MANUFACTURE AND ACCEPTABILITY OF AN ORIENTAL DRIED PORK PRODUCT

H. W. Ockerman and J. C. Kuo

The Ohio State University, Columbus, Ohio 43210 and The Ohio Agricultural Research and Development Center, Wooster, Ohio 44691, USA.

INTRODUCTION

Dried pork is a very popular, tasty and nutritional Chinese meat product. It is made from partially-frozen ham or pork loin which is sliced paper-thin, soaked in a curing mixture for 24 hours and then placed slightly overlapping on a lightly oiled bamboo basket. The meat slices are then placed outside for air drying when weather conditions are appropriate until they reach approximately 50% of their original weight. The meat slices are then cooked at approximately 150°C on a grill until brown (Huang, 1974). This conventional manufacturing method requires a great deal of labor and time in addition to being non-sanitary and depending upon natural environmental conditions. Karel et al. (1975) defined intermediate moisture foods (IMF) as product with a a_w range of 0.7 to 0.9; and, a moisture content ranging from 20 to 50%. IMF are sufficiently low in a_w to prevent bacterial growth. However, these foods may be susceptible to yeast and mold growth unless appropriate preventive measures are taken (Troller and Christian, 1978).

Dried meat is microbiologically stable but is subject to oxidative and browning reactions. The oxidation of the lipid portion of meat can result in rancidity. The removal of all visible fat and the packaging of the dried product using an inert gas or vacuum will help retard rancidity (Banwart, 1979). Labuza (1970) showed an increase in oxidative rancidity rate with an increase in water activity (from 0.35 to 0.80) in food. However, he did not include products with a a_w value of 0.90.

Cross and Ziegler (1965) concluded that nitrite minimizes the oxidation of unsaturated lipids. Hadden et al. (1975) stated that nitrite can retard the rate of oxidative rancidity (TBA value) in comminuted pork.

This research was conducted to develop a new economical, practical technique to produce uniform and attractive high sugar and high salt dried pork. In addition the effect of nitrate, packaging method and storage time on dried pork sensory properties, residual nitrite, TBA values (lipid oxidation) and microbiological counts were studied.

MATERIALS AND METHODS

Preparation of samples and experimental design

Hams were collected after 4 days aging at 1°±1°C and boned from pigs slaughtered at The Ohio State University Meat Laboratory, stored frozen approximately 2 weeks at -32°C and thawed (3°±1°C) for 48 hours prior to use.

All subcutaneous fat was removed from the hams prior to freezing. Four pairs of hams were assigned to two groups of four hams each. Group 1 was dry cured, 62 g per kg of meat, using a mixture of brown sugar (79.1%), salt (19.4%), sodium nitrite (0.29%) (180 ppm of meat block), and sodium nitrate (1.2%) (740 ppm of meat block). Current procedure allow use of nitrite and or nitrate in dry cured products as long as the residual nitrite does not exceed 200 ppm (Federal Regulation, 1975). Group 2 was cured with the same ingredients except no sodium nitrate was used. The curing mixture was evenly rubbed on the surface of each ham and the whole boned ham was then tumbled at a speed of 12 revolutions per minute for a 5 hr. continuous cycle. The hams were held in a cooler (3±1°C) for 7 days following tumbling. Before further processing, the hams were again tumbled for 1 hr. The hams were pressed (24.5 kg/sq cm) and shaped in a rectangular mold by using a Carver Laboratory Press, Model B (Fred S. Carver Inc.) in order to produce a uniform, compact finished product. Hams were cooked within the molds in an oven at 177°C to an internal temperature of 63°C, cooled, removed from the molds and sliced to a 0.2 cm thickness. The ham slices were soaked in soy sauce (Kikkoman) for 12 hours to obtain a desirable flavor and color. The soy sauce contained 16% salt and the absorption increased the salt level of the finished product. Finally, these ham slices were dried in a forced air oven (The G. S. Blodgett Co., Inc.) until reaching approximately 45% of their original weight. This manufacturing procedure for dried pork was developed by varying many of the production parameters and evaluating the finished product to simulate dried pork produced by the conventional method. The sliced dried pork was either vacuum packaged (LC Flex 90366 film by Smith Co., Vacuum by Super Vac) or non-vacuum packaged (LC Flex 90366 film by Smith Co., non-sealed). Packages for storage test were placed in a cooler (3±1°C) without exposing to light. Packages of dried pork were randomly assigned to be held for 0, 4, 8 and 16 weeks at 3±1°C.

Analytical Methods

Moisture, crude fat, protein, ash, residual nitrite (Griess reagent procedure) and salt content of the finished products were determined according to AOAC Procedures (1975) as modified by Ockerman (1980). Sugar content was determined by subtracting the percentage of moisture, fat, proteins and ash from 100%.

Thiobarbituric acid (TBA) values were determined using the distillation method of Tarladgis et al. (1960) as modified by Zipser and Watts (1962) and as described by Ockerman (1980). A "K" value of 7.29 was experimentally obtained and results were expressed as mg. of malonaldehyde per kg of sample.

A hydrometer (Hygrodynamics, Silver Spring, MD) was used to determine the water activity.

The pH of the dried pork was determined with a Beckman Expandomatic SS-2 pH meter according to Ockerman (1980).

Microbiological Evaluations

At each storage interval packages were carefully opened to prevent microbial contamination of the meat samples. A 20 g sample was removed and mixed in a Stomacher (Model #400, Dynatech Laboratory) with 180 ml of distilled water for 2 minutes.

Total aerobic plate counts were made by using Tryptone Glucose Extract Agar (Difco), and incubating at 37°C for 48 hrs. Lactic acid producing bacteria, yeasts and molds were all determined by using the Tomato Juice Agar (Difco) and incubating at 37°C for 5 days. Coliforms were evaluated by using Violet Red Bile Agar (Difco) and incubating at 37°C for 24 hrs. Anaerobic microbiological counts were established by using Anaerobic Agar (BBL) and incubating at 25°C for 5 days in anaerobic jars.

Sensory Panel Evaluation

Samples were served without reheating to each of the six (5 Oriental, 1 American) members of a descriptive attribute panel. Panel members averaged 5 years of meat sensory panel evaluation. Panelists evaluated each sample for tenderness, color, rancid odor (by olfactory evaluation) and rancid or off flavor (by gastatory and olfactory evaluation) and overall acceptability, using a 10-point structured scale with 10 representing extremely tender, dark in color, rancid in odor, rancid in flavor and acceptable and with 1 representing extremely tough, light in color, not rancid in odor, not rancid in flavor and unacceptable.

Statistical Analysis

Data were analyzed by analysis of variance procedures of the Statistical Analysis System (SAS) and Maximum Likelihood General Purpose Program of Harvey (1977). Individual F-tests were used to determine the significance of nitrate, packaging method, storage time and the interaction effects. Means were separated by the Duncan (1955) technique.

RESULTS AND DISCUSSION

Table 1 shows the proximate composition of the product prior to processing and of the dried pork. Dried pork contains a high percentage of protein (38.9), sugar (8.0) and salt (7.6). However, it only contains 6.3% fat. This results from considerable quantities of the fat being cooked out during dehydration of the product (initial fat content was 19.1%). The residual nitrite at the various storage times is shown in Table 2. There was considerable variation in residual nitrite levels and the analysis of variance indicated a highly significant difference due to nitrate, vacuum packaging and storage time. The interaction of nitrate x time, and vacuum packaging x time was also significant (P<0.01). At 0 time, there was no difference between the treatments. However, the group with nitrite + nitrate + vacuum packaging had the highest quantity of residual nitrite among all groups at the 4, 8 and 16 weeks of storage. The nitrite + non-vacuum packaged group had the smallest amount of residual nitrite throughout the same storage time. Obviously, this suggested that nitrate had been reduced to nitrite during storage. Vacuum packaging retained a higher residual nitrite than non-vacuum packaging after 4, 8 and 16 weeks of storage. This suggested that nitrite could be broken down faster to nitrous acid in non-vacuum packaging or that nitrite could be oxidized to nitrate. Cassens et al. (1974) reported nitrite may undergo auto-oxidation resulting in the formation of nitrate and nitric acid.

Table 1 - The proximate composition of the product prior to processing and the dried pork

	Prior to processing	Dried pork
Water %	59.9	38.4
Protein %	20.5	38.9
Fat %	19.1	6.3
Ash %	0.5[a/]	8.4
Salt %		7.6
Sugar %		8.0[b/]
a_w		0.90
pH	5.80	5.90

[a/] Ash value determined by subtracting other composition values from 100%.

[b/] Sugar value determined by subtracting the percentage of moisture, fat, protein and ash from 100%.

Table 2 - Residual nitrite[a] (ppm) in dried pork as influenced by nitrate, packaging method and storage time.

	Vacuum packaged				Non-vacuum packaged			
Weeks	0	4	8	16	0	4	8	16
Nitrate + Nitrite cure	$36.5^{b,x}$	$31.5^{c,x}$	$17.5^{d,x}$	$12.3^{e,x}$	$36.5^{b,x}$	$24.5^{c,x}$	$15.0^{d,x}$	$10.3^{e,x}$
Nitrite cure	$36.3^{b,x}$	$24.0^{c,y}$	$14.3^{d,y}$	$10.0^{e,y}$	$36.3^{b,x}$	$17.8^{c,y}$	$11.3^{d,y}$	$8.8^{e,x}$

[a] Data within horizontal rows within packaging treatment with different letters (b, c, d, e) are significantly different (P<0.01); data within vertical columns with different letters (x, y) are significantly different (P<0.01).

In all four groups, residual nitrite decreased with increased storage. This agrees with the work of Kemp et al. (1975) who found decreased levels of nitrite in vacuum-packed dry-cured sliced hams with increased storage time. Woolford and Cassens (1977) indicated that there was a general dissipation of nitrite with storage time at a decreasing rate due to various reactions of the NO_2 ion with meat tissue.

TBA values were significantly affected by the presence of nitrate (P<0.01), vacuum packaging (P<0.01) and storage time (P<0.01). The interaction of nitrate x time and vacuum packaging x time was also significant (P<0.01). TBA values for the various treatments stored at 3±1°C for different intervals are shown in Table 3. At 0, 4 and 8 weeks, all 4 groups showed very low TBA values (less than 1.0). However, TBA values increased sharply during the 8-16 week storage period. The difference was significant (P<0.01) among the 4 groups. The group with nitrate + nitrite + vacuum packaged had the lowest TBA value (2.76) and the group with nitrite + non-vacuum packaged showed the highest TBA value (7.46). These results suggest that nitrite/nitrate and vacuum packaging can be used to retard oxidation of dried pork stored at 3±1°C. Hadden et al. (1975) reported nitrite retarded the rate of oxidative rancidity. Fooladi et al. (1979) suggested that nitrite protects against oxidation of phospholipids. Nitrite has been reported as a metal chelator for trace metals present in meat which are catalysts for lipid oxidation (MacDonald et al., 1980).

Tenderness, color, rancid odor, rancid flavor and overall acceptability are shown in Fig. 1 at various

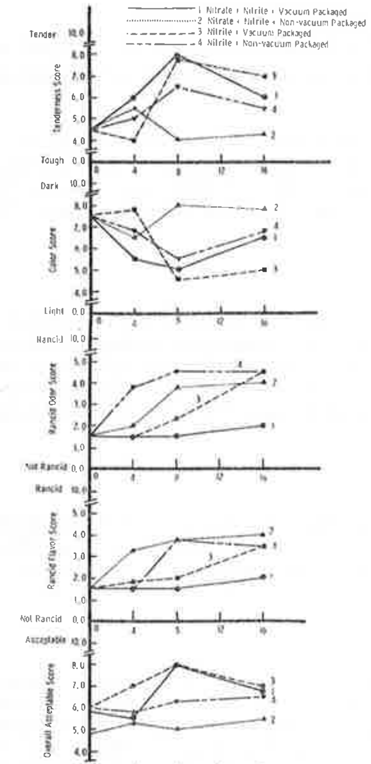

Figure 1 - Tenderness, color, rancid odor, rancid flavor and overall acceptability scores at various intervals of storage for dried pork.

Table 3 - Oxidative rancidity[a] (TBA value) in dried pork as influenced by nitrate, packaging method and storage time.

	Vacuum packaged				Non-vacuum packaged			
Weeks	0	4	8	16	0	4	8	16
Nitrate + nitrite cure	$0.17^{b,x}$	$0.18^{b,x}$	$0.42^{b,x}$	$2.76^{c,x}$	$0.17^{b,x}$	$0.22^{b,x}$	$0.60^{c,x}$	$4.25^{d,x}$
Nitrite cure	$0.18^{b,x}$	$0.27^{b,x}$	$0.64^{c,x}$	$6.34^{d,y}$	$0.18^{b,x}$	$0.45^{b,x}$	$0.88^{c,y}$	$7.46^{d,y}$

[a] Data within horizontal rows with different letters (b, c, d) are significantly different (P< 0.01); data within vertical columns with different letters (x, y) are significantly different (P<0.01).

intervals of storage (3±1°C). Tenderness was affected (P<0.05) by vacuum packaging and storage time but not by nitrate. Vacuum packaging retards moisture loss during storage which should maintain a greater tenderness than non-vacuum packaged dried pork particularly in the late stages of storage. Color scores were not significantly affected by nitrate, vacuum packaging and storage time; but, are in almost reverse order from tenderness scores (the darker, the tougher); which would also be influenced by evaporation.

In general, rancid odor scores increased with increased storage. However, the rancid odor scores are relatively low (below 4.5) even after 16 weeks of storage. This may be due to the dried pork being served cold without reheating. Most of the volatile compounds were hard to detect by the panelists.

As shown in Fig. 1, rancid flavor scores also increased with increased storage except during the last storage period for group 4 which had the highest average TBA value at 16 weeks of storage (Table 3). The only explanation for this is that soy sauce may mask some of the rancid flavors at high rancidity levels in dried pork. Cho and Bratzler (1970) stated that nitrite is important in developing the unique flavor of cured hams. The role of nitrite in dried pork flavor is not so important, since most of the flavor comes from soy sauce, sugar and salt. The purpose of adding nitrite/nitrate to dried pork is to retard oxidative rancidity and bacterial growth during storage.

The overall acceptability was not affected by nitrate and storage time (Figure 1). It was, however, affected (P<0.05) by vacuum packaging. Since vacuum packaging would be expected to reduce the evaporation of moisture during storage; therefore, it should maintain the tenderness of dried pork compared to non-vacuum packaged product open to the atmosphere. Rancid odor and rancid flavor cause no major problem (values never exceeded 5.0) in dried pork; and, the overall acceptability was probably most influenced by tenderness.

Tables 4, 5, and 6 give the effect of nitrate, packaging method and storage time on microbiological counts (log 10) of dried pork. The total plate counts, lactic acid producing bacterial counts and anaerobic counts in dried pork were affected (P<0.01) by storage time at 3±1°C. Both in vacuum and non-vacuum packaging, the counts (Table 5) of lactic acid producing bacteria, in the nitrate + nitrite group were equal to or higher than that of the nitrite group. Kemp *et al*. (1975) suggested that nitrate could enhance the growth of lactobacilli.

Table 4 - Total plate counts[a] (log 10) in dried pork as influenced by nitrate, packaging method and storage time.

	Vacuum packaged				Non-vacuum packaged			
Weeks	0	4	8	16	0	4	8	16
Nitrate + nitrite cure	$2.67^{b,x}$	$3.28^{c,x}$	$4.28^{d,x}$	$5.10^{e,x}$	$2.67^{b,x}$	$3.26^{c,x}$	$4.30^{d,x}$	$5.11^{c,x}$
Nitrite cure	$2.66^{b,x}$	$3.27^{c,x}$	$4.29^{d,x}$	$5.13^{e,x}$	$2.66^{b,x}$	$3.30^{c,x}$	$4.32^{d,x}$	$5.15^{e,x}$

[a] Data within horizontal rows with different letters (b, c, d, e) are significantly different (P < 0.01); data within vertical columns with different letters (x, y) are significantly different (P < 0.01).

Table 5 - Lactic acid producing bacterial counts[a] (log 10) in dried pork as influenced by nitrate, packaging method and storage time

	Vacuum packaged				Non-vacuum packaged			
Weeks	0	4	8	16	0	4	8	16
Nitrate + Nitrite cure	$1.00^{b,x}$	$1.39^{c,x}$	$2.72^{d,x}$	$3.56^{e,x}$	$1.00^{b,x}$	$1.30^{c,x}$	$2.71^{d,x}$	$3.55^{e,x}$
Nitrite cure	$1.00^{b,x}$	$1.30^{c,x}$	$2.71^{d,x}$	$3.56^{e,x}$	$1.00^{b,x}$	$1.15^{b,x}$	$2.70^{c,x}$	$3.55^{d,x}$

[a] Data within horizontal rows with different letters (b, c, d, e) are significantly different (P < 0.01); data within vertical columns with different letters (x, y) are significantly different (P < 0.01).

Coliforms, molds and yeasts were not found in this study. High percent sugar (8.0) and salt (7.6), low a_w (0.90) and low storage temperature (3±1°C) probably inhibited their growth during the storage period.

Table 7 shows the correlation coefficients between chemical, sensory and microbiological properties of dried pork. As would be expected, TBA values are positively correlated (P<0.01) with rancid odor (r=0.63), rancid flavor (r=0.56) and negatively correlated (P<0.01) with residual nitrite (r=-0.64). This indicates that TBA values can be used as a measure of the degree of oxidative rancidity for dried pork during 16 weeks of storage. Tenderness is negatively correlated (P<0.01) with color (r=-0.89) and positively correlated (P<0.01) with overall

Table 6 - Anaerobic bacterial counts[a] (log 10) in dried pork as influenced by nitrate, packaging method and storage time

	Vacuum packaged				Non-vacuum packaged			
Items	0	4	8	16	0	4	8	16
Nitrate + nitrite cure	$1.00^{b,x}$	$1.00^{b,x}$	$2.70^{c,x}$	$3.64^{d,x}$	$1.00^{b,x}$	$1.00^{b,x}$	$2.67^{c,x}$	$3.65^{d,x}$
Nitrite cure	$1.00^{b,x}$	$1.00^{b,x}$	$2.68^{c,x}$	$3.64^{d,x}$	$1.00^{b,x}$	$1.00^{b,x}$	$2.67^{c,x}$	$3.64^{d,x}$

[a] Data within horizontal rows with different letters (b, c, d) are significantly different (P<0.01); data within vertical columns with different letters (x, y) are significantly different (P<0.01).

Table 7 - Correlation coefficients between chemical, sensory and microbiological properties of dried pork

							Microorganisms		
	TBA	Tenderness	Color	Rancid odor	Rancid flavor	Over all accepta.	TPC (log 10)	Lactic (log 10)	Anaerobic (log 10)
Residual nitrite	-0.64^{**}	-0.48^{**}	0.45^{**}	-0.70^{**}	-0.66^{**}	-0.26^{*}	-0.92^{**}	-0.88^{**}	-0.85^{**}
TBA		0.31^{*}	-0.29^{*}	0.63^{**}	0.56^{**}	0.17	0.77^{**}	0.76^{**}	0.77^{**}
Tenderness			-0.89^{**}	0.10	-0.06	0.75^{**}	0.47^{**}	0.48^{**}	0.46^{**}
Color				-0.15	-0.01	-0.60^{**}	-0.42^{**}	-0.40^{**}	-0.39^{**}
Rancid odor					0.94^{**}	-0.03	0.65^{**}	0.61^{**}	0.61^{**}
Rancid flavor						-0.09	0.64^{**}	0.60^{**}	0.60^{**}
Over all acceptability							0.33^{**}	0.36^{**}	0.33^{**}
Microorganisms									
TPC (log 10)								0.98^{**}	0.97^{**}
Lactic (log 10)									0.99^{**}

* $P<0.05$

** $P<0.01$

acceptability (r=0.75). The lighter the color the more tender the dried pork. Rancid odor and rancid flavor scores are negatively correlated (P<0.01) with residual nitrite (r=-0.70, r=-0.66, respectively). Although rancid odor and rancid flavor increased with increased (P<0.01) TBA values, overall acceptability did not seem to be influenced by rancid odor and flavor.

Overall acceptability scores are positively correlated (P<0.01) with tenderness scores (r=0.75) and negatively correlated (P<0.01) with color scores (r=-0.60). Tenderness is also correlated (P<0.01) with total plate counts (r=0.47) lactic acid producing bacterial counts (r=0.48) and anaerobic bacterial counts (r=0.46). This is probably due to the influence of moisture content on both of these parameters in dried pork. Total plate counts are positively correlated (P<0.01) with lactic acid producing bacterial counts (r=0.98) and anaerobic bacterial counts (r=0.97).

REFERENCES

AOAC. 1975. "Official Methods of Analysis," 12th ed. Assoc. of Official Analytical Chemists, Washington, D.C.

Banwart, G. J. 1979. "Basic Food Microbiology." AVI Publishing Co., Inc. Westport, CT.

Cassens, R. G., Sebranek, J. G., Kubberod, G. and Woolford, G. 1974. Where does the nitrite go? Food Product Development 8(10):50.

Cho, I. C., Bratzler, L. G. 1970. Effect of sodium nitrite on flavor of cured pork. J. Food Sci. 35:668.

Cross, C. K. and Ziegler, P. 1965. Comparison of the volatile fraction from cured and uncured meat. J. Food Sci. 30:610.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11:1.

Federal Register. 1975. Vol. 40 No. 216 - Tuesday, November 11.

Fooladi, M. H., Pearson, A. M., Coleman, T. H. and Merkel, R. A. 1979. The role of nitrite in preventing development of warmed-over flavor. Food Chem. 4:284.

Hadden, J. P., Ockerman, H. W., Cahill, V. R., Parrett, N. A. and Borton, R. J. 1975. Influence of sodium nitrite on the chemical and organoleptic properties of comminuted pork. J. Food Sci. 40:626.

Harvey, W. R. 1977. Least squares analysis of data with unequal subclass numbers. Agricultural Research Service 20-9 USDA.

Huang, S. H. 1974. "Chinese Snacks." Dept. of Home Economics. Wei-Chuan Food Corp., Taipei, Taiwan.

Karel, M., Fennema, O. R. and Lund, D. B. 1975. "Principles of Food Science. Part II Physical Properties of Food Preservation." Dekker, New York, p. 350.

Kemp, J. D., Langlois, B. E., Fox, J. D. and Varney, W. Y. 1975. Effects of curing ingredients and holding temperatures on organoleptic and microbiological properties of dry-cured sliced ham. J. Food Sci. 40:634.

Labuza, T. P. 1970. Proceedings of 3rd International Congress Food Sci. Technol. Washington, D.C. (1971), p. 618.

MacDonald, B., Gray, J. I. and Gibbins, L. N. 1980. Role of nitrite in cured meat flavor: Antioxidant role of nitrite. J. Food Sci. 45:893.

Ockerman, H. W. 1980. "Quality Control of Post-Mortem Muscle Tissue." Animal Science Dept., The Ohio State University, Columbus, OH.

Tarladgis, B. G., Watts, B. M. and Younathan, M. T. 1960. A distillation method for the quantitative determination of malonaldehyde in rancid foods. The Journal of the American Oil Chemists' Society. 37:44.

Troller, J. A. and Christian, J. H. B. 1978. "Water Activity and Food." Academic Press, p. 186.

Woolford, G. and Cassens, R. G. 1977. The fate of sodium nitrite in bacon. J. Food Sci. 42:586.

Zipser, M. and Watts, B. 1962. A modified 2-thiobarbituric acid (TBA) method for the determination of malonaldehyde in cured meats. Food Technol. 16:102.