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A STUDY OF FACTORS AFFECTING THE FLAVOUR OF CURED HAM

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SUMMARY

A number of curing, processing, and feeding factors have been investigated for their effect on ham flavour. As little as 0.1 g./l. of sodium nitrite in the curing pickle was as effective in producing satisfactory flavour as the normal 1.5 g./l., but 4.5 g./l. caused a bitter flavour which decreased the acceptability. Within the range of conditions studied, neither the time nor the temperature of curing had any appreciable effect on flavour, nor did the re-use of cover pickles. It was found, however, that flavour acceptability decreased with an increase in the amount of pickle injected into the ham.

Higher-pH hams (pH 6.1 to 6.6) were preferred for flavour over lower-pH hams (pH 5.4 to 5.6) but when the pH was raised artificially by alkali addition to the curing pickle, or by adrenaline injection prior to slaughter, this preference no longer existed. Hams pumped hot, immediately after slaughter, received the same flavour rating as hams pumped after normal holding and chilling.

None of the numerous curing pickle additives tested, including sodium isoascorbate, sugar, combinations of higher levels of sugar and sodium chloride, sodium inosinate and sodium guanylate with and without admixture with monosodium glutamate, hydrolysed plant protein, and autolized yeast improved flavour acceptability appreciably.

Sodium sulphide, when added to ham in sufficient quantity to be detectable, reduced flavour acceptability but methional and 3-methyl-thiopropanol, at the levels tested, had no effect on flavour. The addition of as little as 0.2 ml. of methanethiol per 450 g. of ham produced an undesirable odour in the product.

Numerous cultures of bacteria and yeasts were tested for their effect on ham flavour but, under the curing conditions employed, none altered flavour levels to a detectable degree. Conversely, the addition of the broad-spectrum antibiotic chlortetracycline did not reduce flavour acceptability.

Increasing the internal temperature to which hams were cooked or smoked brought about a modest increase in flavour acceptability. Smoking, too, increased over-all preference ratings although a substantial number of consumers preferred ham with out smoke (boiled ham in this case).

Feeding of hogs with elemental sulphur, or with a mixture of DL methionine and L-cystine added to the feed, did not increase the flavour acceptability of the hams, nor change the composition of volatiles from the hams as determined by gas-liquid chromatography. In other studies, no flavour differences could be established between hams from male and female hogs from the same litter, nor between hams from litter-mates slaughtered at 4, 6, 8 and 10 months of age.

INTRODUCTION

In the United States, beef consumption has increased by over 50% in the period from 1953 to 1964, while the population increased by about 20%. Pork consumption, on the other hand, has increased by only 10% over the same period, and has thus not kept pace with the population growth.

A similar situation exists in Canada. Since pork is largely marketed as a cured, processed item, it seemed worthwhile to study the effect of various factors in breeding, feeding, curing, and processing practices on flavour. Ham was chosen as the product for study.

A. Curing Conditions

1. Concentration of Sodium Nitrite in the Pumping Pickle

The essential ingredient for development of cured ham flavour is nitric oxide, whether from nitrate, nitrite, or added directly as the gas. This, therefore, seemed a logical place to start, and in one experiment we determined the effect of increasing amounts of sodium nitrite in the pumping pickle

on the flavour acceptability. Except for the variations in sodium nitrite content, a standard commercial pumping pickle was used. Left and right hams from the same hog were used in each comparison, the control ham being pumped with a normal pickle containing 1.5 grams sodium nitrite per liter. Preference ratings were made on the product on the basis of a minimum of 50 panel judgements.

TABLE I

Effect of Concentration of Sodium Nitrite in Pumping Pickle on Flavour Acceptability

Sodium Nitrite in Test Pickle (g./liter)	Number of Panel Judgements Prefering	
	Test	Control (1.5 g. $NaNO_2$/l.)
0.10	31	33
0.50	24	26
1.00	33	45
4.50	41	92

It thus appears that while very small amounts of sodium nitrite will produce "normal" ham flavour, larger amounts may reduce the acceptability by imparting a bitter flavour to the product.

2. Time and Temperature of Curing

The normal curing period for hams in North America is 1 to 5 days at 3°C. to 4°C. When commercially pumped hams were cured for 5 days at 13°C., instead of for 5 days at the normal curing temperature of 3°C., there was no significant preference for the hams cured at either temperature (148 judge-

ments, 69 for hams cured at 3°C., 79 for hams cured at 13°C.).

The effect of curing time on flavour was investigated in a series of tests in which commercially pumped hams were cured for 5 days at 3°C., then matured for an additional 7 days at -2°C.

TABLE II

Effect of Maturing Time on Flavour Acceptability of Smoked Ham

Type of Ham	Number of Panel Judgements Preferring	
	Test (5 days @ 3°C. + 7 days @ -2°C.)	Control (5 days @ 3°C. No Maturing)
Boneless	46	50
Boneless, defrosted	13	27
Bone-in	57	76
Bone-in, shoulder	73	86
Boiled	54	87
TOTAL	243	326

These results indicate a preference for the non-matured hams. However, in another experiment in which hams were matured for 30 days at -2°C., 124 judgements favoured the matured hams, 129 the non-matured. It would therefore appear that the effect on flavour of maturing at -2°C. is not large.

3. Re-Use of Cover Pickle

The practice of re-using cover pickles was discontinued in Canada many years ago. In order to investigate the effect this change may have had on flavour, hams were cured 6 days at 3°C. The spent cover pickle was returned to its original analysis, then reused in 3 additional curing cycles. After cooking, the hams were panelled on a scale of increasing acceptability from 1 to 7, with 4 being "average".

TABLE III

Effect of Re-Use of Cover Pickle on Flavour Acceptability of Ham

Age of Cover Pickle (days)	Panel Acceptability Rating
6	3.5
12	3.8
18	4.2
24	3.1

It would appear that the re-use of cover pickle, for the limited number of cycles employed in this test, had no appreciable effect on the flavour of the product.

4. Effect of Pumping Gain

Two studies conducted in the United States have indicated a flavour preference for hams pumped to give yields, after processing, 10% or even 20% in excess of their original weight (1) (2).

In our tests, however, in which we compared left and right hams pumped to different percentage gains, a preference was registered in each case for hams with the lower gains.

TABLE IV

Effect of Pumping Gain on Flavour Acceptability of Ham

	Number of Panel Judgements Preferring	
Type of Ham	8% Gain	14% Gain
Bone-in, Smoked	85	43
Boneless, Smoked	114	39
Boneless, Cooked	83	59
TOTAL	282	141

In addition, hams pumped 12% in comparison with 14% were preferred 58 to 20 and hams pumped 14% in comparison with 20%, 112 to 56.

5. Effect of Meat pH

We have investigated the effect of meat pH on ham flavour from a number of different angles. In our first tests we selected low-pH hams (ultimate pH 5.4 to 5.6 as measured in the Gluteus medius muscle) and high-pH hams (pH 6.1 to 6.6). After routine commercial curing and processing, hams from the two groups were preference-rated for flavour. In 312 judgements, 224 preferred the higher-pH hams and only 88 the lower-pH hams.

Since the number of high-pH hams available in a normal commercial cut is limited, we determined the effect on flavour of artificially increasing the pH of the meat by adding 5 g. of sodium hydroxide per liter of pumping pickle. This, on average, increased the final pH of the ham by about 0.4 units, but no significant preference was obtained for the hams whose pH had been artificially increased.

TABLE V

Effect of Alkali pH Adjustment on Flavour Acceptability of Ham

Experiment	Number of Judgements Preferring	
	Normal pH	Alkali Increased pH
1	78	86
2	75	78
3	31	37
TOTAL	184	201

Similarly, in a series of tests in which adrenaline was injected in amounts varying from 2 to 8 mg. per 100 lb. live body weight 17 hours prior to slaughter, in order to increase the average ultimate pH by about 1 unit, only 60 panellists preferred the flavour of the cured hams from adrenalized hogs, in comparison with 92 in favour of the control hams.

6. Effect of Pre-Rigour Curing Pickle Injection

In a study of the volatile fractions from cured and uncured ham conducted by these laboratories (5), it has been established that valeraldehyde and hexanal are present in the volatiles of uncured meat but not in those of cured meat, and it is postulated that the absence of these compounds reveals the characteristic flavour of cured meat. It is further postulated that valeraldehyde and hexanal are produced by the oxidation of linoleate, catalysed by hematin compounds such as hemin, hemoglobin, or cytochrome.

In order to determine if curing of the ham immediately after slaughter, before extensive oxidation of linoleate could occur, would increase the cured ham flavour a number of hams were pumped as soon as possible after slaughter while the corresponding pairs were pumped after normal holding and chilling. Both lots of hams, after smoking were rated on a 1 to 7 scale (increasing acceptability) by a taste panel. No differences in flavour were detected.

TABLE VI

Effect of Pre- and Post-Rigour Curing Pickle Injection on Flavour Acceptability of Ham

Ham Pair No.	Panel Acceptability Rating: Pre-Rigour Injection	Panel Acceptability Rating: Post-Rigour Injection
I	4.2	3.9
II	3.6	4.2
III	4.2	4.0
AVERAGE	4.0	4.0

This shows that introduction of nitrite immediately after slaughter, even though it prevents the appearance of higher aldehydes in the cooked ham volatiles, has no effect on the underlying ham flavour itself.

B. Curing Solution Components and Additives

1. Effect of Added Sugar

Sugar, traditionally, has been a component of curing pickles for hams in Canada. The normal level of use has been 50 to 60 grams per liter. Mills et al., (3) in 1960, demonstrated that the threshold level for detection of sweetness in hams corresponds to 50 to 75 g. of sugar per liter of pump pickle, but commented that the general level of use in the United States is something less than that.

In our own tests in which we compared left and right hams cured with 0 and 60 grams of sucrose per liter of pump pickle, 49 panellists preferred the sugar-cured hams, 49 the non-sugar cured. When we compared hams cured with 60 grams of sucrose per liter with hams pumped with 60 grams of dextrose per liter, 37 panellists preferred the sucrose-cured ham, 43 the dextrose-cured, indicating no difference in acceptability.

In later work conducted at Michigan State University (4), Pearson et al. showed that the addition of 3% sodium chloride plus 2% sucrose provided maximum flavour acceptability in minced hams. By adjusting the make-up of our pumping pickle we tested this ratio in artery pumped hams, but were

unable to demonstrate any increased flavour acceptability over hams containing no sugar and only normal amounts of sodium chloride.

TABLE VII

Effect of Increased Sodium Chloride and Sucrose on Flavour Acceptability of Ham

	% Sucrose	% Salt	Panel Acceptability Rating*
Test	2.7	3.6	3.7
Control	-	2.2	3.7

* 1 to 7 scale of increasing acceptability.

2. Effect of Added Sodium Inosinate - Sodium Guanylate Mixture

A mixture of the above two compounds, known commercially as "Ribotide", recently appeared on the market as a flavour - enhancer for meat products. No significant improvement in ham flavour was detected at any level of use tested when this additive was incorporated in the product by addition to the pumping pickle.

TABLE VIII

Effect of Sodium Inosinate-Sodium Guanylate Mixture on Flavour Acceptability of Ham

Sodium Inosinate-Sodium Guanylate		Control (No additive)
% of Weight of Ham	Acceptability Rating*	Acceptability Rating*
0.009	3.9	3.8
0.044	4.1	3.9
0.220	4.0	4.3

* 1 to 7 scale of increasing acceptability.

On the possibility that the effect of the sodium inosinate-sodium guanylate combination was being lost on curing and processing, we added the material directly to slices of cooked ham at a concentration of 0.05%. In 3 separate tests no significant improvement in acceptability was observed.

TABLE IX

Effect of Direct Addition of Sodium Inosinate-Sodium Guanylate Mixture on Flavour Acceptability of Cooked Ham

	Flavour Acceptability Rating *	
Test No.	"Ribotide" 0.05%	Control No additive
1	4.5	3.9
2	3.5	3.6
3	3.7	3.8
AVERAGE	3.9	3.8

* 1 to 7 scale of increasing acceptability.

We also tested another commercial mixture known as "EE-CHEE-BAN" for its effect on ham flavour. This mixture combines 92 parts of monosodium glutamate with 8 parts of the sodium inosinate-sodium guanylate combination. No improvement in acceptability was noted.

TABLE X

Effect of Sodium Inosinate-Sodium Guanylate-Monosodium Glutamate Mixture on Flavour Acceptability of Ham

Sodium Inosinate-Sodium Guanylate-Monosodium Glutamate Mixture		Control (No additive)
Combined % of Weight of Ham	Acceptability Rating *	Acceptability Rating*
0.11	4.2	4.0
0.55	3.8	3.4

* 1 to 7 scale of increasing acceptability.

3. Effect of Added Monosodium Glutamate, Hydrolysed Plant Protein, and Autolized Yeast

These materials have been widely cited as flavour-enhancers for meat products but none proved particularly effective when added to the pumping pickle for cooked hams.

TABLE XI

Effect of MSG, HVP and Autolized Yeast on Flavour Acceptability of Cooked Ham

Additive	Concentration in Pump Pickle	No. of Judgements Preferring	
		Additive	No Additive
Monosodium Glutamate	10 g./l.	15	20
Hydrolysed Plant Protein	10 g./l.	59	39
Autolized Yeast	50 g./l.	102	93

4. Effect of Added Sulphur-Containing Compounds

It is generally believed that the main contributors to cured ham aroma and flavour are hydrogen sulphide, methyl mercaptan and perhaps other sulphur-containing compounds. We therefore tested a number of compounds to determine their effect on the flavour acceptability of ham.

In one series of tests sodium sulphide was added to the pumping pickle in concentrations ranging from 0.33 to 330 mg./Kg. expressed as hydrogen sulphide. At 33 mg./Kg. a difference in flavour was detectable between the treated and control hams, but no preference was established by the panel. At 165 and 330 mg./Kg. the odour was objectionable and the product could not be panelled.

In another test methional and its corresponding alcohol 3-methyl thiopropanol were added to separate pumping pickles, each at a concentration of 40 mg./liter. Both solutions smelled strongly when injected into the hams but after normal curing and processing the obnoxious odour had disappeared. On panelling against corresponding hams from the same hogs, cured without the additives, no differences could be established.

In a third series of tests, 450 gram pieces of fresh uncured ham were injected with gaseous methanethiol, by means of a hypodermic syringe, in amounts ranging from zero to 4 ml. Immediately after injection the meat samples were covered with pickle and cured for 4 days. They were then canned, cooked, and examined for aroma. As little as 0.2 ml. of methanethiol produced an undesirable odour in the product.

Finally, the effect of doubling the amount of methionine normally present was determined by injecting a slurry of methionine into cured ham at the rate of 2.9 g./Kg. After "maturing" for 4 days, the meat was canned, cooked, and panelled for aroma. There was no increase in ham aroma but a foreign odour similar to that encountered with the hams treated with methanethiol was readily detected.

5. Effect of Added Sodium Isoascorbate

Sodium isoascorbate was added to commercial pumping pickle at a concentration of 1.5 g./liter. Hams were artery pumped with this pickle and corresponding pairs from the

same hogs with pickle without the additive. In triangular taste panels members were unable to match the samples in more than 50% of the cases:

Matching		Preference	
Correct	Incorrect	Test	Control
17	16	49	35

C. Microbiological Effects

It is generally believed that with present-day short curing times, bacteria, yeasts, and moulds play little part in developing normal ham flavour(6).

We did, however, isolate a large number of pure cultures of bacteria and yeasts from fresh pork and from fresh pork bone marrow. These were screened for their ability to grow in the presence of 5% and 10% sodium chloride. 48 of these cultures were added to the pump and cover pickles used to cure separate cubes of ham, but after curing for 6 days at 3°C., in no case was an improved ham flavour noted.

In another series of tests, 28 cultures of bacteria were isolated from various types of used cover pickle, and 22 yeast cultures from the surfaces of cured hams, backs, and shoulders. 8 of the bacterial cultures and 3 of the yeast cultures were added to the cover pickles used to cure separate cubes of ham. After 5 days of curing at 7°C. panel tests showed no improvement in flavour over the controls.

Finally, in order to determine whether or not microorganisms play any role in our present ham curing process we cured a ham in the presence of chlortetracycline, which, being a broad spectrum antibiotic, affects a very wide variety of Gram-positive and negative bacteria.

One ham of a pair was pumped with our regular pickle containing sufficient chlortetracycline to give a final concentration in the meat of 5 p.p.m. The same level was also added to the cover pickle. The control ham was pumped and covered with regular pickle without the additve. After curing for 7 days at 3°C. both hams were cooked and panelled. In a total of 186 panel judgements, 99 preferred the test ham, 87 the control.

It seems clear from the results of these tests that microorganisms do not contribute to the development of ham flavour under present-day commercial curing conditions.

D. Processing Effects

A number of commercially cured hams were processed to an internal temperature of 68°C. The corresponding pairs from the same hogs were smoked to an internal temperature of 77°C. The panel, in triangular tests, was able to detect a difference and showed a modest preference for hams given the extra degree of cooking:

Matching		Preference	
Correct	Incorrect	68°C. Int.	77°C. Int.
113	28	60	82

Similarly, when pairs of canned whole hams were cooked to internal temperatures of 70°C. and 77°C., and panelled on a 1 to 7 rating of increased acceptability, average ratings were 4.5 and 5.1 respectively.

The effect of smoking on the acceptability of ham flavour was determined in two experiments. In the first, standard panel tests were conducted to establish acceptability ratings for smoked and unsmoked cooked hams.

TABLE XII

Effect of Smoking on the Flavour Acceptability of Cooked Ham

Ham Pair No.	Panel Acceptability Rating *	
	Smoked	Unsmoked
1	4.5	3.8
2	5.0	3.8
3	4.2	3.8
4	4.5	4.3
AVERAGE	4.5	3.9

* 1 to 7 scale of increasing acceptability.

In the second experiment, samples of smoked and unsmoked cooked ham were home-tested by a group of consumers who were asked to state a preference and to indicate the strength of that preference. The following results were obtained:

50 preferred the smoked ham strongly
49 " " " " moderately
18 " " " " slightly

2 found no difference

23 preferred the unsmoked ham slightly

40 " " " " moderately

32 " " " " strongly

While the numerical preference of 117 for the smoked product to 95 for the unsmoked is not significant, there is indeed a significant preference if one considers the higher number of strong preferences for the smoked ham. Thus if the samples are scored 1, 2 or 3 for slight, moderate, or strong preference respectively, the total score for the smoked ham would be 266 and for the unsmoked 199, which is significant at the 1% level.

E. Effect of Sulphur-Containing Feed Additives

An experiment was conducted to determine the effect of feeding hogs elemental sulphur, and sulphur-bearing amino acids, on cured ham flavour.

6 hogs from one litter were divided into 3 groups of two. The first group was fed the regular growing and finishing feed. The second and third groups received the same feed except that 0.4% sulphur was added in the case of the second group, and 1.5% DL methionine and 0.25% L-cystine in the case of the third group. After 25 weeks the hogs were slaughtered, dressed, and the hams cured and processed. Extensive panelling was done on different muscles from the three lots of hams but when all the results were averaged the scores for each group were exactly the same.

Samples from each lot of ham were also gas chromatographed, but no differences were observed.

F. Effect of Hog Age and Sex

Hogs from one litter were fed on our regular feeding program for this test. One male and one female pig were slaughtered at 4, 6, 8 and 10 months of age. After dressing, the hams were removed, cured, canned and processed, all canned hams being stored at 3°C. to permit panelling together at the completion of the test program. The panels rated flavour on the 1 to 7 scale of increasing acceptability. Neither age nor sex had appreciable effect on the flavour acceptability.

TABLE XIII

Effect of Hog Age and Sex on the Flavour Acceptability of Canned Ham

	Panel Acceptability of Rating	
Age (months)	Male	Female
4	3.9	3.9
6	3.4	3.5
8	3.8	4.1
10	4.0	4.1
AVERAGE	3.8	3.9

G. Effect of Breeding

We are currently conducting an extensive series of tests to determine if certain breeds of hogs, or crosses between breeds, produce hams of increased flavour acceptability. Included in this series are Yorkshire, Landrace, Hampshire, Birkshire, and Lacombe, together with many crosses between these breeds. There is insufficient data at the present time to draw any conclusions from these experiments.

Concluding Remarks

It is perhaps significant that in this rather extensive investigation of curing and processing variables, no one factor has been encountered which could be said to produce a marked improvement in flavour acceptability. On a number of occasions we have compared hams prepared by present-day curing and processing practices with those generally employed 20 or more years ago, and almost invariably the "modern" ham has been preferred.

In spite of this, many of our old-timers recall the day when merely cutting a ham filled the room with tantalizing aroma, and the flavour on eating was equally as delightful.

However, to paraphrase a recent editorial in Food Manufacture on sausage, perhaps hams never did taste like they used to.

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RÉSUMÉ

Certains facteurs tels que le saumurage, le procédé et l'alimentation, ont été etudiés quant à leur effet sur la saveur du jambon. Aussi peu que 0.1 g./l. de nitrite de sodium dans la saumure fut aussi efficace à produire une saveur satisfaisante que la concentration normale de 1.5 g./l.; cependant une concentration de 4.5 g./l. donna une saveur amère qui réduisit l'acceptabilité. Dans les conditions d'étude, ni le temps ni la température du saumurage eut un effet appréciable sur la saveur, pas plus d'ailleurs que l'emploi de saumure ayant déjà servie. Il fut trouvé toutefois que l'acceptabilité de la saveur diminuait avec une augnementation de la quantité de saumure injectée dans le jambon.

Les jambons à haut-pH (pH 6.1 à 6.6) furent préférés pour la saveur aux jambons à bas-pH (pH 5.4 à 5.6); quand le pH était élevé artificiellement, soit par l'addition d'alcali à la saumure ou par injection d'adrénaline avant l'abattage, cette préférence n'existait plus. Les jambons saumurés chauds, immédiatement après l'abattage, reçurent la même préférence que les jambons traités après un entreposage et un refroidissement normal.

Parmi les nombreux additifs à la saumure étudiés, incluant de l'isoascorbate de sodium, du sucre, des combinaisons de hautes concentrations de sucre et de chlorure de sodium, de l'inosinate de sodium et du guanylate de sodium avec et sans addition de glutamate monosodique, des protéines végétales hydrolysées et des levures autolysées, aucun n'a amélioré sensiblement l'acceptabilité de la saveur.

Le sulfure d'hydrogène, lorsqu'ajouté au jambon en quantité suffisante pour être détecté, réduisit l'acceptabilité de la saveur. La présence de méthional et du 3-méthylethiopropanol aux concentrations étudiées, n'eut aucun effet sur la saveur. L'addition d'aussi peu que 0.2 ml. de méthyle mercaptan par 450 g. de jambon produisit une odeur désagréable dans le produit.

Plusieurs cultures de levures et de bactéries furent étudiées pour leur effet sur la saveur du jambon, aucunes, sous les conditions de saumurage employées, n'affectaient sensiblement la saveur. Réciproquement, l'emploi de l'antibiotique à spectre d'action étendu, chlorotétracycline, n'a pas réduit l'acceptabilité de la saveur.

L'augnementation de la température interne du jambon, à la cuisson et au fumage, ne donna qu'une modeste augnementation dans l'acceptabilité de la saveur. Le fumage aussi, augnementa la préférence générale bien qu'un nombre substantiel de consommateurs préférèrent le jambon non-fumé (jambon bouilli dans ce cas).

Des additions de soufre élémentaire ou de mélange de DL méthionine et de L-cystine à la ration des porcs, n'amenèrent aucune augnementation dans l'acceptabilité de la saveur ni ne changèrent la composition des fractions volatiles telles que déterminées par chromatographie en phase gazeuse. D'autres études n'ont pu établir de différences, quant à la saveur, entre des porcs mâles et femelles venant d'une même litière et entre des porcs abattus à 4, 6, 8 et 10 mois, ces porcs provenant aussi d'une même litière.