the pork loin groups taken from each of the ten carcasses, we selected four samples that had values within the mean values±standard differences in the polyunsaturated fatty acid composition and the melting characteristics of fat (analyzed as we later describe) and used them in the following sensory test.

Sample preparation for sensory test

The loin block samples were formed into 1.0-cm thick subcutaneous adipose tissues, and their surfaces were sprinkled with 1.0% (w/w) of NaCl. The loin block was then placed into a steam convection oven SSC-10DCNU (Maruzen Co., LTD., Tokyo) set at 150°C and cooked without steam until the core temperature reached 75°C.

The samples were then cooled in a refrigerator and sliced in 8-mm thicknesses. They were then stored in a refrigerator and later re-heated for 7.0 min on a gas-heated hot plate FGFT60S (Fujimak Co., Tokyo) set at 60°C before being submitted immediately for sensory testing.

Sensory evaluation

Thirty-nine participants, formed from the National Institute of Livestock and Grassland Science, participated in the sensory evaluation. The evaluation items were generated by preliminary sensory studies using fifteen panels at the National Institute of Livestock and Grassland Science that involved research on porcine production and animal product quality. The items, indicated in Table 4, included the objective properties and preferences regarding meat and fat traits. Each sliced meat sample, including intermuscular adipose tissues of both FCFL- and formula-fed pork loin, was presented to each panelist. Sensory evaluation for the evaluation items presented in Table 4 was carried out by a pair test. Each panel member was placed during the sensory evaluation in an individual booth illuminated by a white fluorescent light.

Immediately before the sensory evaluation, each participant was informed of the cooking conditions and the safety of the pork samples and then consented to participate in the experiments as a sensory panelist.

Physical and chemical properties of samples

The moisture and crude fat content, cooking loss, Warner-Bratzlar shear force values (WBSFV), and fatty acid composition of the intermuscular adipose tissue were assessed.

For the WBSFV analysis, the muscle samples were formed into circular disks 5.08 cm in diameter and 2.5 cm thick, and incubated at 85°C in a nylon-polyethylene bag (N-4, Asahi Kasei Pax Corp., Tokyo) until the core temperature reached 70°C. From these heat-treated samples, 1.27 cm diameter cores were prepared that were sheared perpendicularly to the muscle fiber orientation using a Warner-Bratzler shear V-blade attached to an Instron Universal Testing Machine (Model 5542, Instron Corp., Canton, MA) fitted with a 500 N compression load cell with a crosshead speed of 250 mm/min. The peak force values that were measures of the shearing through the centers of the cores were used to determine the mechanical WBSFV of the sample.

The fatty acid composition was analyzed by using gas-liquid chromatography (GLC). Methyl esters of fatty acids were prepared with a boron trifluoride methanol complex solution obtained from Wako Pure Chemical (Osaka, Japan). We used a GC-12A GLC system (Shimadzu, Kyoto, Japan) equipped with a flame-ionization detector and a HR-SS-10 capillary column (0.25 mm×30 m, Shinwa Chemical Industries, Tokyo) for GLC analysis.

The melting properties of the intermuscular fat were determined by direct differential scanning calorimetry (DSC) using a DSC-60 system equipped with a thermoanalysis workstation TA-60WS (Shimadzu, Kyoto, Japan), as described in our previous report (Sasaki et al., 2006). The onset temperature (T_o), melting peak temperature (T_p), and conclusion temperatures 1 and 2 (T_{c1} and T_{c2}) were obtained from the DSC curve, as described previously.

Statistical analysis

Binominal and chi-square analyses were done for the sensory data by SPSS (Version 12.0J, SPSS Inc., Chicago,

Table 2. Moisture and crude fat content, cooking loss, and Warner-Bratzler shear force values (WBSFV) for the lean pork loin meat used in the sensory test (n = 4)

	Feed		Prob.
	Formula	FCFL[1]	
Moisture content (%)	73.0	70.1	0.023
Crude fat content (%)	1.65	5.99	0.017
Cooking loss (%)	23.6	23.0	0.775
WBSFV (N)	32.4	26.7	0.266

[1] Food co-products fermented liquid.

IL). Correspondence analysis was done for the raw data for the pair test by the CORRESP procedure of SAS (Version 9.1, SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

Physiochemical characteristics of the samples that underwent the sensory test are presented in Table 2. The FCFL samples were significantly ($p<0.05$) higher in crude fat content and significantly lower in moisture content than the formula-fed pork loin samples. No significant differences between the two groups were observed in cooking loss and WBSFV ($p>0.05$).

The samples' intermuscular fat qualities are presented in Table 3. In the FCFL samples, the saturated fatty acid composition was significantly ($p<0.01$) lower and the unsaturated fatty acid composition was significantly higher than in the formula-fed samples. Both the monounsaturated fatty acid and polyunsaturated fatty acid compositions were also significantly higher ($p<0.05$ and $p<0.001$, respectively) in the FCFL pork than in the formula-fed samples. In addition, regarding melting properties, T_p, T_{c1}, and T_{c2} were significantly lower ($p<0.01$) in the FCFL-fed pork loin than in the formula-fed samples. The results regarding melting properties showed close agreement with the results regarding fatty acid profiles-that is, the FCFL pork had higher mono- and poly-unsaturated fatty cid compositions and a lower melting temperature. These findings in the present study indicated that FCFL pork fat was more meltable than the formula-fed pork fat.

Table 4. Results of pair test and binominal analysis

	Number of panelists		Prob.
	Formula	FCFL[1]	
Objective properties			
Meat tenderness	10	29	0.003
Meat juciness	16	23	0.337
Meat flavor	17	22	0.552
Fat meltability	9	30	<0.001
Preferences			
Meat flavor	18	21	0.749
Fat flavor	22	17	0.522
Fat texture	20	19	1.000
Whole meat preference	17	22	1.000
Whole fat preference	19	20	1.000
Overall preference	19	20	1.000

[1] Food co-products fermented liquid.

The results of the binominal test are presented in Table 4. Two objective properties, meat tenderness and fat meltability, were judged to be significantly different in the two samples ($p<0.01$). The sensory result - the evaluation of fat meltability - was in close agreement with the machine-derived results of the fat's melting properties, as indicated in Table 2 and 3. Specifically, the panel members judged the fat in the FCFL samples as more meltable than that in the formula-fed pork loin samples. The meat in the FCFL samples was also judged tenderer than that in the formula samples ($p<0.01$). The crude fat content in the muscle was significantly higher in the FCFL-fed group than in the formula-fed group ($p<0.05$), as presented in Table 2. The results regarding sensory tenderness may be caused by the crude fat content in the longissimus muscle. Our results regarding sensory tenderness are in accordance with the findings of Fortin et al. (2005) who have reported that in pork muscle both the machine-measured and sensory tenderness significantly increased as the intramuscular fat content increased.

No significant differences regarding other objective properties were detected. Similarly in items relating to preferences, including overall preference, no significant

Table 3. Melting properties and fatty acid composition of intermuscular adipose tissue of pork loin used in the sensory test in the present study (n = 4)

	Feed		Prob.
	Formula	FCFL[1]	
Fatty acid composition (%)			
Saturated	47.2	38.7	0.004
Unsaturated	52.8	61.3	0.004
Monounsaturated	37.7	43.4	0.020
Polyunsaturated	15.1	17.9	0.0009
Melting properties (°C)			
Onset temperature (T_0)	26.3	26.0	0.315
Melting peak temperature (T_p)	33.1	30.5	0.002
Conclusion temperature 1 (T_{c1})	38.2	35.1	0.002
Conclusion temperature 2 (T_{c2})	52.3	48.0	0.006

[1] Food co-products fermented liquid.

Table 5. Chi-square analysis for evaluation items

	Chi-square	Prob.
(A) Whole meat preference		
Meat tenderness	0.070	1.000
Meat juciness	6.985	0.011
Meat flavor intensity	1.072	0.345
Meat flavor preference	27.897	<0.0001
(B) Whole fat preference		
Fat melting property	0.219	0.716
Fat flavor preference	16.472	<0.0001
Fat texture preference	16.080	<0.0001
(C) Fat texture preference		
Fat meltability	0.219	0.716
(D) Overall preference		
Meat tenderness	1.886	0.273
Meat juciness	2.063	0.200
Meat flavor intensity	1.232	0.341
Fat meltability	1.509	0.273
Meat flavor preference	27.977	<0.0001
Fat flavor preference	28.630	<0.0001
Fat texture preference	7.442	0.010
Whole meat preference	24.862	<0.0001
Whole fat preference	18.681	<0.0001

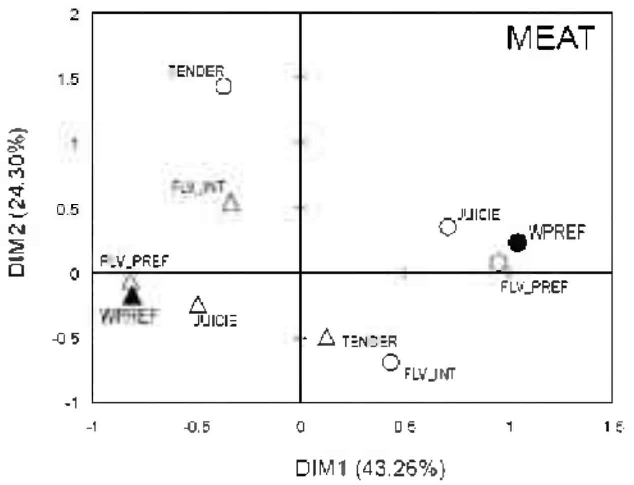

Figure 1. Correspondence analysis for evaluation items regarding lean meat. Circles indicate food co-products fermented liquid-fed samples, and triangles indicate formula-fed samples. WPREF, whole preference for meat; TENDER, tenderness; FLV_INT, flavor intensity; JUCIE, juiciness; and FLV_PREF, flavor preference.

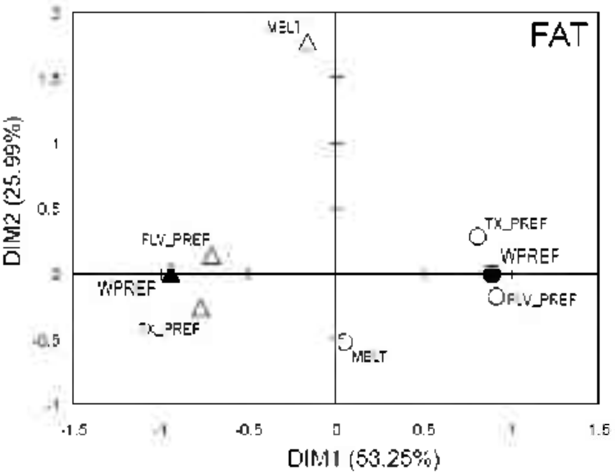

Figure 2. Correspondence analysis for evaluation items regarding fat. Circles indicate food co-products fermented liquid-fed samples, and triangles indicate formula-fed samples. WPREF, whole preference for fat; MELT, meltability; TX_PREF, texture preference; and FLV_PREF, flavor preference.

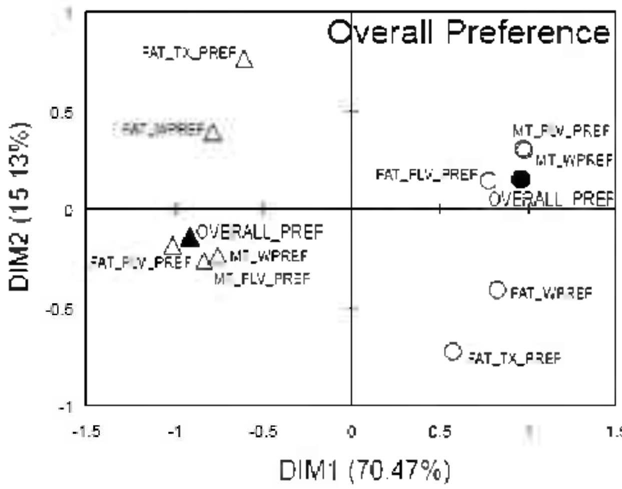

Figure 3. Correspondence analysis for evaluation items regarding overall preference. Circles indicate food co-products fermented liquid-fed samples, and triangles indicate formula-fed samples. OVERALL_PREF, overall preference; MT_FLV_PREF, meat flavor preference; MT_WPREF, whole preference for meat; FAT_FLV_PREF, fat flavor preference; FAT_TX_PREF, fat texture preference; and FAT_WPREF, whole preference for fat.

differences were found between the formula- and FCFL-fed pork loins.

The relationship between the whole meat preference, whole fat preference, and overall preference and individual evaluation items was analyzed by chi-square analysis and visualized by correspondence analysis, as indicated in Table 5 and Figure 1, 2 and 3, respectively.

The whole meat preference correlated with the meat juiciness and meat flavor preference ($p<0.05$ and $p<0.0001$, respectively), as indicated in Table 5(A). Figure 1 presents the results of the correspondence analysis for the items evaluated that concern lean meat. The meat juiciness and flavor preference correlated with the whole meat preference found in each sample ($p<0.05$). On the other hand, meat tenderness did not significantly ($p>0.05$) correlate with the whole meat preference (Table 5(A)), although tenderness was judged differently for each of the two samples, as indicated in Table 4.

The results of the correspondence analysis between the evaluated items regarding fat are presented in Figure 2. The results of the chi-square analysis of the fat evaluation are also presented in Table 5(B). Preferences for fat flavor and fat texture were related to the whole fat preference. The fat meltability did not correlate with either the whole fat preference or the fat texture preference (Figure 2 and Table 5(C)), although in the present study the fat in the FCFL-fed pork was judged by the panel members to be more meltable than that in the formula-fed samples (Table 4), a result which was attributed to the samples' melting temperatures, as presented in Table 3.

The correspondence and chi-square analyses of the evaluation items regarding preference are presented in Figure 3 and Table 5(D), respectively. Overall preferences for both samples were strongly related to the whole and the flavor preference for meat and the flavor preference for fat rather than to the whole and texture preference for fat.

Babji et al. (1998) compared preferences regarding beef burgers, including fat, with different melting points. Of the beef samples evaluated in their experiments, they found that the highest overall acceptance was found in the samples that included the most meltable fat. It is generally considered that meltable fat affects the mouth feeling in humans (O'Brien, 1998). In pork samples, Miller et al. (1990) reported that the alteration in fatty acid profiles affected the overall palatability of the pork longissimus muscle. Corino et al. (2003) indicated that dietary conjugated linoleic acid improved the "melting" of dry-cured pork hams. In addition, Øverland et al. (2005) reported that an increase in polyunsaturated fatty acid content decreased the sensory "hardness" of pork longissimus muscles that had been stored for three months. On the other hand, several reports have indicated that fatty acid profiles, which strongly affect fat texture, did not relate to the overall acceptance and sensory texture of pork and pork products as judged by human panels (e.g., St. John et al., 1987; Hansen et al., 2000; Engel et al., 2001; Wiegand et al., 2002). These reports indicated that the characteristics of fat were related to the sensory texture and acceptability of pork and other species of muscle foods, and that the relationship between fat quality and sensory traits could not always be detected.

In the present study, the difference in fat meltability between the formula- and FCFL-fed pork loin samples as assessed by the sensory panel was significant ($p<0.01$). The fat texture preference related significantly to the whole fat preference ($p<0.0001$, Figure 2 and Table 5(B)) and the overall preference ($p<0.01$, Figure. 3 and Table 5(D)). On the other hand, the panel expressed no overall preference between the two loin samples. As presented in Figure 2 and Table 5(C), the preference for fat texture, which is a subjective item, was not related to the assessment of fat meltability, which is an objective item. We consider that the difference between the judgment concerning meltability and the fat and overall preferences was caused by differences having to do with the participants' individual preferences toward meltable fat.

In addition, we performed an additional chi-square analysis and found that the fat texture and overall preferences were not related to the gender or age group of the panelists (data not shown). In order to improve the production and marketing system of pork and other muscle foods, the details regarding the preference for pork fat texture must be investigated from the viewpoint of the individual panelists' profiles and their knowledge about and attitude toward meat consumption.

In conclusion, our sensory and mechanical investigation indicated that FCFL-fed pork had a higher fat meltability than did formula-fed pork, as determined using an oven-cooked pork loin. The number of panelists who judged FCFL-fed pork preferable did not differ from the number of participants who judged formula-fed pork preferable. Sensory fat meltability did not correlate with the fat texture preference and the overall preference, although the fat texture preference was related to the overall preference. We considered that the preference for meltable fat found in the present sensory study differed between each panelist. To enhance pork quality and its marketing, additional investigation is needed to classify the consumer in terms of his or her individual preferences toward the physical properties of fat and lean meat, especially regarding FCFL- or other new feed resource-fed pork.

ACKNOWLEDGEMENTS

The present study was financed by the Ministry of the Agriculture, Forestry and Fisheries of Japan, through the Bio Recycle Research Project.

The authors are grateful for the help of Yumiko Endoh of the National Institute of Livestock and Grassland Science, Japan.

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