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Effect of PSE Pork on Physiochemical and Microbiological Properties of European Style Fermented Sausages during Ripening

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Abstract

European style fermented sausages were made with normal pork, PSE and a 50 : 50 mixture, inoculated with *Lactobacillus plantarum* 1-74 and *Staphylococcus simulans* MIII and ripened for 21 days following commercial manufacturing procedures. In all treatments, pH droped sharply between 0 and 3 days during ripening. PSE sausages showed the lowest pH and Aw at the end of ripening than other treatment groups. Protein solubility, hardness, cohesiveness and chewiness were significantly ($P<0.05$) low for PSE sausages. Springiness was the highest for normal sausages but the other two treatment were not different. PSE sausages had poor texture low redness value during the ripening. The addded sugars apparently dropped the pH fast in PSE sausages. Total bacterial count and lactobacilli increased from 0 day to the third day of ripening. The number of *Staphylococcus sp.* decreased in normal sausages by the end of the ripening period. Fermented sausages with PSE meat could be produced if the mixture had lower (<50%) amounts of PSE meat. In addition, added sugar must be reduced to prevent lowering the pH to a level that will affect processing and quality attributes of fermented sausages.

Key words: fermented sausages, PSE, lactobacilli, staphylococci, Aw

Introduction

In some European countries, such as Germany, the annual consumption of fermented meat products per capita comprised about 8% of the total meat consumption.[1] Extension of shelf-life of fermented sausages is achieved mainly by lowering water activity and decreasing pH during ripening. Water activity can be lowered by addition of salt and dehydration of the product. On the other hand, pH decline is achieved by organic acids produced by bacterial breakdown of glycogen in meat and the addition of sugars. A low water activity and pH inhibit the growth of spoilage microorganisms during fermetation and drying.[2-5]

In addition to inhibition of growth of spoilage bacteria, low pH improve the binding capacity of meat, and fat particles, and improve color.[6,7] Also, low pH makes the dehydration of fermented sausages easy as the water holding capacity of the protein decrease at low pH. In contrast to emulsion making, low pH is ideal for manufacturing of fermented sausage. The ideal pH of the raw meat for fermented sausages is between 5.4-5.8.[8-10] Wirth[10] suggested that PSE meat could successfully be incorporated in making of fermented sausage if added in proportions that will not affect the ultimate quality of the product.

The protein solubility, pH and water holding capacity are low in PSE meat. When PSE meat is mixed with normal meat for the manufacture of fermented sausage, it reduced the drying time. Also, the sausages had high moisture diffusion rates as well as rancidity problems.[11] The interrelationships of physical and chemical properties of PSE meat and the quality of fermented sausages need further investigation. Honkavaara[12] examined attributes of fermented sausages made with a mixture of PSE meat, beef and pork fat. He concluded that PSE meat could be mixed with normal for production of fermented dry sausage without quality defects. Approximately 50% of the pork carcasses might have PSE meat in Korea during summer. So, the utilization of PSE meat in fermented meat products is an alternative way for meat products manufacturing. Therefore, the objectives of this study were to investigate the quality, physiochemical and microbiological properties of European style fermented sausage.

Materials and Methods

Manufacture of fermented sausage

Pork lean was obtained from carcasses 24 hrs postmortem. Normal quality of PSE loins were selected

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on the basis of color, structure and firmness.[13] Normal pork lean had pH 5.9-6.0, while the pH of PSE meat was below 5.5. There dfferent groups of fermeted sausages were prepared. The first group of fermented sausage was manufactured by using only PSE pork. The second group was processed by using 50% of normal PSE pork and 50% of PSE lean. Only normal pork lean was used to prepare the last groups fermented sausage. Four kilograms of fermented sausage were made at each group. Pork was cut into small pieces (~4 cm^2) and stored −20℃ for 2 weeks. Back fat was frozen at −20℃ to reduce its moisture content before cutting pork lean. Then, fat was tempered at −5℃ for easy cutting just before manufacturing. Starter culture was *Lactobacillus plantarum* 1-74 and *Staphylococcus simulans* MIII (Rudolf Mü ller, Germany) which were inoculated at the rate of 10^6 and 10^5 cells per one gram of material, respectively.

The processing of fermented sausages in this study followed European commercial procedures. Meat and fat (−5℃) were cut in a commercial cutter (Seydelmann, Germany). Fat was then gradually added after the meat was cut. Other ingredients and starter culture were carefully added and mixed during cutting (Table 1).

Table 1 shows the amount and percentage of ingredients at each group of the fermented sausage mixture. About 350g portions of the mixture were stuffed in securex-fibrous casings, 5.5 cm in diameter (Walsrode, Germany). After stuffing, sausages were allowed to ferment and dry for 21 days. Two days after stuffing, the sausages were smoked at 20℃ for 3 hrs. The sausages were fermented and dried at 22 ℃ for 95% relative humidity (RH) in first two days. In next four days, the sausage were fermented and dried at 15℃ for 95% RH, and then at 15℃ for 80% RH in the rest of the ripening period.

Table 1. Ingredient percentages and amount of fermented sausage mixture

Composition	Content (%)	Amount (g)
Pork (Loin)	66	2640
Speck	30	1200
NaCl	2.7	108
GdL	0.7	28
$NaNO_2$	0.015	0.6
Pepper	0.435	17.4
Ascorbic acid	0.1	4
Corriander	0.05	2
Starter culture		
Lactobacillus plantarum (DSM-Nr. 1952) 10^6 cells/g		
Staphylococcus simulans (DSM-Nr. 1954) 10^6 cells/g		

Chemical and physical analyses

All pH measurements were conducted by using the Knick (No. 654, Germany) pH meter in all samples. The measurement was done at 0, 3, 7, 10, 14 and 21 days samples during ripening. Two sausages were removed from each treatment on each sampling day for pH measurements. On each sausage, pH is measured on the exposed surface at 5 different locations. The average of the five pH measurements was used to determine pH values. Water activity (Aw) of samples measured by using Novasina hygrometer (EEJA-3/Switzerland) at three different locations of sample. The hygrometer was standardized by using saturated solution of $BaCl_2 \cdot 2H_2O$, NaCl and $Mg(NO_3)_2 \cdot 6H_2O$. The texture measurements of each treatment were performed at 7, 14 and 21 days using Instron Universal Testing Machine (Model No, 1140 Instron Corp., U.S.A.). Four slices (1.2 cm in thickness) were obtained to determine the texture from each treatment. The texture measurement was done five times at each slice. All measurements were expressed for hardness, springness, cohesiveness and chewiness as the texture measurements. These analyses were conducted by following the method of Peleg (1976).

Color values were determined by using the color different meter (UC600IV, Yasuda Co, Japan) equipped with an M head. The color instrument was standardized with a standard color plate (L=89.2, a=0.023, b=0.783). Results were expressed as Hunter L, a and b values.

Protein solubility were determined at 0, 7, 14 and 21 days by the procedure of Klement *et al.*[15]

Total bacteria count was determinded by plating on standard I agar (Merck) and incubation at 30℃ for 48 hrs. Also, the growth of lactic acid bacteria was determined by using MRS agar (Difco) and incubated at 25℃ for 3-4 days. Seletive agar (Difco) and incubation days were used for the growth of staphylococci by incubating at 30℃ for 3 days. On the other hand, streptococci were evaluated by using KF strepto agar (Difco) and incubated at 25℃ for 3-4 days. The KF agar is sterilized, cooled to about 60℃ at which 1% solution of the antibiotic 2, 3 5-triphenyltetrazolium chloride was aseptically injected and mixed.

Statistical analyses

Data was subjected to analysis of variance and

Table 2. Water activity (Aw) in different groups of sausages with increasing days on ripening

Days	NML	50 : 50	PSE
0	0.972[a]	0.967[b]	0.961[c]
3	0.960[a]	0.958[b]	0.952[c]
7	0.955[a]	0.950[b]	0.945[c]
10	0.932[a]	0.921[b]	0.915[c]
14	0.904[a]	0.897[b]	0.892[c]
21	0.864[a]	0.860[b]	0.847[c]

*Values within each row with different superscripts are significantly different (P<0.05)

mean separation to determine the effect of treatments (type of lean) and days on ripening on pH, protein solubility, water activity, Hunte color values and structural parameters.

Results and Discussion

pH

Fig. 1 shows pH values for fermented sausages made with normal, PSE and mixture of normal with PSE during ripening. In this figure, it could be observed that pH dropped rapidly on the third day of ripening in all treatments. There was a significant difference in pH among all treatments (P<0.05). After mixing of all ingredients, pH of the initial mixture of normal sausage was 5.9, while that of 50 : 50 mixture and PSE were 5.75 and 5.50, respectively. The addition of PSE meat resulted in a significant drop of pH in the mixture. In the third day of ripening, pH values was 4.92, 4.79 and 4.68 for normal, 50 : 50 and PSE sausage, respectively. The pH of PSE sausages was lowest at the end of ripening period. In contrast to the findings of this study, Honkavaara[12] reported that the final pH of PSE fermented sausages at the end of the ripening period were similar to that of normal meat. It is worth of mentioning that Honkavaara[12] used beef trimmings in his formulation (36.5 %). The beef he used had a low pH similar to PSE, which explained the discrepancy between his findings and the results of this study (Fig. 1). However, Rödel[16] sampled fermented sausages from different grocery store in Germany and found that the average pH was 4.92. This agrees with pH of the normal fermented sausages observed at the end of the ripening period in this study. PSE sausages have same amounts of added sugar (0.7%) as other treatments. This might explain that the low pH of PSE sausages observed at the end of the ripening period could have been in part due to the added sugars.

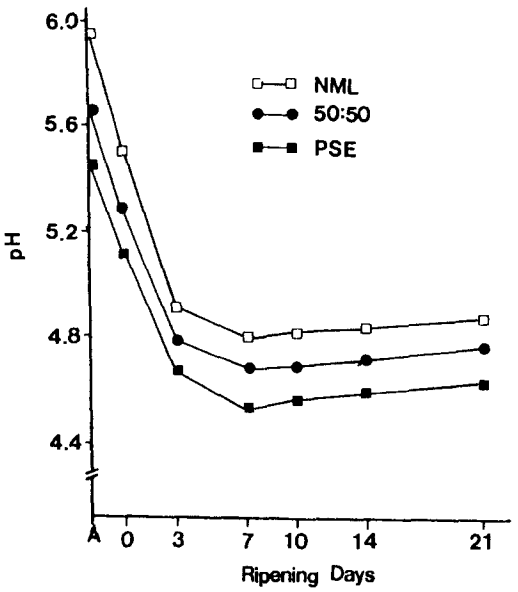

Fig. 1. Changes in pH fermented sausage during ripening in different sausage groups
A: After mixing in cutter, 0: After stuffing

Water activity (Aw)

At 0 day (after stuffing), the Aw of normal sausage is the highest while that of PSE is the lowest. Water activity is significantly different (P<0.05) among all treatments at each ripening period. However, there is no significant difference between normal and 50 : 50 mixture at 21 days sample. The lower pH of PSE meat decreased the sausages water holding capacity and accelerated dehydration of the sausages during ripening. Similar results were reported by Townsend *et al.*[11] who concluded that sausages made with PSE pork had significantly (P<0.05) more shrinking than those of normal pork. Lee *et al.*[9] documented a pattern of water activities for all pork salami similar to the findings of this study. Large amounts of moisture must be lost from fermented sausages before a conspicuous decrease of Aw can be observed. In PSE sausages, Aw decreased at a faster rate (P<0.05) as ripening period increased.

Texture

Changes of texture in fermented sausage during ripening were illustrated in Fig. 2. Hardness increased (P<0.05) in all sausage groups. Chewiness increased (P<0.05) until the 14th day of ripening in all

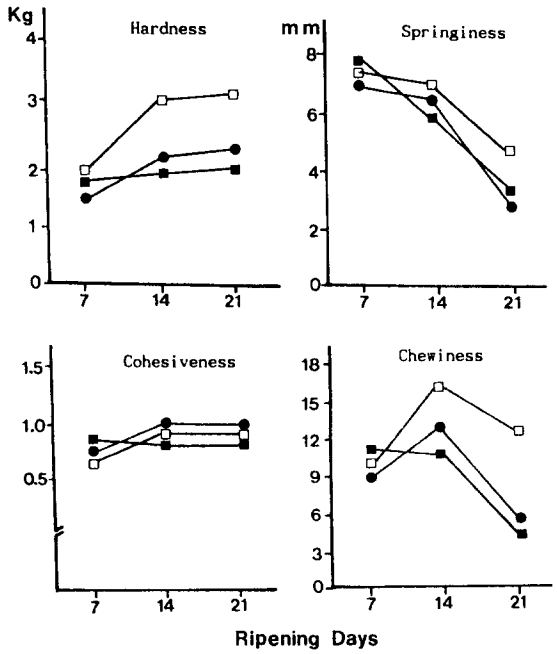

Fig. 2. Changes in texture in fermented sausage during ripening
□—□; NML, ●—●; 50 : 50, ■—■; PSE

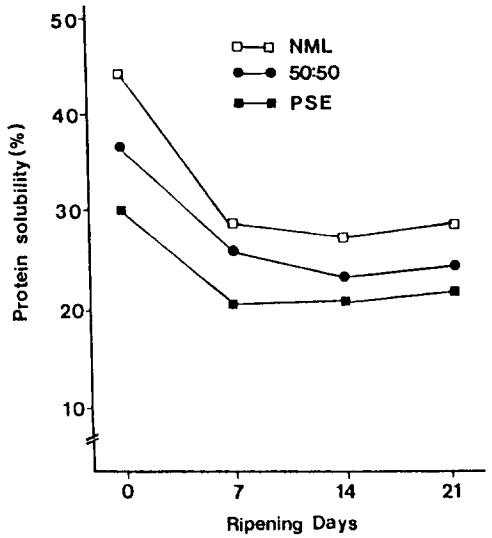

Fig. 3. Changes of protein solubility in fermented sausage during ripening

groups except PSE sausages which showed same value. From the 14th day to end of ripening, chewiness decreased at a faster rate in 50 : 50 and PSE than in the normal sausage group. Springness decreased as ripening prologed. Hardness, springiness and chewiness were higher ($P<0.05$) at the end of the ripening period in normal sausages than the other two treatments which were not very different. Hardness and chewiness is aiso significantly higher for the normal sausages at the 14th day of ripening. Cohesiveness was not very different among all treatments. Shear values obtained from Townsend *et al.*[11] were the lowest for PSE sausages at each drying interval tested except 21 days. In their study, shear values increased as drying time increased. Similar results were obtained from drying intervals between 7 and 14 days. However, the hardness plateaued in all treaments between 14 and 21 days. The results of this study was similar to those of Townsend *et al.*[11]. The low structure values for PSE sausages in this study could have been due to its low protein solubility (Fig. 3). Soluble meat proteins played important role as binding material between fat and meat particles.[15,17] Since PSE sausages had the lowest Aw at the end of ripening, the sausage product is expected to be crumbly and lack bind.[11] On the other hand, the sausages made with normal meat has the highest pH, protein solubility and hardness. The 50 : 50 mixture had higher protein solubility and pH than PSE meat but the structural parameters were not different ($P>0.05$) at the end of the ripening.

Protein solubility

Before ripening (after directly stuffing), all treatment had different ($P<0.05$) protein solubilities (Fig. 3). Protein solubility sharply declined ($P<0.05$) between 0 and 7 days and stayed the same value until the end of ripening. The decrease of protein solubility follows a similar pattern to that of pH. Waldlaw *et al.*[18] investigated solubilities of myofibrillar and sarcoplasmic proteins during ripening of summer sausages and concluded that protein solubility declined with ripening. Similar results were reported by Klement *et al.*[15]. Protein solubility decreased because acid was formed during ripening by lactic acid bacteria which lowered the pH and resulted a nondenaturing isoelectrical precipitation. Electrostatic forces and hydrogen bonding increase at a lower pH. A decreases in solubility of about 45% ($P<0.01$) was observed for myofibrillar proteins as the pH decreased from 6.2 to 5.5.[15] A similar pattern is evident among treatments in this study (Fig. 1 and 3). Meat protein solubility must be high to produce good consistency and slicing quality product. As showen in

Table 3. Hunter color values in fermented sausages during ripening

Color value	Sausage groups[a]	Ripening days[b]		
		7	14	21
Hunter L (Whiteness)	Normal	53.8[a]	50.5[a]	47.9[a]
	50 : 50	56.2[b]	53.5[b]	49.6[b]
	PSE	64.8[c]	57.3[c]	53.0[c]
Hunter a (Redness)	Normal	10.3[a]	11.0[a]	11.8[a]
	50 : 50	9.1[b]	10.1[b]	10.6[b]
	PSE	6.5[c]	8.3[c]	9.0[c]
Hunter b (Yellowness)	Normal	8.3[a]	8.2[a]	8.3[a]
	50 : 50	8.6[b]	8.7[b]	8.9[b]
	PSE	6.8[c]	9.0[c]	8.2[c]

[a]Normal=Normal quality pork, 50 : 50=equal mixture of PSE and normal pork, PSE=only pale, soft, exudative pork

[b]Values within the same column with different superscripts are significantly different ($P<0.05$)

Fig. 3, sausages made with PSE meat had lower ($P<0.05$) cohesiveness, chewiness and springiness than normal meat, which is expected a low protein solubility product.

Color

Hunter color values in fermented sausages for different sausage groups is shown in Table 3. Redness (a-value) increased ($P<0.05$) with increasing ripening intervals in all groups of sausages because the nitric oxide, formed as a result of the breakdown of sodium nitrite, reacted with myoglobin to form nitric oxide myoglobin during ripening. Nitric oxide myoglobin became concentrated by drying, thus resulted in higher color a-values. The differences ($P<0.05$) in a-values among treatments are more at the 7 day ripening than at the end of the ripening period. The pigment of PSE sausage, which lost more moisture, became more concentrated at the end of the ripening period, thus resulting in less differences in a-values than those shown at 7 days (Table 3). a-values were 10.3, 9.1 and 6.5 for normal, 50 : 50 and PSE sausages, respectively at the 7 day interval, while at 21 days they were 11.8, 10.0 and 9.0, respectively.

The whiteness (L-value) decreased ($P<0.05$) with increasing ripening days in all treatments (Table 5). PSE sausages had the highest ($P<0.05$) value while 50 : 50 mixture showed the second higest value at the end of the ripening period.

Yellowness (b-value) was not different among the sausage groups at the end of the ripening period.

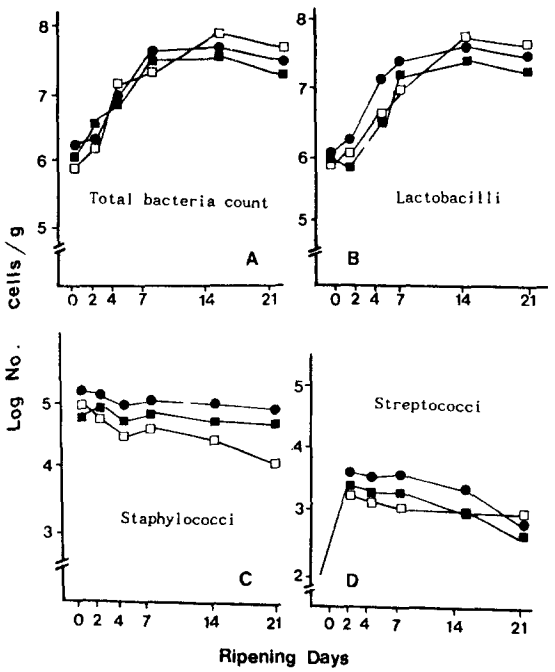

Fig. 4. Growth of microorganisms in fermented sausage during ripening

□—□; NML, ●—●; 50 : 50, ■—■; PSE

Microbial analyses

In all treatments, total bacterial counts and lactobacilli increased by two log during the ripening intervals from 0 day to 14 days (Fig. 4A and B). They slightly decreased between the 14 days and 21 days. Waldlaw *et al.*[18] observed a similar increase trend in lactic acid bacteria during the 36 hrs fermentation of summer sausage. The trends of development of microflora, in European style fermented sausages documented by Lücke,[1] is similar to those observed in this study. PSE sausages had slightly lower total bacterial counts and lactobacilli than other sausage group (Fig. 4) because of low pH and Aw.

Staphyloccoci, inoculated as a part of the mixed starter culture in sausages, decreased slightly with increased ripening intervals. However, the reduction is one log cycle in sausages made with normal meat (Fig. 4D).

Streptococci, which originally present in raw meat ($<10^2$ cells/g), increased rapidly in the first two days of ripening (10^5), then decreased slowly until the end of the ripening period (Fig. 4D). Except for staphylococci, all treatment didn't affect microbial counts during ripening of fermented sausages. Similar results

were documented by Lücke.[1]

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References

1. Lücke, F.K.: Fermented sausage. In *Microbiology of Fermented Foods*, Wood, B.J.(ed), Elsevier Applied Science publishers, London, p. 41(1985)
2. Baldini, F., Palmia, F. and Raczyrisk, R.G.: Effect of chemical and physiochemical properties of sausage mixes on decrease of pH and weight loss during ripening of typical italian dry salami. The 29th European Meetings of Meat Research Workers, p. 189(1983)
3. Frey, W.: Schnittfest Rohwurst. In *Die sichere Fleischwaren Herstellung*, Frey, W.(ed.), Hans Holzmann Verlag, Bad Worishofen S. 7(1983)
4. Leistner, L., Rödel, W. and Krispien, K.: Microbiology of meat and meat products in high-and intermediate-ranges. In *Water Activity*, Rockland, L.B. and Stewart, G.F.(ed.), Academic Press, New York, p. 855(1981)
5. Sirri, P., Nurmi, L., Puolanne, E. and Niinivaara, F.P.: Der Einfluss von Starterkulturen und verschiedenen Zusatzstoffen auf das Wachstum von *Salmonella senftenberg* in Rohwurst. *Fleischwirtschaft*, **57**, 1007(1977)
6. Solokolov, A.A. and Tehekhovskaya, V.S.: On the structure formation during dry sausage aging. 17th European Meeting of Meat Research Workers, p. 767(1971)
7. Klettner, P.G. and List, D.: Effect of type of carbohydrate on course of dry sausage ripening. *Fleischwirtschaft*, **60**, 1589(1980)
8. Koch, M.: Die Fabrikation feiner Fleisch und Wurstwaren. Verlaghaus Sponholz, Frankfurt am Main. 17 Aufl. S., 171(1982)
9. Lee, I.C., Harmon, L.G. and Price, J.F.: Growth and enterotoxin production by staphylococci in Genoa salami, *J. Food Protect.*, **40**, 325(1977)
10. Wirth, F.: The technology of processing meat not of standard quality. *Fleischwirtschaft*, **66**, 1256(1986)
11. Townsend, W.E., Davis, C.E., Lyon, C.E. and Mescher, S.E.: Effect of pork quality on some chemical-physical and processing properties of fermented dry sausage. *J. Food Sci.*, **45**, 622(1980)
12. Honkavaara, M.: Influence of PSE pork on the quality of economics of cooked cured ham and fermented dry sausage manufacture. *Meat Sci.*, **24**, 201(1988)
13. Anon.: *Pork Quality Standards*. Wisc. Agr. Expt. Sta. Special Bull. No. 9(1963)
14. Peleg, M.: Texture profile analysis parameters obtained by a Instron universal testing machine. *J. Food Sci.*, **41**, 472(1976)
15. Klement, J.T., Cassens, R.G., Fennema, O.R. and Greaser, M.L.: Effect of direct acidulation and heat on the solubility of protein extract from a fermented sausage. *J. Animal Sci.*, **41**, 554(1975)
16. Rödel, W.: Einstufung von Fleischzeugnissen in leichtverderbliche, verderbliche, and lager-fähige Produkte auf Grund des pH Wertes und Aw Wertes. Berlin. Dissertation(1975)
17. Shin, H.K., Choi, S.S. and Kang, I.S.: Effect of added NaCl levels on the physical, chemical and microbial properties of dry sausage during ripening period. *Korean J. Food Sci. Technol.*, **20**, 755(1988)
18. Waldlaw, F.B., Skelley, G.C., Johnson, M.G. and Acton, J.C.: Changes in meat components during fermentation, heat processing and drying of a summer sausage. *J. Food Sci.*, **38**, 1228(1973)

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원료육질이 발효소세지의 이화학적인 성상과 미생물 특성에 미치는 영향

진구복 · 지승택 · 서선우 · 신현길

건국대학교 축산가공학과

본 연구는 PSE(pale, soft, exudative)육의 이용성을 조사하기 위하여 정상돈육 처리구, PSE 돈육처리구 및 정상돈육과 PSE 돈육의 1 : 1 혼합처리구로 하여 *Lactobacillus plantarum*과 *Staphylococcus simulans*를 첨가한 유럽스타일의 발효소세지를 제조하여 21일간 발효 및 숙성을 실시하였다. PSE육 처리구가 최종제품에서 가장 낮은 Aw 및 pH를 나타내었고, 단백질 용해도도 가장 낮았다. 이러한 저하는 PSE육의 혼합정도와 높은 유의성을 나타내었다($P<0.01$). 또한 PSE육 처리구가 경도, 점착성 및 저작성에 있어서도 낮았다. 이러한 결과는 PSE육 특성뿐만 아니라 PSE육에 의한 낮은 pH값과도 관계 있으리라 본다. 따라서 PSE육으로 발효육제품을 생산함에 있어 당의 첨가수준을 낮게 조절하여야 할 것이다. 정상육과 PSE육의 혼합육으로 바람직한 발효소세지를 제조하기 위해서는 PSE육을 50% 이하로 혼합하여야 할 것이다.