Effects of Salt Concentration of Brine, Curing Temperature, and Curing Period on Quality of Loin Roll Ham

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Introduction

In recent years, the curing process for producing ham in Japan has markedly been shortened by the use of machines such as pickle-injector and massager, with a result of omitting the aging process. This trend has caused a problem related to the taste of products, including flavor. On the other hand, the amount of salt-uptake from food comes to be discussed actively from the view-point of human health, and consumers preference has turned toward "less salt and sweet taste".

The taste of meat products also has shown a tendency to become "plain". With such a background, ham produced by the conventional method so far employed is regarded too salty to consumers preference. It becomes necessary to re-examine the curing methods.

Therefore, to re-examine the curing methods and to find out the condition for producing loin roll ham with salt content in harmony with taste including flavor, a series of experiments on curing methods and quality of products were carried out.

Experimental materials and methods

1) Meat materials

For one set of experiment, 8 hybrid pork pigs (LH, 90–100 kg) raised in our Institute were slaughtered. After 24 hr of cold storage, 4 loins were collected from 1 pig, and were boned and trimmed to make loin roll ham. As 2 sets of experiment were carried out, a total of 16 pigs were slaughtered.

2) Experimental sets

(1) Experiment 1 on NaCl concentration of brine

The conventional method employs NaCl concentration higher than 10%. In the Expt 1, NaCl concentration of 4, 6, 8 and 10% was combined with 5, 10, 15 and 20 days of curing period. The curing temperature was 1°±1°C.

(2) Experiment 2 on curing temperature

The conventional curing is made at low temperature (not fixed temperature). In the Expt 2, temperature of 0, 4, 8 and 12°C was combined with 4, 8, 12 and 16 days of curing period.

3) Composition of brine

It is shown in Table 1. The amount of brine used was equivalent to 1/2 weight of each raw meat. After the curing, samples were taken to be submitted to physico-chemical measurements, while the balance was used for manufacturing product.

4) Manufacturing process conditions

After curing, exposing in running water for 30 min (water temp. about 15°C), drying at 55°C for 1 hr, smoking at 60°C for 3.5 hr, and boiling at 70°C for 2 hr.

5) Physico-chemical measurements

(1) Color tone

Color of section of the samples was

Table 1. Composition of brine of various salt concentrations
(per 10 kg raw meat)

Items \ Salt concentration	4%	6%	8%	10%
Water (*l*)	5.0	5.0	5.0	5.0
Salt (g)	200	300	400	500
Sugar (g)	200	200	200	200
Sodium nitrite (g)	0.7	0.7	0.7	0.7
Monosodium L-glutamate (g)	20	20	20	20
Sodium 5'-Ribonucleotide (g)	0.1	0.1	0.1	0.1

measured with the color difference meter (Tokyo Denshoku, TC-5) immediately after cutting and was indicated with Hunter's L.a.b. values in the uniform chromaticity scale diagram.

(2) Salt

A sample (5 g) was heated in 100 m*l* of pure water for 30 min to extract salt. The water was made up to 100 m*l* after cooled, and submitted to Mohr's method,[1] by which titration with 1/10 N silver nitrate solution was made using an indicator, sodium chromate.

(3) Moisture content

Using a heated air circulating drier, the samples were dried for 16–18 hr at 100–102°C.[2]

(4) Water-holding capacity

Minced meat (10 g) was placed into a water-holding capacity measuring tube, heated at 70°C for 20 min, and submitted to centrifugal-separation[3] at 1,000 rpm for 3 min.[5]

(5) pH

Measured by stubbing an electrode of the pH meter (Horiba, F-7II) directly into meat samples.

6) Bacteriological tests

Dilution water (50 m*l*) was added to 5 g of sample and exposed to 6,000 rpm of a blender for 3 min. Total counts on plate count agar,[9] 30°C incubation for 48 hr.

Coliform counts on desoxycholate agar,[9] 37°C incubation for 24 hr.

7) Organoleptic test

A panel of 22 staffs of our Institute carried out a 5-level ranking assessment.[13]

Results and discussion

1) Penetration of NaCl

To examine the behavior of salt under different curing conditions, salt contents in surface, intermediate (about 3 cm of depth), and central portion (about 6 cm of depth) of loins and products were measured. As given in Table 2, the higher the salt concentration of brine, the higher the salt content in the surface portion, followed by the salt content of intermediate portion and central portion in that order. With the lapse of curing time, the amount of salt penetration increased with higher salt concentrations, resulting in remarkable differences in salt contents of ham as related to salt concentration of brine.

As curing temperature influences velocity of salt penetration, it was observed that even when the brine with the same concentration of salt was used, the higher the temperature, the higher was the salt content of the product (Fig. 1).

Wistreich et al.[10,11] treated muscle biceps femoris and muscle semi-membranous with the brine of high salt concentrations (10, 20, and 30%), and found out that the value of salt accumulation expressed by mg NaCl penetrated per 1 cm^2 of meat surface increased with the time of the treatment, and the use of the brine of higher salt concentration or that of increased volume per 1 cm^2 gave greater values of salt accumulation after the same period of the treatment. Such increases of the value were more remarkable with higher salt concentration of the brine used. The treatment using the brine of 20% salt concentration conducted at 3, 18, 27, or 40°C for 24 hr also showed that the higher the temperature, the higher the value of salt accumulation, irrespective of the difference of muscles. These results are consistent with our results.

2) Water holding capacity and moisture content of cured meat

Water-holding capacity of cured meat,

Table 2. Salt contents of various locations in the loins and the products cured with various salt concentrations of brine and curing periods

Curing Period (day)	Salt concentration of brine	Cured meats			Prodncts		
		Surface	Intermediate	Center	Surface	Intermediate	Center
5	4%	1.63	1.31	1.19	1.61	1.18	0.97
	6	1.88	1.27	1.14	1.81	1.34	1.13
	8	2.44	1.62	1.34	2.17	1.46	1.21
	10	3.02	1.72	1.17	2.42	1.69	1.33
10	4	2.11	1.96	1.82	1.60	1.35	1.33
	6	2.16	2.04	1.92	2.21	1.79	1.58
	8	3.05	2.78	2.40	2.53	1.99	1.72
	10	3.56	3.19	2.84	2.89	2.45	2.12
15	4	2.28	2.11	1.90	1.91	1.68	1.59
	6	2.97	2.69	2.60	2.47	2.26	2.17
	8	3.47	3.21	2.95	2.78	2.49	2.38
	10	4.01	3.59	3.37	3.41	3.05	2.76
20	4	2.41	2.31	2.29	2.09	1.95	1.92
	6	3.19	2.96	2.89	2.73	2.59	2.44
	8	3.76	3.66	3.64	3.17	3.06	2.89
	10	4.25	4.07	4.05	3.95	3.91	3.61

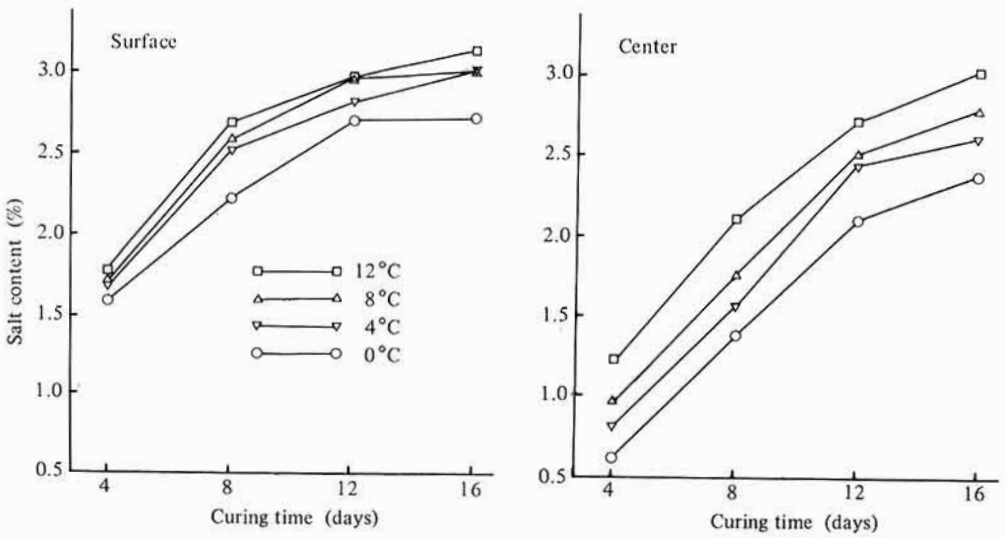

Fig. 1. Changes in salt contents of the loins cured at various temperatures

determined by the method of centrifugal-separation showed a high positive correlation with salt content of the cured meat (Table 3). At the initial stage of curing, when salt penetration into meat was not sufficient, the higher the salt concentration of brine, the higher was the water-holding capacity. When salt content in meat exceeded 2%, the water-holding capacity showed the highest value in all experimental plots. However, in the plot of 10% salt concentration, the curing for 20 days reduced the water-holding capacity. This result was different from the results of other plots.

Yasui[12] attempted to produce sausage by stepwise addition of salt to meat, starting

Table 3. Correlation coefficients among water holding capacity, color value, salt contents, moisture contents, and sensory evaluation

	Water holding capacity	Color value			Salt contents		Moisture contents		Sensory evaluation	
		L	a	b	Cured meats	Products	Cured meats	Products	Color	Flavor
Color value L	-0.495*									
Color value a	0.267	-0.650**								
Color value b	-0.022	-0.101	-0.238							
Salt contents in cured meat	0.691**	-0.836**	0.594*	0.039						
Salt contents in products	0.593*	-0.875**	0.632**	0.094	0.973**					
Moisture contents in cured meat	-0.059	0.506*	-0.032	-0.557*	-0.509*	-0.620**				
Moisture contents in prodncts	-0.277	-0.458	-0.040	-0.665**	-0.560*	-0.564*	0.758**			
Color	0.655**	-0.740**	0.461	0.013	0.825**	0.763**	0.286	-0.578*		
Saltiness	0.628**	-0.867**	0.491*	0.196	0.924**	0.936**	-0.628**	-0.635**	0.793**	
Flavor	0.832**	-0.743**	0.450	0.165	0.811**	0.768**	-0.277	-0.483*	0.837**	0.778**

* $P<0.05$, ** $P<0.01$

from 1% addition to 2, 3% and so on, and found out that the salt addition ranging from 2.5 to 3.0% gave the best binding property, showing about 0.6 of ionic strength. Ikeda et al.[6] also reported that the water-holding capacity became the highest at 0.6 of molar concentration when KCl was added. Furthermore, Cate[4] reported that in the range where pH value becomes higher than iso-electric point, the water-holding capacity of meat increased with the increase of salt concentration of brine up to 6–10%, but further increase beyond this point reduced the water-holding capacity. These results accord with the result of our study.

Moisture content of cured meat and product was slightly lower in plots with higher salt concentration of brine, but effect of curing temperature was not recognized.

3) Color and pH

Throughout the whole period of curing, the higher the salt concentration, of brine, the better was the color development of the meat, and the coloration showed high correlations with items of sensory assessment (Tables 3 and 4). In portions of meat where salt content was lower than 1%, areas in which color development had not occured were recognized. It implies that sodium nitrite added to the brine enters into meat, being accompanied with the penetration of salt, so that more salt penetration results in more color development.

The pH of meat hardly changed during the curing at low temperature. However, it showed a tendency to lower with the rise of curing temperature. It seems that this change of pH was induced by the brine affected by bacteria which multiplied in the brine, and also the meat strongly influenced by it (Figs. 2 and 3).

4) Examination of bacteria in brine

The number of living bacteria in the brine in the plots of curing at low temperature (0.4°C) was maintained at the level of 10^3/ml during the whole experimental period, while that in the plot of curing at 8°C exceeded 10^6/ml after 16 days of curing. In the plot of 12°C curing, bacteria multiplied very fast, reaching the level of 10^8/ml after 16 days of

Table 4. Sensory scores by 5 point evaluation for color, saltiness and flavor of the products

	Curing temperature (°C)	Curing time (day) 4	8	12	16
Color	0	3.13	3.22	3.27	3.09
	4	3.52	3.48	3.23	3.27
	8	3.35	3.26	3.41	3.18
	12	3.87	3.57	3.18	–
Saltiness	0	2.57	2.91	3.00	3.27
	4	2.87	3.13	3.32	3.32
	8	2.70	3.30	3.50	3.41
	12	3.17	3.65	3.64	–
Flavor	0	3.09	3.26	3.41	3.68
	4	3.17	3.65	3.23	3.59
	8	3.22	3.30	3.23	3.55
	12	3.57	3.22	3.23	–

curing. It caused the lowering of pH of brine and formation of white turbidity with yeasty odor. Thus the temperature of brine markedly influenced multiplication of bacteria (Figs. 4 and 5). Bothast et al.[3] reported that the number of living bacteria in brines ranged from 10^3 to 10^6/ml, in general, and the number and microflora were influenced by salt concentration, pH, temperature, etc.

As the species of the bacteria was not identified in the present study, it can not be concluded, but it seems that bacteria which are able to multiply under the experimental condition of 0–12°C with NaCl addition are *Micrococcus* genus, which is said salt tolerant among mesophilic and psychrophilic bacteria, and gram-negative bacilli belonging to psychrophilic bacteria, such as genera *Pseudomonas*, *Vibrio*, *Achromobacter*, *Flavobacterium*, *Alcaligenes*, etc., all of which are able to multiply easily at low temperature.

5) Organoleptic test of product

Ham produced with high salt concentration of brine and longer period of curing tended to be highly ranked for color and flavor. However, the curing with salt concentration of brine higher than 8% for 20 days resulted in too salty ham. Curing at 12°C gave higher ranks of ham for color, saltiness, and flavor at an early stage of the curing but these ranks for color and flavor declined with the passage of curing time (Table 4). On the contrary, curing at 0 and 4°C gave higher ranks for flavor with the passage of curing time. Curing at 0–4°C for 15 days with brine of 6% salt concentration gave the best result.

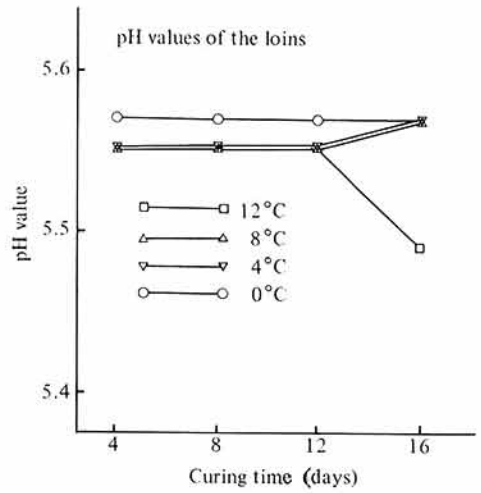

Fig. 2. Changes in pH values of the loins cured at various temperatures

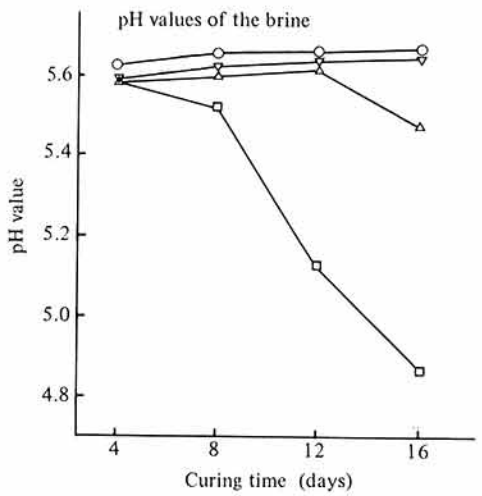

Fig. 3. Changes in pH values of the brine at various temperatures

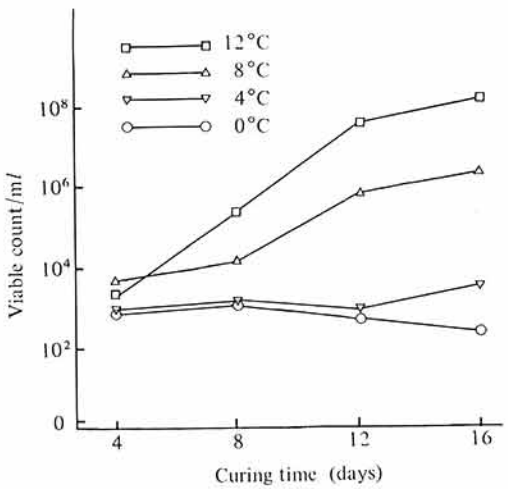

Fig. 4. Changes of viable counts of bacteria and yeasts in the brine cured at various temperatures

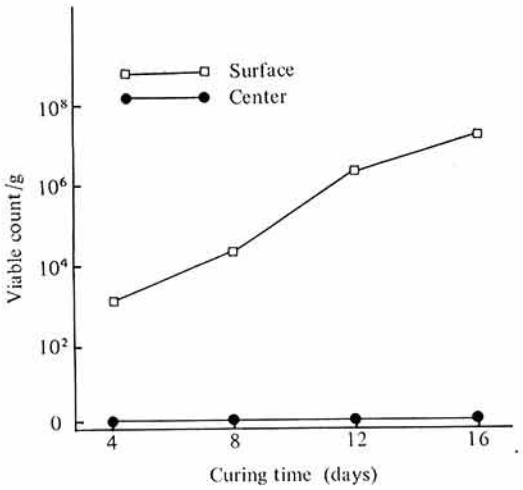

Fig. 5. Changes of viable counts of bacteria and yeasts on the surface and in the center of the loins cured at 12°C

Summary

To obtain basic information regarding effects of NaCl concentration of brines and curing temperature on the quality of loin roll ham, a series of experiments to produce loin roll ham, using brines of different salt concentrations at different temperatures were carried out and the quality of the product was examined by physicochemical measurements, bacteriological tests, and organoleptic test.

1) Penetration of NaCl into meat was faster with brines of higher salt concentration than those of lower salt concentration, and at higher curing temperature than lower curing temperature, resulting in better color development.

2) After the 8th day of curing at 12°C, bacteria and yeast multiplied extremely in the burines, causing the lowering of pH, and formation of white turbidity with yeast odor in the brines after 16 days.

3) Salt content of the loin roll ham which was accepted by each panel of sensory assessment as the most appropriate salty taste ranged from 2.0 to 2.5%.

4) Flavor of the hamf was more strongly influenced by the number of curing days than by salt concentration of brines: longer curing period gave higher ranks of sensory assessment than shorter curing period. Low curing temperature gave better flavor than high curing temperature.

5) Based on the results of physico-chemical measurement, bacteriological tests, and organoleptic test, it was made possible to produce loin roll ham with excellent flavor by 15 days of curing at 0–4°C using the brine of 6% salt concentration, under the curing condition of the present study.

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