Meat Science 5 (1980-81) 57-70

ACCEPTABILITY AND STORAGE STABILITY OF PORK PRODUCTS WITH INCREASED LEVELS OF POLYUNSATURATED FATTY ACIDS

J. H. HOUBEN

Department of the Science of Food of Animal Origin, Sub-Department of Meat Technology, Faculty of Veterinary Medicine, University of Utrecht, Utrecht, The Netherlands

&

B. KROL

Central Institute for Nutrition and Food Research TNO (CIVO/TNO), Zeist, The Netherlands

(Received: 18 October, 1979)

SUMMARY

Several batches of back bacon, belly bacon, Dutch-style cervelat sausage, pork loin roll, shoulder with fat, Bologna, Guelders ring sausage, Saxon liver sausage and luncheon meat were produced with increasing PUFA-levels using raw materials containing up to 30% linoleic acid in their fats. Only the preparation of the high linoleic fermented Dutch-style cervelat sausages gave problems. Fatty acid composition did not change during preparation, nor during a two months' storage of back bacon at 15°C. Sensory evaluations of the products by an expert-panel revealed only a few differences, mostly related to consistency. Penetration measurements on luncheon meat showed an increase of softness as the PUFA-level was increased. Products were stored for up to 61 days at 4 or 15°C. During storage, peroxide numbers and p-*anisidine values were determined and sensory evaluations performed by an expert-panel. The unheated, and some of the pasteurised, highly unsaturated products appeared to be very susceptible to lipid oxidation.*

INTRODUCTION

Pork meat, and fat with increased levels of polyunsaturated fatty acids (PUFA), derived from carcasses which contained up to about 30% linoleic acid in the depot fats, appear to be organoleptically acceptable even after chilled and frozen storage (Houben & Krol, 1978). Meat containing unsaturated fats was, however, rather susceptible towards oxidation.

Only one recent report appears to relate to pork products with increased PUFA

Meat Science 0309-1740/80/0005-0057/$02·25

content (Skelley *et al.*, 1975). These authors studied only unheated products, which were subjected to a sensory evaluation after two months' storage at −30°C.

The current study is concerned with both unheated and heated products. Fresh meats and fats from the investigation of Houben & Krol (1978) were used for their preparation. All products were stored for two months under various conditions. Fresh and stored products were judged by an expert-panel and chemically analysed with particular reference to the fat fraction.

As some recent investigations (Benedict *et al.*, 1975; Bielski *et al.*, 1975; Kanner & Mendel, 1977; Deng *et al.*, 1978) suggested a possible pro-oxidant effect of ascorbic acid under certain conditions, experiments were conducted to ascertain the action of this additive in a fermented sausage since it seemed likely that this type of product was particularly susceptible to oxidation.

MATERIALS AND METHODS

Animals and diets

Pigs were fed with the aim of establishing approximately 10, 20 and 30% of linoleic acid in the depot fats. 30 Great Yorkshire barrows were randomly allotted (by origin and weight) in three equal groups. Diets (Table 1) were formulated in consultation with the Unilever Research Laboratory (Vlaardingen). Codes N (Normal), M

TABLE 1

COMPOSITION OF THE DIETS (% BY WEIGHT)

Component	*Diet*		
	Normal	*Medium*	*High*
Corn	44·00	30·85	17·70
Soybean meal	27·00	24·68	22·37
Wheat grit		15·00	30·00
Tapioca meal	13·00	11·50	10·00
Molasses	7·50	7·50	7·50
Tallow	4·00	2·00	
Soy-oil		4·25	8·50
Dicalcium phosphate	3·04	2·53	2·02
Calcium carbonate	0·19	0·55	0·90
Sodium chloride	0·25	0·24	0·23
Trace minerals[a], essential amino acid[b], vitamins[c], antibiotics[d] and stabiliser[e]	1·06	0·95	0·83

[a]mg/kg: $CuSO_4 \cdot 5H_2O$, 1000; $FeSO_4 \cdot 7H_2O$, 900; ZnO, 140; MnO, 100; KI, 2; Sodium-Selenite (diluted × 700), 105.
[b]mg/kg: Methionine resp. 360, 475 and 590.
[c]mg/kg: A plus D_3, 20; B_2 (10%), 54; B_6, 2; B_{12} (0·1%), 25; Nicotinic acid, 20; Calcium pantothenate resp. 12, 10 and 7; Choline chloride (4%) resp. 7700, 6500 and 5200; E (50% *dl*-α-tocopherol acetate), 13.
[d]mg/kg: Payzone (30%), 33; Virginiamycine (50%), 10.
[e]mg/kg: Santoquin (50%), 50.

(Medium) and H (High) were assigned to the three blocks. Pigs (fed on an energy base for feeder pigs) were kept at an experimental farm of the Research Institute for Livestock Feeding and Nutrition, 'Hoorn'. Feeding started at an average weight of 30·4 kg (range 23·5–37·0 kg). Feed intake and growth proceeded normally. Mean weight at slaughter was 104·1 kg (range 95·5–111·5 kg). After a 24 h chill at 4 ± 1°C, the carcasses were partially deboned and split up into large joints. Visually there were no differences between carcasses. Nevertheless, the butchers (who were unaware of experimental details) occasionally noticed that the fat of M- and H- pigs had a weaker and softer consistency. (For further details see Houben & Krol (1978)).

Preparation of products

The products were made in the experimental butchery of the Meat Technology Laboratory (Utrecht) according to formulations drafted by the Netherlands Centre for Meat Technology of the CIVO/TNO (Anon., 1976).

The codes N (Normal), M (Medium) and H (High) were used again. All products (N, M and H) were prepared and stored identically, using only pork materials from the corresponding diet group. For each group, material derived from 10 pigs was used. Four pigs (chosen at random) were used to make coarsely-cut mixed samples of lean, fat and rind. These mixed samples were used for the preparation of the comminuted products. The prepared meats were derived from the remaining six pigs (animals again chosen at random). In the comminuted products (except the liver sausage) some beef was also included.

Unheated products

For this category the following were studied: Back bacon, belly bacon and a Dutch-style cervelat sausage. (At least four units (per block) were produced for the two bacons.) Two random back bacon strands were used for the storage tests. These products were exposed to air at 15 ± 1°C and sampled fresh, and after 1 and 2 months, subjected to sensory evaluation and chemical analyses. To accelerate lipid oxidation, however, a relatively high storage temperature was chosen. On the two other strands penetrometer measurements were performed after a careful removal of the rind. On the belly bacons (five per block) only penetrometer measurements (after careful derinding) were carried out. The measurements were always performed on the fatty side in at least 10 places per specimen.

For the N- and H- groups of the cervelat sausages, some batches were produced in which the ascorbate component was varied. Products were made without ascorbate; with 0·05% (m/m) sodium ascorbate; with 0·005% (m/m) L(+)-ascorbyl palmitate and with both compounds together (concentrations as before). The ascorbyl palmitate was dispersed by spraying an ethanolic solution (5 ml/kg) on the dough in a slowly revolving chopper-bowl. In the sausages without ascorbyl palmitate a similar amount of absolute ethanol was added in the same way.

The only problems in manufacturing products from these raw materials were encountered during the preparation of the M- and H- series of the fermented sausage. The flow of the doughs was obstructed in the chopper (temperature

approximately 0°C) and there was a considerable exudation of fat which continued during stuffing. After a fermentation period of two days in brine at 27°C, the products were cold smoked. The maximum temperature during smoking was 28°C. Upon smoking and ripening (at 15 ± 1°C) fat continued to 'sweat out'. The final M- and H- products neither looked well nor had a good 'design' internally. The cervelat sausages were sampled both when fresh and after 1 and 2 months storage at 15 ± 1°C exposed to air.

Heated products

The pasteurised products made were: Pork loin rolls and cured shoulders with fat and rind (both prepared meats); and the sausage types 'Boterhamworst' (a type of Bologna, smoked), 'Gelderse rookworst' (Guelders ring sausage, smoked, lowered pH, stuffed in commercial pork casings) and 'Saksische leverworst' (Saxon liver sausage, spreadable). Luncheon meat was made as an example of a sterilised product.

From the prepared meat, four units per block were always made. Two random products were used for the storage tests (in the case of shoulders, however, after removal of the rind). These products were stored, vacuum packaged, at ± 1°C for 1 and 2 months.

Upon sampling the vacuum was broken and a second short pasteurisation (30 min in a water bath at 72°C) was given after repackaging under vacuum.

The comminuted products were always made in batches of 12·5 kg. The Bologna was stuffed in permeable Nalo Faserbak casing (Kalle); the Guelders ring sausage was vacuum packaged after smoking and pasteurised in the vacuum bag; the Saxon liver sausage was stuffed in an impermeable Nalophan casing (Kalle). These products were all stored for 1 and 2 months at 4 ± 1°C.

The luncheon meat was put in 76 × 54 mm cans (content about 200 g) and sterilised at 115°C (F_c: 2). This product was stored for 2 months at 15 ± 1°C. The luncheon meat was also subjected to penetrometer measurements.

During the preparation of the heated products no significant differences in jelly or fat throw-out were observed.

Sensory evaluations

All products were judged by a CIVO-TNO expert-panel of 4–10 members. This panel was carefully selected and trained for judging meat products. Judgements were carried out by comparing the three blocks for each type of product in one session using blind codes. The products were served at room temperature except for the Guelders ring sausage which was heated (in the vacuum pouch) for 20 min at 75°C prior to tasting. Figures on a scale from 1 (extremely poor) to 10 (excellent) were given for the characteristics which were aroma/taste, external and internal colour, sliceability and consistency. Ranked data were treated statistically (Kahan *et al.*, 1973).

A selection of the freshly prepared products was also judged by a consumer panel. (For the results see Theunissen *et al.* (1979)).

Methods of analysis

p-anisidine value	†IUPAC Annexe II_5-PT 1972 (fat extraction with chloroform).
ash	§ISO/R 936 (1969).
fat	butyrometric method (Krol & Meester, 1963).
fatty acid composition	IUPAC II.D.19; preparation of fatty acid methyl esters and IUPAC II.D.25; gas chromatography of the mixture (fat extraction with chloroform).
hydroxyproline	ISO/DIS 3496/2 (Reference method, 1976).
moisture	ISO 1442 (1973)
nitrite	ISO 2918/2 (Reference method, 1976).
peroxide-number	IUPAC II.D.13 (fat extraction with chloroform).
protein	Kjeldahl method executed with a Kjelfoss instrument (Oberrieth & Mermelstein, 1974).
salt (as NaCl)	ISO/R 1841 (1970).

Most of the analytical work was performed by various departments of the CIVO/TNO.

Penetrometer measurements were carried out at 15°C with a Wykeham Farrance model 7250 (cone weight 130 g; top angle 40°).

RESULTS AND DISCUSSION

Composition of products

Table 2 presents the gross chemical composition of the fresh products. Generally the values agree with the formulations, except for the H-cervelat sausage, where a rather low fat content was found.

Table 3 gives the results of the determinations of some fatty acids present in fresh tissues and products. Only those fatty acids were selected which yielded more than 3% measured as fatty acid methyl esters.

Fatty acid compositions of the products agree fairly well with those from the fresh tissues. Consequently, the preparation of this variety of products did not result in lowered PUFA-levels. The fatty acid compositions of the back bacons did not show a measurable decrease in PUFA-levels during 61 days' storage exposed to air at 15°C.

†IUPAC = International Union of Pure and Applied Chemists
§ISO = International Standards Organisation

TABLE 2

GROSS CHEMICAL COMPOSITION OF THE PRODUCTS, N = NORMAL; M = MEDIUM; H = HIGH; A, B = REPLICATED SAMPLES

Product	*Diet*	*Component*							
		Moisture[b]	*Fat*[b]	*Protein*[bc]	*Hydroxy-proline*[b]	*Ash*[b]	*Salt*[bd]	*Residual nitrite*[e]	*pH*
Back bacon[a]	NA	42·2	42·0	11·6	0·16	3·03	2·5	10	5·65
	NB	53·4	27·0	15·5	0·32	4·20	3·5	16	5·85
	MA	42·8	39·0	13·3	0·21	3·59	3·3	12	5·8
	MB	49·4	33·7	14·2	0·22	3·08	2·5	24	5·9
	HA	49·6	32·6	15·1	0·23	3·45	2·6	14	5·9
	HB	47·5	33·8	14·7	0·15	3·95	3·4	16	5·7
Dutch-style cervelat	N	41·2	35·3	17·8	0·64	4·70	4·0	2	4·8
	M	42·7	36·0	17·8	0·64	4·56	4·15	2	4·6
	H	49·3	23·5	20·7	0·68	5·26	4·7	3	4·6
Pork loin roll[a]	NA	67·4	8·5	20·8	0·14	3·39	2·1	26	6·05
	NB	68·1	9·9	19·0	0·13	3·58	2·0	10	6·0
	MA	67·6	8·0	21·1	0·15	2·92	2·2	7	6·05
	MB	66·0	12·3	19·9	0·13	2·83	2·4	9	6·1
	HA	67·0	9·2	21·5	<0·1	3·11	1·8	6	6·2
	HB	67·9	10·1	18·6	0·15	3·60	2·4	9	6·1

Shoulder with fat[a]	NA	69·3	8·8	19·5	0·24	2·63	1·5	20	6·3
	NB	69·5	10·0	16·5	0·23	3·04	2·0	21	6·2
	MA	70·8	9·3	17·0	0·21	2·93	1·75	9	6·1
	MB	69·2	11·5	17·1	0·22	2·71	1·7	11	6·0
	HA	66·4	14·8	15·6	0·21	2·65	1·65	12	6·2
	HB	68·2	9·8	18·2	0·26	2·63	1·85	7	5·95
Bologna	N	46·8	34·5	13·4	0·40	2·69	2·0	17	6·05
	M	45·4	36·3	12·9	0·36	2·61	2·0	16	6·0
	H	45·1	34·8	13·3	0·40	2·66	2·0	15	6·0
Guelders ring sausage	N	49·8	34·5	13·4	0·19	2·88	2·1	4	5·55
	M	47·2	37·8	12·9	0·22	2·85	2·1	4	5·5
	H	48·6	32·5	13·4	0·22	2·98	2·2	4	5·5
Saxon liver sausage	N	58·7	20·8	18·1	0·38	2·75	1·9	15	6·2
	M	56·8	22·5	17·1	0·34	2·60	2·0	14	6·2
	H	57·0	23·0	16·8	0·33	2·69	2·0	9	6·2
Luncheon meat	N	50·4	32·5	12·4	0·37	2·60	2·0	8	6·0
	M	49·2	32·8	12·2	0·35	2·59	2·0	8	5·85
	H	50·3	31·8	12·6	0·33	2·60	2·0	8	6·1

[a]Two products per block (derived from different animals) have been analysed and subjected to the storage experiments.
[b]% m/m.
[c]Protein content = 6·25 × nitrogen content
[d]As sodium chloride.
[e]ppm as sodium nitrite

TABLE 3

SELECTION OF SOME FATTY ACIDS ESTIMATED IN FRESH TISSUES AND PRODUCTS[b]. N = NORMAL, M = MEDIUM, AND H = HIGH

Product	*Diet*	*Fatty acid*					$\sum$ *PUFA*[d]
		16:0	*18:0*	*18:1*	*18:2*	*18:3*	
Back fat[c]	N	23·9	11·3	43·9	13·8	0·8	15·5
	M	19·5	9·9	36·8	26·3	2·0	30·1
	H	17·1	7·5	31·2	36·0	3·4	41·4
M. longissimus dorsi[c] (ribs 7 to 10)	N	26·2	12·2	48·7	6·2	0·4	7·3
	M	24·5	10·9	46·0	11·7	0·8	13·5
	H	22·8	9·9	39·7	19·9	1·6	23·0
Back bacon (fresh)[a]	N	23·4	12·6	45·6	10·9	0·5	12·3
	M	21·3	11·4	36·6	22·6	2·0	25·9
	H	16·2	10·8	29·5	33·7	3·5	39·4
Back bacon (stored[e])[a]	N	23·7	12·0	44·6	13·1	0·7	14·9
	M	20·5	10·7	35·5	25·8	2·2	29·6
	H	16·3	10·5	30·4	34·6	3·3	39·9
Dutch/style cervelat	N	23·8	13·1	42·6	12·7	0·8	14·1
	M	20·2	11·1	36·3	23·2	1·9	26·9
	H	19·0	11·0	31·0	29·8	3·0	34·6
Pork loin roll[a]	N	25·0	13·4	42·8	10·4	0·8	11·9
	M	20·3	11·6	35·9	23·4	2·3	27·4
	H	16·8	9·8	29·4	34·2	3·8	40·4
Shoulder with fat[a]	N	21·9	10·5	48·8	10·2	0·7	12·1
	M	20·7	9·6	38·2	22·2	2·3	25·9
	H	16·8	9·2	30·7	33·5	3·6	39·6
Bologna	N	24·4	14·6	40·8	12·7	0·7	13·9
	M	19·7	10·7	35·8	24·3	2·2	28·6
	H	17·1	8·9	30·5	33·6	3·6	39·7
Guelders ring sausage	N	22·3	11·9	42·1	12·8	0·8	16·3
	M	19·3	10·5	34·8	24·3	2·2	29·6
	H	16·6	8·6	30·1	34·0	4·0	40·4
Saxon liver sausage	N	23·4	12·5	41·8	12·9	0·9	15·5
	M	20·4	11·3	36·5	22·2	2·1	26·5
	H	18·1	10·0	30·8	30·2	3·3	36·5
Luncheon meat	N	23·5	12·6	42·2	13·5	0·9	15·2
	M	20·1	11·1	36·1	23·8	2·0	27·5
	H	17·2	8·7	30·5	33·0	3·6	38·9

[a]See footnote table 1; in this table only means are presented.
[b]Data present weight percentages of the fatty acid methyl esters
[c]Fresh tissues have been sampled from two animals per block; only means are presented.
[d]Sum of all the detected polyunsaturated fatty acids.
[e]Bacon stored 61 days at 15 ± 1°C in the air.

Lipid oxidation in products

Table 4 presents peroxide numbers, *p*-anisidine values and aroma/taste scores measured during storage of the different products. Noteworthy in this table are the rather high peroxide numbers found with fresh M- and H-back bacons, shoulders with fat and Saxon liver sausages. Such differences, in comparison with the N-products, increased further upon storage.

In the recent literature no comparable figures could be found, most research having been done on model systems. Wurziger (1967) and Pardun (1975) mention that the threshold for the organoleptical detection of rancidity in lard corresponds

TABLE 4

PEROXIDE-NUMBERS (PN; meq/kg FAT), *p*-ANISIDINE-VALUES (PAV; CALCULATED ON FAT BASE) AND MEAN AROMA/TASTE SCORES (AT) DURING STORAGE OF THE DIFFERENT PRODUCTS. N = NORMAL, M = MEDIUM, AND H = HIGH

Product		*Days Storage* 0 *PN*	0 *PAV*	0 *AT*	29 *PN*	29 *PAV*	29 *AT*	61 *PN*	61 *PAV*	61 *AT*
Unheated products stored at 15°C										
Back bacon[a]	N	2·8	1·1	7·7	0·7	0·8	7·2	9·1	3·2	7·2
	M	5·8	1·0	7·2	3·4	1·5	7·1	13·8	3·4	7·0
	H	14·4	1·9	7·2	3·7	1·4	6·6	45	4·3[c]	6·4
Dutch-style cervelat	N	6·9	NR[b]	7·8	5·0	13·8	7·8	2·1	NR[b]	5·2
	M	6·2	10·7	6·6	58	17·5	6·0	72	22·0	2·6
	H	4·9	23·7	6·1	67	51	5·8	315	76	1·7
Pasteurised products stored at 4°C										
Pork loin roll[a]	N	2·5	2·7	7·3			7·4	1·1	2·3	7·3
	M	2·1	3·1	7·4			7·1	1·8	2·7	7·3
	H	2·2	4·9	7·8			7·1	1·5	2·8	7·3
Shoulder with fat[a]	N	3·4	4·9[c]	7·7			7·8	3·4	8·2	7·6
	M	10·8	13·7	7·6			7·4	24	6·4	7·4
	H	34	14·6	7·6			7·3	57	11·5	7·0
Bologna	N	1·6	2·4	7·0	3·0	1·3	6·9	0·9	NR[b]	5·3
	M	0·8	1·7	6·9	0·5	1·5	7·0	1·3	17·1	5·3
	H	1·0	6·5	7·1	0·8	1·1	7·0	1·5	20·3	5·2
Guelders ring sausage	N	0·8	2·1	7·3	1·0	5·5		0·7	NR[b]	7·9
	M	0·7	3·7	7·4	1·7	4·5		0·9	NR[b]	7·8
	H	0·7	NR[b]	7·4	1·3	8·1		1·1	3·1	7·4
Saxon liver sausage	N	8·5	20·3	7·3	2·2	20·2	7·5	5·0	NR[b]	7·0
	M	29	12·1	7·1	7·0	35·6	7·2	2·7	11·0	6·5
	H	14·6	17·2	6·7	3·7	68	7·1	12·8	538	6·4
Sterilised product stored at 15°C										
Luncheon meat	N	1·3	4·9	7·6				2·9	7·7	7·4
	M	2·9	5·5	7·1				8·7	29·7	7·2
	H	0·7	10·8	7·1				9·0	6·3	7·6

[a]See footnote Table 1; in this table only mean values are presented.
[b]NR = no result; extract unworkable.
[c]Only one product gave a reliable result.

generally with a peroxide number of approximately 20 meq/kg fat. Nevertheless higher numbers may be found without any sign of deterioration. This threshold is probably relevant for lard from the N-block. On the other hand fats from the products derived from the M- and H-blocks may behave more like vegetable oils upon oxidation. In vegetable oils onset of rancidity takes place at about 100 meq/kg fat (Pardun, 1975). In practice, it is generally agreed that the best way to assess samples for rancidity is to use a sensory evaluation and some form of lipid oxidation measurement. The chemical determination will give information about the progress of the oxidative processes which are taking place; the sensory evaluation will dominate, however, in most assessments.

The *p*-anisidine value is a substitute for the use of benzidine number (Pardun *et al.*, 1976). With this new method, aldehydes and especially 2-alkenals, both secondary products of lipid oxidation, are estimated. For *p*-anisidine values no data related to meat products have been hitherto available. The values measured for the fresh M- and H- products seemed relatively high.

Peroxide numbers and *p*-anisidine values normally (in sound fats and oils) increase during storage; such a picture was not seen consistently during this investigation. In meat products, however, one is dealing with a very complex system of many different factors which can influence lipid oxidation. Salt is a well known pro-oxidant, whereas nitrite and ascorbic acid usually behave as anti-oxidants (Hadden *et al.*, 1975; Bauernfeind & Pinkert, 1970; Kanner & Mendel, 1977). Under certain conditions, however, the latter may act as pro-oxidants (Ellis *et al.*, 1968; Bauernfeind & Pinkert, 1970). Metal ions, especially copper and iron, and even the iron present in metmyoglobin catalyse lipid oxidation (Liu, 1970 and Love & Pearson, 1974); tocopherols and certain components of spices can inhibit these processes (Schulze, 1971). Smoking also adds anti-oxidants to products (Draudt, 1963). All these antagonistic actions continue to produce lower peroxide numbers and *p*-anisidine values for the freshly prepared products than those measured on the meats from which they were prepared. Peroxide numbers up to 60 meq/kg fat were found on fresh H-meat and -fat (Houben & Krol, 1978).

During storage, rapid oxidation processes were observed with the cervelat sausages, shoulders with fat, Saxon liver sausages and back bacons. This behaviour was rather unexpected for the two heated products. Possible explanations may be the large fat surface for the shoulder, and, for the liver sausage, the comminuted character plus the presence of 30% liver (with a highly unsaturated fat and a high copper content). Furthermore, it may be that the packaging materials (casings) possess a critical oxygen permeability for such sensitive products.

With the Saxon liver sausages very high *p*-anisidine values were observed during storage, whereas the peroxide numbers did not increase. The aldehydes (being secondary products of lipid oxidation) were possibly produced by a rapid breakdown of continuously emerging peroxides.

The changes in aroma/taste scores in general do not correlate well with the fat oxidation measurements.

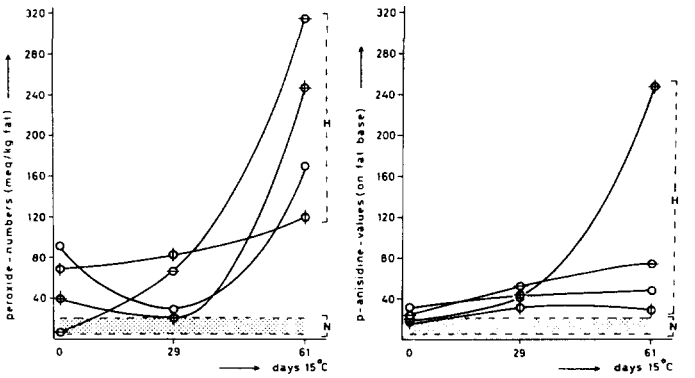

Fig. 1. Progress of the peroxide numbers and *p*-anisidine values during storage of the different batches of cervelat sausages. -O-no ascorbic acid derivative; -Θ-with sodium ascorbate; ϕ with L (+)-ascorbyl palmitate; -⊕-with sodium ascorbate and L (+)-ascorbyl palmitate. N-measurements all in dotted zones.

Figure 1 gives lipid oxidation measurements for the different batches of the cervelat sausages. The measurements for the H-sausages suggest that ascorbate (0·05% m/m), in that situation, may act as a pro-oxidant, whereas ascorbyl palmitate (0·005% m/m) functioned as expected. The number of determinations made, however, was too small to draw definite conclusions. Kanner & Mendel (1977) observed a pro-oxidant effect of ascorbic acid at this level of application in a model system. They state that, in general, ascorbic acid at higher levels (0·2–1%) would be required to produce anti-oxidant effects in foods.

Sensory evaluations

Table 5 presents the consistency-scores for the freshly prepared products and summarises all the results from the sensory evaluations. The basic data were ranked and treated statistically.

Significant differences were not observed with the back bacon. There were no comments on rancidity for the N-products even after storage; however, with the M- and H-bacon, respectively, 3 and 5 (out of 10) panel members remarked on rancidity at the final judgement. Three (out of 10) detected rancidity in the H-bacon after a storage of 29 days at 15°C.

The N- cervelat sausages appeared by all the judgement criteria employed to be very significantly superior to both other products. Many remarks were made on the consistency of these last products which were regarded as being too soft/weak. Rancidity was noticed more often with M- and H- cervelat sausages and even with N- products. (This type of product was stored for a longer period than would occur in good commercial practice.)

Rancid off-flavours were sometimes detected here (and also with some other products) at peroxide numbers below 20 meq/kg fat, once again demonstrating the necessity of organoleptical judgements.

TABLE 5

CONSISTENCY-SCORES (CS) OF THE FRESHLY PREPARED PRODUCTS AND MEAN VALUES OF ALL THE SENSORY JUDGEMENTS (MSJ) CARRIED OUT BY THE EXPERT-PANEL DURING STORAGE. N = NORMAL, M = MEDIUM AND H = HIGH

Product	*Diet*	*CS*	*MSJ* *Days Storage*		
		0	0	29	61
Unheated products stored at 15°C					
Back bacon	N	7·5	[a]7·1	7·3	7·1
	M	7·3	6·9	7·1	6·7
	H	7·1	7·0	6·9	6·6
Dutch-style cervelat	N	7·6	[a]7·6	7·6	6·4
	M	5·8	6·5	6·0	4·4
	H	5·9	6·3	5·5	3·6
Pasteurised products stored at 4°C					
Pork loin roll	N	6·9	[b]7·2	7·4	7·1
	M	7·3	7·4	7·6	7·4
	H	7·1	7·4	7·4	7·3
Shoulder with fat	N	7·8	[b]7·7	7·7	7·5
	M	7·2	7·3	7·6	7·5
	H	7·7	7·5	7·6	7·3
Bologna	N	5·3	[a]6·4	5·7	4·8
	M	5·6	6·9	5·9	5·0
	H	6·1	7·2	6·0	5·0
Guelders ring sausage	N	6·9	[a]7·2	7·4	7·7
	M	7·3	7·1	7·6	7·3
	H	6·3	7·1	7·3	7·2
Saxon liver sausage	N	8·0	[a]7·6	7·4	7·6
	M	6·7	7·1	7·1	7·4
	H	6·9	7·0	7·0	7·1
Sterilised product stored at 15°C					
Luncheon meat	N	6·9	[c]7·0	—	7·1
	M	7·3	7·2	—	7·2
	H	7·4	7·2	—	7·6

[a]Means of figures for external and internal colour, aroma/taste and consistency.
[b]Means for internal colour, sliceability, aroma/taste and consistency.
[c]Means for internal colour, aroma/taste and consistency.

For the Bologna, significant differences were found only in respect of their consistency. The N- product was judged as the worst, being tougher. With the Saxon liver sausages some comments on rancidity in the outer layers were made on the H-product after 61 days at 4°C.

For the luncheon meat, the H-product was judged very significantly to have the best consistency, the N-product having the worst.

In regard to the pork loin rolls, the shoulders with fat and the Guelders ring sausages, no significant differences were detected.

Penetration measurements

Table 6 gives a summary of the penetrometer measurements. No differences in

TABLE 6

SUMMARY OF THE PENETROMETER MEASUREMENTS[a] (MEAN ± SD)

Product	*Diet*		
	Normal	*Medium*	*High*
Back bacon (n = 24)	24·1 ± 8·28[b]	23·8 ± 8·53[b]	30·6 ± 13·32[c]
Belly bacon (n = 51–69)	55·8 ± 21·57[d]	59·4 ± 18·62[d]	55·1 ± 15·24[d]
Luncheon meat (n = 20)	47·8 ± 3·77[e]	58·5 ± 5·41[f]	68·8 ± 4·27[g]

[a]Measurements at 15°C in 0·1 mm

[b,c,d]Means in a row followed by the same letter are not significantly different (Wilcoxon's test; one tail, $\alpha = 0{\cdot}05$)

[e,f,g]Means in a row followed by the same letter are not significantly different (Wilcoxon's test; one tail, $\alpha = 0{\cdot}005$)

softness were found with the belly bacon; this is in contrast to the back bacon where a significant difference was observed. In this case penetration measurements showed differences which the sensory evaluations did not detect.

The luncheon meat gave significantly increasing penetration measurements in relation to the PUFA-content.

CONCLUSIONS

The use of pork raw materials with increased PUFA-levels (up to about 30% linoleic acid in the backfat) for the preparation of a variety of products did not present any major problem except for cervelat type sausages. Such fermentation type products could not be prepared at an acceptable level of quality using standard procedures. The sensory evaluations revealed only a few (mostly minor) differences between freshly prepared products. Upon storage, rancid off-flavours were more often detected with M- and H-products. With the unheated products the fatty acid compositions did not change significantly during the various preparation procedures, nor during a two month storage (exposed to the air at 15°C).

The fat oxidative stability of some products appeared to be rather critical. This might be improved by starting with better stabilised raw materials and by including anti-oxidants like ascorbyl palmitate and/or tocopherols in the formulations. Some effect can also be expected from the incorporation of citric acid (Roth & Scheid, 1977) and polyphosphates. A careful choice of casings, packaging materials and storage (preferably in the dark) at lower temperatures can also be helpful.

ACKNOWLEDGEMENTS

We gratefully acknowledge financial support from the Dutch Heart Foundation, grant no. 24.005.

REFERENCES

ANON. (1976). *Recepten voor vleeswaren en eisen voor slagerijapparatuur.* Centraal Instituut voor Voedingsonderzoek TNO, Zeist, The Netherlands.
BAUERNFEIND, J. C. & PINKERT, D. M. (1970). *Adv. Fd Res.*, **18**, 219.
BENEDICT, R. C., STRANGE, E. D. & SWIFT, C. E. (1975). *J. Agric. Fd Chem.*, **23**, 167.
BIELSKI, B. H. J., RICHTER, H. W. & CHAN, P. C. (1975). *Ann. N. Y. Acad. Sci.*, **258**, 231.
DENG, J. C., WATSON, M., BATES, R. P. & SCHROEDER, E. (1978). *J. Fd Sci.*, **43**, 457.
DRAUDT, H. N. (1963). *Food Technol.*, **17**, 85.
ELLIS, R., CURRIE, G. T., THORNTON, F. E., BOLLINGER, N. C. & GADDIS, A. M. (1968). *J. Fd Sci.*, **33**, 555.
HADDEN, J. P., OCKERMAN, H. W., CAHILL, V. R., PARRETT, N. A. & BORTON, R. J. (1975). *J. Fd Sci.*, **40**, 626.
HOUBEN, J. H. & KROL, B. (1978). *Proc. Eur. Meet. Meat Res. Wkrs.*, **24**, 4; 1.
KAHAN, G., COOPER, D., PAPAVASILIOU, A. and KRAMER, A. (1973). *Food Technol.*, **27**, 63.
KANNER, J. & MENDEL, H. (1977). *J. Fd Sci.*, **42**, 60.
KROL, B. & MEESTER, J. (1963). *Fleischwirts.* **15**, 488.
LIU, H. P. (1970). *J. Fd Sci.*, **35**, 590.
LOVE, J. D. & PEARSON, A. M. (1974). *J. Agric. Fd Chem.*, **22**, 1032.
OBERRIETH, R. & MERMELSTEIN, N. H. (1974). *Food Technol.*, **28**, 40.
PARDUN, H. (1975). *Fette Seifen Anstrichm.*, **77**, 296.
PARDUN, H., VOGEL, P. & ARENS, M. (1976). *Fette Seifen Anstrichm.*, **78**, 317.
ROTH, B. & SCHEID, D. (1977). *Fleischwirts.*, **57**, 1001.
SCHULZE, H. (1971). *Arch. Lebensmittelhyg.*, **7**, 160.
SKELLEY, G. C., BORGMAN, R. F., HANDLIN, D. L., ACTON, J. C., MCCONNELL, J. C., WARDLAW, F. B. & EVANS, E. J. (1975). *J. Anim. Sci.*, **41**, 1298.
THEUNISSEN, T. J. J. M., KOUWENHOVEN, T. & BLAUW, Y. H. (1979). *J. Fd Sci.*
WURZIGER. J. (1967). *Fleischwirts.*, **47**, 1355.