KOREAN J. FOOD SCI. ANI. RESOUR. Vol. 26. No. 1, pp. 15~19(2006)

Optimization of the Processing Conditions for the Production of Cooked Pork Sausage as a Ready-to-Serve Product

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Abstract

The aim of this study was to determine the best processing conditions for producing of dried lean pork as a ready-to-serve product without using large-scale machines. Lean pork sausage was produced using 1.27% sodium chloride, 0.075% sodium polyphosphate, 0.06% sodium ascorbate, 0.075% sodium pyrophosphate, 0.009% sodium nitrite, 0.009% dextrin, 0.11% sodium glutamate and 1.4% spice mixture. The most appropriate slice thickness for drying was examined by slicing the sausage at a 0.5, 1 and 2 cm thickness. The drying temperatures were determined by drying the sausage slices at 35, 48 and 68 ℃. The total drying period was for 12 hr. In order to examine the ability of this process to sterilize the pork, the raw meat materials were inoculated with *Escherichia coli* (*E. coli*). The optimal conditions for producing lean pork sausages were a 2 cm slice thickness and drying temperature of 68 ℃ for 12 hr. The moisture content, water activity, color, hardness and pH were measured in the dried product. The product had a moisture content of 47.5% and a water activity of 0.93. There was a 47.7% percentage reduction in moisture. The dried product tested negative for *E. coli* even though the raw meat materials been inoculated with *E. coli*.

Key words : lean pork sausage, drying temperature, drying period, *Escherichia coli*

INTRODUCTION

Meat processing probably began before the dawn of civilization. At that time, the concept of processing was to preserve food by inhibiting or retarding microbial decomposition (Pearson *et al.*, 1999). Today, processed meat provides both convenience and variety to the meat portion of the diet. In addition, meat itself is important because of its high nutritional value (Hultin, 1996). There is a wide range of processed products available including fresh or frozen meat, cured meat either non-smoked or cooked as dry cured ham, smoked, dried and cooked as sausages and convenience foods such as pizza, pies, etc (Pearson *et al.*, 1999). Sausage is one of the oldest forms of meat product, and has a wide consumer acceptance. There is wide variety of sausage products worldwide and also many classification systems are available. According to the USDA (United State Department of Agriculture) Meat Inspection Service, sausages are categorized as follows: fresh sausages, uncooked smoked sausages, cooked smoked sausages, cooked sausages, dry and semi dry sausages and luncheon meat, loaves and jellied products (Pearson *et al.*, 1999).

There is a low level of meat consumption in developing countries compared with developed countries, for example, Sri Lanka now and Japan 100 years ago compared with Japan now, USA and European countries. In Sri Lanka, more than 80% of the population practices Buddhism or Hindu, in which vegetarianism is a long established feature (Varnam *et al.*, 1995).

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However, the consumption of meat or processed meat products in the developing countries is increasing because the intake of an appropriate animal protein has been recommended for human health. Therefore, there is potential for increase the rate of meat consumption using processed meat products. The aim of this study was to determine the optimum processing conditions for producing dried lean pork as a ready- to-serve product.

MATERIALS AND METHODS

Sausage Processing Conditions

Ground lean pork from the hind leg (3~5 days after slaughtering) was purchased from a local butcher, Obihiro, Japan. The raw meat batter was prepared by mixing the ground meat with 1.27% sodium chloride, 0.075% sodium polyphosphate, 0.06% sodium ascorbates, 0.075% sodium pyrophosphate, 0.009% sodium nitrite, 0.009% dextrin, 0.11% sodium glutamate and 1.4% of spice mixture. The batter was kept overnight at 4 ℃ in order to allow the ingredients to diffuse into meat. The resulting batter was stuffed into presoaked cellulose casings (Viskase, USA), which were 20 cm in length and 4 cm in diameter using a grinder (National, MK-G3S, Japan) and knotted with cotton string. The raw sausages were cooked in a hot water bath at 80 ℃ in order to achieve an internal temperature of 63 ± 2 ℃ for 30 min. The sausages were sliced at 0.5, 1 and 2 cm in thickness. The slices were then loaded into plastic trays and air-dried using a food dehydrator (Nesco, Model FD 60, USA) at 68 ℃ for 12 hr. The optimum slice thickness was determined based on the results of a tasting panel consists of 15 individuals.

Physico-chemical Analysis

The sausages were made, cut into 2 cm slices and peeled off to remove the cellulose casings. Those were then loaded into plastic trays and air-dried using a food dehydrator at 68 ℃ for 12 hr. Then they were analyzed for their moisture content in triplicates according to the AOAC (1999). The water activity was measured in a constant temperature and humidity enclosure using a water activity meter (Rotronic Hygroskop, BT-RST, Switzerland). The pH was measured using a pH meter (TOA, Japan) and the hardness was measured, as the maximum force required to cut the dried sausage surface using a Rheometer (Fudoh, Japan) . The *L**, *a** and *b** color indexes were obtained by averaging values of three readings performed on the dried sausage slices using a chromameter (C light source and 2^0 observer, Minolta CM-1000, Japan). The spectral reflectance curves were determined in the visible wavelength region between 400 and 700 nm. The moisture content, water activity, color and hardness of a control sample the inoculum was examined.

Escherichia coli Inoculation and Its Survival Temperature

Escherichia coli (ATCC 25922) was incubated on standard plate agar slants (Eiken Chemical Co., Japan) at 37 ℃ for 24 ± 2 hr, after which it was maintained at 4 ℃. One loop of *Escherichia coli* was then transferred into a trypticase soy broth (Becton Dikinson & Co., England) containing 1% glucose and incubated at 37 ℃ for 24 ± 2 hr. The inoculum was maintained at 4 ℃ for less than 30 min.

The inoculum was added at a rate of 12 mL/ kg of meat batter and mixed thoroughly manually. The resulting was kept overnight at 4 ℃, and sausages were produced as described in the former paragraph. In order to determine the drying temperature, the sausages were sliced at a 2 cm thickness and dried at 35, 46 and 68 ℃ for 12 hr. From each heat-treated samples, 10 g was excised from the middle of each slice using a sterile knife. Ninety mL of sterile saline (0.85% sodium chloride solution) was then added and homogenized for two min. Ten grams of the inoculated raw meat was diluted ten times, as described above and homogenized for 2 min. One milliliter of each was plated on the Chromocult (Merck, Germany) and incubated at 37 ℃ for 24 ± 2 hr. The heat-treated samples drawn at 3 hr intervals were evaluated for the *Escherichia coli* content and the drying temperature was determined.

Statistical Analysis

Each analysis was carried out at least in triplicate. The significance of the differences between the mean values was determined using a Student's *t*-test (SPBC, Comworks, Tokyo). A P value <0.05 was considered significant.

RESULT AND DISCUSSION

Table 1 shows the effect of the different drying temperatures on the physical properties of the sausages. The samples dried at 68 ℃ for 12 hr had the lowest moisture content and water activity.

Table 1. Effect of the drying temperatures on the physical properties of dried sausages

Property		Temperature		
		35 ℃	46 ℃	68 ℃
Moisture (%)		58.9 ± 1.02[a]	53.4 ± 2.0[b]	47.5 ± 2.0[c]
Water activity		0.956± 0.004[a]	0.953± 0.006[a]	0.930± 0.003[b]
Color	L*	34.8 ± 12.8	29.8 ± 3.3	27.6 ± 8.2
	a*	26.8 ± 9.4	44.5 ± 2.9	28.3 ± 8.7
	b*	15.7 ± 6.0	29.4 ± 4.8	16.1 ± 5.9
Hardness		0.31 ± 0.05[a]	0.26 ± 0.02[a]	0.46 ± 0.02[b]

Data are shown as mean ± SD. Means with same letter not significantly different ($p<0.05$) within the same rows.

This might be due to the high rate of thermal and mass transfer at 68 ℃ compared with that of 35 and 46 ℃. The increased hardness may be due to high rate of protein denaturation and case hardening at 68 ℃. In terms of color, the highest a* value was observed at 46 ℃. The lowest L* value was observed at 68 ℃, which indicates a high level of browning pigments which resulting from non-enzymatic browning. Table1 also shows the percentage weight loss at each drying temperature. At the end of the 12 hr drying period, the highest level of moisture reduction was observed at 68 ℃ and the lowest was observed at 35 ℃.

It was reported that a high fat content (more than 35% on a dry weight basis) significantly reduces the drying rate (Varnam et al., 1995), which is why only lean meat was used in this study. Many processors adopt hurdle technology to reduce the level of food-borne illnesses (Casey *et al.*, 2002). Drying is one of the most important food processing techniques used to preserve foods for a long period (Heldman *et al.*, 1998). The use of preservatives such as sodium chloride, sodium nitrite, spices, etc along with the application of heat would have a higher inhibitory effect on the pathogens than that of each alone. The product quality is superior when cooked prior to drying, because protein denaturation is less severe with cooking in the presence of water. The commonly used cooking temperatures around 60 ℃ or below improve the texture by degrading collagen without the accompanying shrinkage and water loss (Varnam *et al.*, 1995). Protein denaturation severely affects the textural changes during drying (Hultin, 1996). Dried products must be packaged in order to prevent water and oxygen entering the finished product, and the non-enzymatic browning and oxidative reactions (Hultin, 1996). Therefore vacuum packaging has been recommended.

The occurrence of coli forms in foods is an important indication of health hazards (Yassien *et al.*, 1998). There were many reports on the control of *Escherichia coli* in meat and meat products (Yassien *et al.*, 1998; Getty *et al.*, 1999; Cosansu *et al.*, 2000). Fig. 1 shows the change in the *Escherichia coli* population during drying at the three different temperatures. The highest *Escherichia coli* content at drying temperatures of 35 and 46 ℃ were be observed at 9 hr of drying after which they began to decline. This may be due to favorable internal temperature for the growth of *Escherichia coli*. The gradual destruction of the organism could be observed at 68 ℃ (Fig. 1). This might be due to the lower moisture content associated with the high temperature, which is more detrimental to the survival of *Escherichia coli*, as suggested by Cosansu and Ayhan (Cosansu *et al.*, 2000).

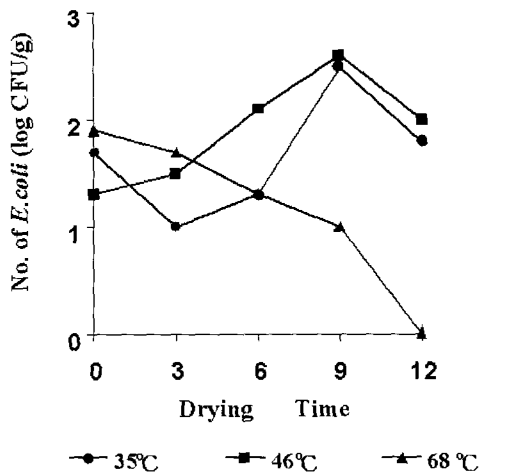

Fig. 1. Change in the *E. coli* population during drying at different temperatures. The mean values at 9 and 12hrs at 68℃ are significantly lower than those of 35 and 46 ℃.

Table 2. Effect of the slice thickness on the physical properties and chewing characteristics of dried sausages at 68 ℃ for 12 hrs

Slice thickness	Color			Hardness (kg/cm^2)	Chewing characters
	L*	a*	b*		
0.5 cm	29.2 ± 3.0	36.9 ± 3.5	15.8 ± 5.1	0.24 ± 0.03[a]	Rubbery
1.0 cm	28.9 ± 6.7	30.4 ± 9.3	15.4 ± 11.6	0.42 ± 0.01[b]	Rubbery
2.0 cm	27.6 ± 8.2	28.3 ± 8.7	16.1 ± 5.9	0.46 ± 0.02[c]	Not rubbery

The data is shown as a mean ± SD. Mean with the same letter not significantly different ($p<0.05$) within the same columns.

Drying at 68 ℃ for 12 hr completely eliminated the *Escherichia coli.* therefore, 68 ℃ was selected as the most appropriate drying temperature.

Table 2 shows the results obtained for drying the sausages at different slice thickness at 68 ℃ for a period of 12 hr. The L* and a* values, which indicate the lightness and redness respectively, decreased with increasing slice thickness from 0.5 cm to 2 cm. The highest lightness given by the highest L* value was observed in the 0.5 cm thick slices where-as the lowest was observed at 2 cm. This is due to dark pigments resulting from the non-enzymatic browning using the Maillard reaction, which is a common phenomenon during drying (Hultin, 1996). The redness given by the a* value was higher in the 0.5 cm slices, which is desirable. Color is a major factor that determines the consumer acceptability. Many researchers have used the L*, a* and b* values as a measurement to investigate the color stability of meat products (Warren *et al.*, 1996; Eikelenboom, 2000).

The variation in L*, a* and b* increased with increasing slice thickness, as indicated by the larger standard deviation (Table 2). Therefore, uniform drying was observed in the 0.5 cm thick slices. The hardness increased with increasing slice thickness (Table 2). This was measured as the maximum shear force using a rheometer. According to Spadaro and Keeton (Spaaro *et al.*, 1996), the texture measurements using the shear method not only evaluates a single property but also measures a composite of compressive, shear and tensile forces. A slice thickness of 0.5 cm was best in terms of the color and hardness, but it gave poor chewing characteristics, which would not appeal to consumers. Texture is the major quality attribute that alters during drying (Hultin, 1996), which are mainly caused by case hardening and protein denaturation leading to a poor texture during drying (Varnam *et al.*, 1995). Therefore, a 2 cm slice thickness in recommended. Table 3 summarizes the results obtained for some of the physico-chemical properties of the 2 cm slice dried sausages. The water activity, moisture content and pH were 0.93, 47.5% and 6.1 respectively. Getty *et al.*, (1999) reported a water activity of 0.938 and a pH of 4.37 in large diameter (115 mm) Lebanon style bologna. They also noted the importance of the lactic acid bacteria count in achieving a low pH. The pH of the dried sausages in this experiment was higher. This might be due to the condition of the starter culture including lactic acid bacteria, which produce lactic acid that is responsible for the preservative activity. However, *Escherichia coli* inoculated in to the sausage can be completely sterilized by just dry processing at 68 ℃ for 12 hr using a simple device.

Table 3. Physico-chemical properties of the dried sausages

Property		Mean ± SD
Water activity		0.930± 0.003
Moisture %		47.5 ± 2.0
pH		6.1 ± 0.1
Color	L*	27.6 ± 8.2
	a*	28.3 ± 8.7
	b*	16.1 ± 5.9
Hardness (kg/cm^2)		0.46 ± 0.02

Data is shown as a mean ± SD. Means with same letter not significantly different ($p<0.05$) within the same columns.

CONCLUSION

Drying at 68 ℃ for 12 hr is sufficient for completely destroying inoculated *Escherichia coli* during the production of dried lean pork sausages with a 2 cm slice thickness and a 6 cm diameter.

ACKNOWLEDGEMENTS

This study was supported in part by a grant from the 21 Century COE Program (A-1), and a Grant-in Aid for Scientific Research (B-2:#16380178), from the Ministry of Education, Culture, Sports, and Technology, Japan.

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(2005. 3. 8. 접수 ; 2005. 12. 31. 채택)