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P.O. Box 52
North Ryde, NSW 2113

TELEPHONE: (02) 887 8333
TELEX: AA23407
TELEFAX: (02) 887 3107

Located at: Gate 1
51 Delhi Road, NORTH RYDE

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Texture of Ham

L.M. Eadie, P.N. Jones & P.V. Harris
CSIRO Division of Food Processing, Cannon Hill, Queensland 4170

Introduction

The number of attributes believed by various researchers to be required to adequately describe the quality of table (i.e., carcass) meats ranges from two to seven. The latter number included juiciness, connective tissue toughness and five muscle fibre attributes (Cover *et al.*, 1962 a,b,c,d). The five muscle fibre attributes were all highly correlated with each other so, in essence, they could be considered as one - a measure of the muscle fibre contribution to toughness. There seems to be agreement that toughness and juiciness are important attributes (Harries *et al.*, 1972; Horsfield and Taylor, 1976; Frijters, 1976 and Dransfield *et al.*, 1984) but additional attributes appear to be required, e.g., where reformed meat, liver and textured vegetable protein products were included along with meat or for chicken breast muscle. 'Flavour' was considered to be important (Horsfield and Taylor, 1976) for the former, while 'fattiness' was included for the latter. The most recent work (Dransfield *et al.*, 1984) included three connective tissue factors ('closeness', 'amount of connective tissue' and 'amount of residue').

Unlike fresh meat, ham is a processed meat product in which the injection of different curing solutions can produce major changes in texture and/or taste. Ham also differs from most of the meat products used for the work mentioned previously as it does not usually require cooking (or further cooking) before being eaten. In recent work, Nute *et al.* (1987) examined the sensory characteristics of hams and investigated the relationships with various mechanical measurements. They initially produced a profile of 26 attributes and three hedonic ratings to describe appearance, texture and flavour but rationalised these to 22 attributes and three hedonic ratings. This sensory profile (Nute *et al.*, 1987) was, however, developed using hams available in the U.K. which could differ from those available in Australia. A sensory profile has, therefore, been developed for the types of ham available in Australia. In parallel with the development of this sensory profile, a number of objective methods have been investigated.

Materials & Methods

Experimental Material

In order to obtain a suitable range of hams, the local shops and supermarkets were surveyed and 26 different types of ham were bought. From these hams 10 were selected to cover a wide range of types, flavours and textures. Sufficient of each of the selected hams were then purchased to allow both sensory and physical assessments. The hams listed in Table 1 are identified only by code since the intent was to compare hams and not to compare manufacturers. The ham numbers (1-10) in Table 1 have been used throughout the text to identify the various types of ham.

Composition of Hams

The percentage water, fat and protein contents of duplicate samples of each ham were measured using the standard AOAC methods (AOAC 1975). Salt content was measured using the Volhard method (AOAC 1975, Egan *et al.*, 1981).

Sensory Profile Development

The panellists were all highly experienced in flavour and texture sensory testing and all had considerable experience in both free choice and consensus sensory profiling. All panellists were initially screened to ensure they liked ham. The procedure previously used for free choice profiling (Jones *et al.*, 1989) was employed, the panelists tasted the full range of samples and developed individual sensory profiles using their own selection of descriptive words. After an initial session, they used their individual profiles at three separate trial sessions to determine whether the profile adequately described the samples and to decide which attributes were pertinent. At this stage they could add to, or subtract from, their lists of attributes as they saw fit until they considered their profiles to be finalised. Once they were satisfied with their profile, a meeting of all the panellists was called at which each panellist discussed and explained his/her individual profile. From these discussions a consensus profile was derived.

Sensory Assessment

Each sample at each session was identified using a three digit code. Five samples were tasted at each session in an arrangement determined by a balanced incomplete block design (Bose *et al.*, 1954). The 10 ham types were assessed in groups of five at a total of eight sessions for each of 12 panellists. Each ham was thus tasted four times. Samples were tasted one at a time under daylight conditions. Each panellist was served the samples in an individual test booth and was supplied with both dry toast and water to help cleanse his palate between tastes. Their results for each sample and each attribute were recorded directly onto a multi-user computer system on a continuous, unstructured linescale.

Samples were all served at room temperature and in 3 mm thick slices. As the hams were not of a standard size, the taste panel samples were all cut to similar sizes (i.e. 4 x 8 cm with 3 mm thickness). Each panellist received two such samples per ham type.

Mechanical Measurements

Four different physical methods were tried. One was a compression method, identical to that used previously for cooked meat (Bouton and Harris, 1972). In this, a flatended cylindrical plunger (0.63 cm diameter) was twice driven (at 50 mm/min) 80% of the way into a 1.0 cm thick sample at the same site. By measuring the work done on the first (W_1) and second (W_2) penetrations and by measuring the force (F) required to achieve the first compression, the factor chewiness can be obtained ($F \times W_2/W_1$).

A tensile method, previously described for use on comminuted meat products (Macfarlane *et al.*, 1984), required 1.0 cm thick samples which were 2.5 cm wide and 5-6 cm long. The two sets of jaws were mounted (on an Instron 1122 Universal testing machine) at a jaw separation of 2.0 cm. The maximum force (kg) measured as the clamped sample was pulled apart was taken as its tensile strength.

As well as the compression and tensile methods, two versions of the Warner-Bratzler (WB) shear device were used. One required rectangular samples (1.5 x 0.67 cm cross section and 5-6 cm long) and was used in a WB shear device described previously (Bouton and Harris, 1972). The second WB shear method used samples with a length of 5-6 cm and a cross sectional area of 1.5 x 1.5 cm. The shear blade was 3 .41 mm thick and the gap width was 0.63 mm. This compared with a 0.58 mm thick shear blade with similar gap width used for the other WB shear method. Both these WB shear devices were mounted on an Instron (Model 1122) and operated with a crosshead speed of 100 mm/min. For all four methods it was not possible to maintain a constant orientation of the meat fibres, so fibre direction was random.

The pH of each ham was measured at room temperature (23 ± 2°C) using a Townson expanded scale meter fitted with a Philips C64/1 combined electrode.

Statistical Methods

The Genstat V statistical package (Genstat V, Lawes Agricultural Trust, Rothamsted Experimental Station) was used to carry out analyses of variance and to calculate standard errors. Least significant difference (LSD) values at $P = 0.05$ were calculated from the standard errors. Principal Components Analysis (PCA) was carried out on the correlation matrix of the sensory variates.

Results & Discussion

Composition of Hams

The results of the analyses for moisture, fat, protein and salt contents of the 10 experimental hams are listed in Table 1.

Table 1
Percentage fat, moisture, salt and protein in the 10 types of ham

	Ham number and description	Percentage			
		Moisture	Fat	Salt	Protein
1.	Leg A	70.5	5.2	3.3	19.5
2.	Pressed B	75.0	2.8	3.4	17.4
3.	Pressed C	68.0	3.0	4.0	13.6
4.	Processed D	74.1	5.0	3.1	13.7
5.	Pressed leg E	75.8	1.5	2.0	19.1
6.	Shoulder/pressed F	72.9	6.5	3.0	16.3
7.	Pressed leg G	69.4	2.2	3.9	17.3
8.	Pressed H	74.5	1.8	2.7	17.7
9.	Leg B	72.6	2.8	3.3	17.3
10.	Trimmed I	75.4	3.1	2.5	17.7

• Manufacturer identified by letter only.

Fat contents ranged from 1.5 to 6.5% while salt content ranged from 2.0 to 4.0%. Moisture contents varied from 68.0 to 75.8% and protein content from 13.6 to 19.5%. These differences in composition are considered large.

Sensory Profile

The consensus sensory profile developed by the panellists contained 15 attributes and five acceptability ratings. Four of these attributes were for appearance, three for aroma, four for texture and four for flavour. The acceptability ratings were for appearance, aroma, texture and flavour together with an overall rating which took into account the other four ratings. The attributes and a short explanation of each one plus the scale/limits are listed in Table 2.

Sensory Results

The mean values (averaged over the 12 panellists) obtained for each of the sensory attributes and for each of the hams are listed in Table 3. These results (Table 3) show that the panellists detected significant differences in attributes between the various hams. In 'appearance', fat content was lowest for ham No. 5 and highest for hams No. 6 and 8. Ham 5 was rated as having the greatest homogeneity (i.e., consistency of texture) while 4 and 6 had the lowest. Hams 3 and 8 had the darkest colour, while 5, 6 and 10 were the palest. Colour variation was greatest for hams 4 and 7 and least for ham 5. There was little to choose between hams 1, 2, 3, 5, 7, 8 or 9 in acceptability of appearance (high acceptability) or between 4, 6 and 10 (low acceptability).

In terms of aroma, ham 3 had the most pronounced smoke aroma, and 4 and 6 had the least. The lowest meat/ham aroma was for hams 3 and 4 with hams 1, 2, 5, 7, 8 and 9 all equally strong. 'Other aroma' was strongest in 4, 6 and 10 and weakest in 1, 7 and 9. 'Acceptability of flavour' was strongly related to 'other aroma', so that 4 and 6 were rated as the least acceptable while 1, 5, 7 and 9 were rated as most acceptable.

For texture, the better accepted hams were those with high 'structure' scores, such as 1, 5, 7 and 9, while the worse were those with low 'structure' scores, such as 4, 6 and 10. Flavour acceptability was dominated by ham/meat flavour and other flavour (which, in turn, were highly related).

Table 2

The attributes, explanation of attribute meaning and scale limits for the consensus sensory profile developed for ham products

Attributes	Explanation	Scale limits (0-100)
Appearance		
Fat content	Amount of visible fat	v.low - v.high
Homogeneity of texture	Evenness and consistency of texture	non uniform-uniform
Dominant colour	Overall impression of colour intensity	pale - dark
Colour variation	Evenness of colour	constant - varied
Acceptability	Appearance	v.poor - v.good
Aroma		
Smoke	Strength of smoke aroma	v.low - v.high
Meat	Strength of meat aroma	v.low - v.high
Other	Strength of aromas other than above	v.low - v.high
Acceptability	Aroma	v.poor - v.good
Texture		
Tenderness	Impression of tenderness	v.tender - v.tough
Juiciness	Moisture - amount released during chewing	v.juicy - v.dry
Homogeneity	Inhomogeneities perceived in sample while chewing	v.even - v.lumpy
Structure	Fibrosity or structure perceived in sample while chewing	v.soft-v.structured
Acceptability	Texture	v.poor - v.good
Flavour		
Smoke	Strength of smoke flavour	v.weak - v.strong
Salt	Strength of salt flavour	v.low - v.high
Ham/meat	Strength of meat flavour	v.weak - v.strong
Other	Strength of flavours other than above	v.weak - v.strong
Acceptability	Flavour	v.poor - v.good
Overall acceptability	Acceptability taking into account appearance, aroma, texture & flavour	v.poor - v.good

Table 3

Mean values obtained for each of the hams for both the sensory profile attributes and for the acceptability ratings

	1	2	3	4	5	6	7	8	9	10	LSD
Fat content	28.1	28.3	36.6	29.4	11.8	41.5	28.6	42.5	36.5	35.5	10.9
Homogeneity	58.3	54.7	40.0	20.9	77.5	17.8	54.0	47.6	57.5	43.4	12.0
Dominant colour	45.0	51.6	67.6	29.6	38.8	32.1	43.3	65.9	50.9	32.5	14.0
Colour variation	45.4	51.9	56.0	74.3	23.6	77.1	46.7	54.6	38.3	45.7	16.1
Acceptability of appearance	62.2	53.4	56.0	30.6	58.3	31.1	66.0	60.9	63.4	39.9	7.8
Smoke aroma	52.6	49.8	68.9	21.4	52.6	26.7	44.4	33.3	44.0	29.5	7.8
Meat aroma	51.8	53.3	37.6	37.7	51.5	39.7	54.6	52.1	57.8	47.2	6.1
Other aroma	19.3	25.4	38.8	44.1	23.1	50.0	17.5	25.1	18.8	46.4	7.1
Acceptability of aroma	64.6	51.8	49.2	25.6	61.1	26.0	64.2	54.4	65.7	39.8	8.1
Tenderness	46.5	51.6	43.7	32.3	31.3	32.8	36.2	43.4	39.0	10.0	9.0
Juiciness	52.2	50.2	51.7	49.1	52.1	47.5	38.9	44.6	44.8	43.9	8.1
Homogeneity	34.5	46.7	47.4	58.0	23.1	57.5	29.8	42.2	31.7	23.9	8.5
Structure	73.6	50.9	52.6	38.2	65.0	32.1	64.2	60.3	78.6	14.8	8.9
Acceptability of texture	73.2	52.9	55.4	32.5	72.2	30.0	69.0	60.0	76.0	23.4	6.5
Smoke flavour	59.3	52.2	71.8	26.0	52.3	31.1	55.4	32.7	51.6	31.5	6.5
Saltiness	59.3	53.3	63.1	50.1	45.3	51.7	66.9	35.9	65.0	54.7	5.3
Ham/meat flavour	62.4	55.9	51.5	48.3	59.6	46.5	59.3	50.0	65.9	51.0	5.7
Other flavour	20.8	26.2	43.8	41.6	25.5	50.8	23.6	46.3	22.5	50.7	8.1
Acceptability of flavour	64.9	49.6	50.3	26.2	62.1	27.0	59.8	43.4	63.2	31.5	9.4
Overall acceptability	67.9	47.4	49.1	26.8	64.8	26.8	63.9	50.8	66.6	31.4	9.3

Samples such as 1, 5, 7 and 9, which scored high for the former and low for the latter, were the most acceptable.

Correlations Between Sensory Measurements

'Acceptability of appearance' was best related to homogeneity (r = 0.80, P<0.01) and to colour variation (r = -0.72, P<0.05). Homogeneity and colour variation were, not surprisingly, strongly related (r = -0.96, P<0.001). In aroma, acceptability was related to smoke aroma (r 0.65, P<0.05), meat aroma (r = 0.82, P<0.01) and other aroma (r = 0.94, P<0.001). Meat aroma and other aroma were negatively correlated (r = -0.86, P<0.01). Acceptability of aroma was, thus, influenced more by the presence of an 'other odour' than by anything else.

Texture acceptability was most strongly affected by structure, or fibrosity, (r = 0.97, P<0.001). Flavour acceptability was influenced by 'other flavour' (r = 0.87, P<0.001) and ham/meat flavour (r = 0.91, P<0.001). As with the aroma acceptability, 'other flavour' and 'ham/meat flavour' were inversely related (r = -0.91, P<0.001). Flavour acceptability was also related to smoke flavour (r = 0.79, P<0.05).

Overall acceptability was highly related to the other acceptability ratings, e.g., appearance (r = 0.94, P<0.001), aroma (r = 0.98, P<0.001), texture (r = 0.98, P<0.001) and flavour (r = 0.99, P<0.001). The attributes which most affected overall acceptability were 'other aroma' (r = -0.94, P<0.001), structure r = 0.91, P<0.001) and ham/meat flavour (r = 0.89, P<0.001). From this it appeared the most acceptable hams were those with good ham/meat flavour, fibrous structure and with no 'off' aroma.

Principal Components Analysis

A Principal Components Analysis (PCA) was carried out using the data in the linear correlation matrix of the ham attribute data. This analysis showed that the first three components accounted for 71.2% of the total variance in sensory attribute scores. This was made up of 43.5% for the first, 16.8% for the second and 10.9% for the third. Similarly, for a PCA based on the acceptability ratings, the first three components accounted for 99.0% of the variance with 91.8% for the first, 4.8% for the second and 2.4% for the third. The vector loadings on the first three Principal Component Axes have been listed in Table 4 for the attributes and in Table 5 for the sensory ratings. For the first component of the PCA of the attributes the most significant attributes were homogeneity (textural appearance), meat aroma, smoke flavour and ham/meat flavour contrasted with colour variation, other aroma, structure and other flavour. For the second component, dominant colour, colour variation, smoke aroma, tenderness, homogeneity (structure) and smoke flavour

Table 4

Vector loadings on the first three principal component axes for the sensory attributes

Attribute	Principal Component 1	2	3
Fat content	0.17	0.25	0.34
Homogeneity	-0.33	-0.22	-0.24
Dominant colour	-0.12	0.41	0.02
Colour variation	0.28	0.29	0.27
Smoke aroma	-0.27	0.29	-0.27
Meat aroma	-0.29	-0.18	0.31
Other aroma	0.35	-0.02	-0.19
Tenderness	-0.17	0.45	-0.03
Juiciness	-0.01	0.16	-0.61
Homogeneity-structure	0.23	0.40	0.10
Structure	0.33	0.17	0.10
Smoke flavour	-0.29	0.28	-0.16
Saltiness	-0.11	0.16	0.18
Ham/meat flavour	-0.32	-0.06	0.27
Other flavour	0.34	0.03	-0.18

were the largest contributors. Juiciness had little impact until the third component.

For acceptability ratings (Table 5), all five ratings were almost equally represented in the first component of the corresponding PCA. In the second component, appearance contrasted with flavour and overall acceptability. The third component had texture contrasting with aroma and flavour.

The location of the attributes measured on the 10 hams relative to the first two PCA components (accounting for 60.3% of the total variation) have been plotted (Fig.l). The co-ordinates of each attribute were given by the correlation coefficient with the two components. Also plotted on Fig.l were the positions of the 10 ham samples relative to the same two principal axes. Samples 1, 9, 7 and 5 have better ratings than the other samples, for structure, ham flavour, meat aroma and homogeneity (appearance), as well as having low scores for other aroma and flavour. Sample 3 scored high (i.e. dark) for dominant colour, while 4, 6 and 10 were all pale and had low scores. Tenderness was not a dominant factor but 2, 1, 3, 6 and 8 appeared to be less tender than say 5 and 10.

The PCA plot of the acceptability ratings, in Fig.2, shows that the most acceptable hams were 1, 5, 7 and 9, with 2, 3 and 8 intermediate, and 4, 6 and 10 low. The most acceptable hams were those with high structure (fibrosity) scores with good flavour (ham/meat) and aroma coupled with low 'other flavour', 'other aroma', fat content, and colour variation scores. Hams 1, 5 and 9 had highest flavour scores, while 7 had best appearance acceptability.

Table 5

Vector loadings for the acceptability ratings on the first three principal component axes

Acceptability	Principal Component 1	2	3
Appearance	-0.43	0.81	0.02
Aroma	-0.45	0.12	-0.53
Texture	-0.45	-0.10	0.81
Flavour	-0.45	-0.45	-0.26
Overall	-0.46	-0.34	-0.03

Objective Measurements

The results obtained for pH and the objective measurements of mechanical strength have been listed in Table 6. There was quite a wide range in pH (5.66 to 6.42) between the various types but the only relationship of significance is between pH and the tensile measurements ($r = -0.73$, $P<0.05$). The normal and modified WB shear measurements are highly correlated ($r = 0.87$, $P<0.001$) with each other and with the Instron hardness measurement ($r = 0.71$ and 0.69, respectively at P<0.0 = 05). The two Instron measurements are highly correlated ($r = 0.95$, $P<0.001$) between themselves. From the results shown in Table 6, it can be seen that all the devices were able to discriminate between samples. It is also clear, from the relatively poor relationships between them, that they measure different textural properties.

Correlations between Objective and Sensory Measurements

The pH values are inversely related to tensile strength but, sensorily, they reflect structure/fibrosity ($r = -0.67$, $P<0.005$), ham/meat flavour ($r = -0.73$, $P<0.005$) and 'other flavour' ($r = 0.70$, $P<0.05$). The WB shear, Instron compression and tensile measurements are all related to structure/fibrosity with the tensile showing the best relationship ($r = 0.77$, $P<0.01$). It also appears that tensile force related well to ham/meat flavour ($r = 0.81$, $P<0.01$), but this probably reflected the fact that the more fibrous samples had a better meat flavour.

Moisture content is inversely related to salt content ($r = -0.84$, $P<0.01$), smoke flavour ($r = -0.67$, $P<0.05$) and saltiness (r = -0.71, P<0.05). Fat content relates to appearance factors such as homogeneity (r = 0.71, P<0.05) and colour variation (r = 0.72, P<0.005). Salt content and saltiness are directly related (r = 0.73, P<0.05). The amount of protein relates to the same appearance factors as fat content, viz. homogeneity (r = 0.72, P<0.05) and colour variation (r = 0.68, P<0.05), but with the relationships reversed. Protein content is also related to meat aroma (r = 0.77, P<0.01) and homogeneity of texture (r = -0.70, P<0.05).

Conclusions

The profile derived by the Australian sensory panellists to describe the appearance, aroma, texture, and flavour of ham products differed from the profile derived by English consumers (Nute *et al.*, 1987).

The English panel used 22 description terms or attributes and three acceptability ratings to score for appearance, texture and flavour. The Australian panel required 15 attributes and five acceptability ratings to score for these same characteristics plus aroma.

Of the six appearance attributes listed by the English panel, only three were in the list compiled by the Australian panel, i.e., fatness (equivalent to fat content), uniformity of lean (= homogeneity) and dominant colour. The Australian panel included 'colour variation' in their profile. In attributes of texture, the English panel had eight attributes, compared with four. Of the four, only three were common to both, viz., tenderness, juiciness, and structure (= fibrosity). The local panel had an homogeneity factor,

Table 6

Results obtained for the 10 selected hams using pH measurements and measurements obtained using both WB shear devices, Instron compression and tensile methods

		Mechanical measurements[a]						
		WB		Mod. WB		Compression I		
Ham Number	pH	IY	PF	IY	PF	H	Ch.	Tensile
1	5.66	0.72	1.01	3.22	3.46	1.28	0.43	2.44
2	6.34	0.92	1.25	1.33	2.43	1.27	0.48	0.32
3	6.36	0.39	0.76	1.36	2.15	0.92	0.27	0.36
4	6.27	0.29	0.56	1.08	1.29	1.54	0.56	0.15
5	5.98	1.02	1.55	2.80	4.07	1.43	0.47	0.50
6	6.35	0.54	0.94	1.57	2.07	0.78	0.26	0.13
7	6.32	0.97	1.29	2.55	3.12	1.52	0.42	0.89
8	6.36	1.12	1.60	4.70	5.99	1.83	0.68	0.96
9	6.01	0.70	1.42	3.01	3.35	1.63	0.47	3.05
10	6.42	0.30	0.54	0.60	0.95	0.40	0.12	0.09
LSD	0.13	0.22	0.28	0.50	0.69	0.32	0.12	0.55

[a] All in kgs apart from pH, WB - Warner Bratzler, Mod. W.B. - modified WB, IY - initial yield, PF - peak force, H - hardness and Ch - chewiness

which related to the way the sample broke up on chewing. The flavour attributes were eight versus four with smokiness, ham/meat flavour and softness being common and 'other flavour' being only in the local profile. Thus, there were quite large differences between the two profiles but, using just the first three components, the local profile explained 71.2% of the variation, compared to 60.0% for the English one. The difference was primarily in the first component (43.5% compared with 33.0%). The local profile explained much of the variation between samples and thus appears to be well suited for use in categorising samples of ham, both commercial and those manufactured in the laboratory.

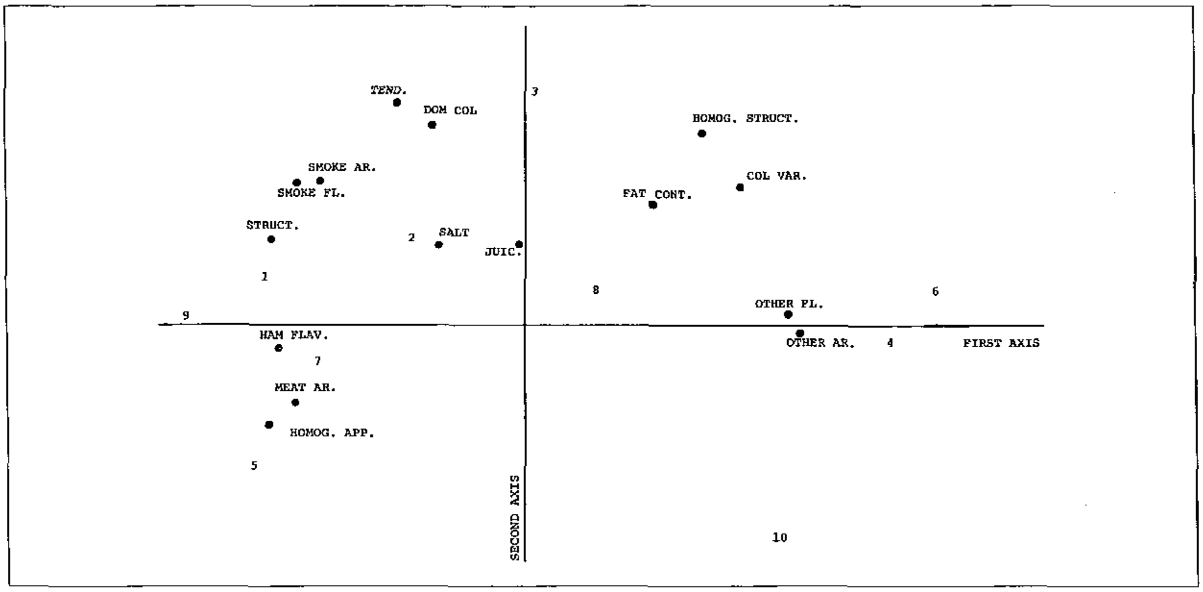
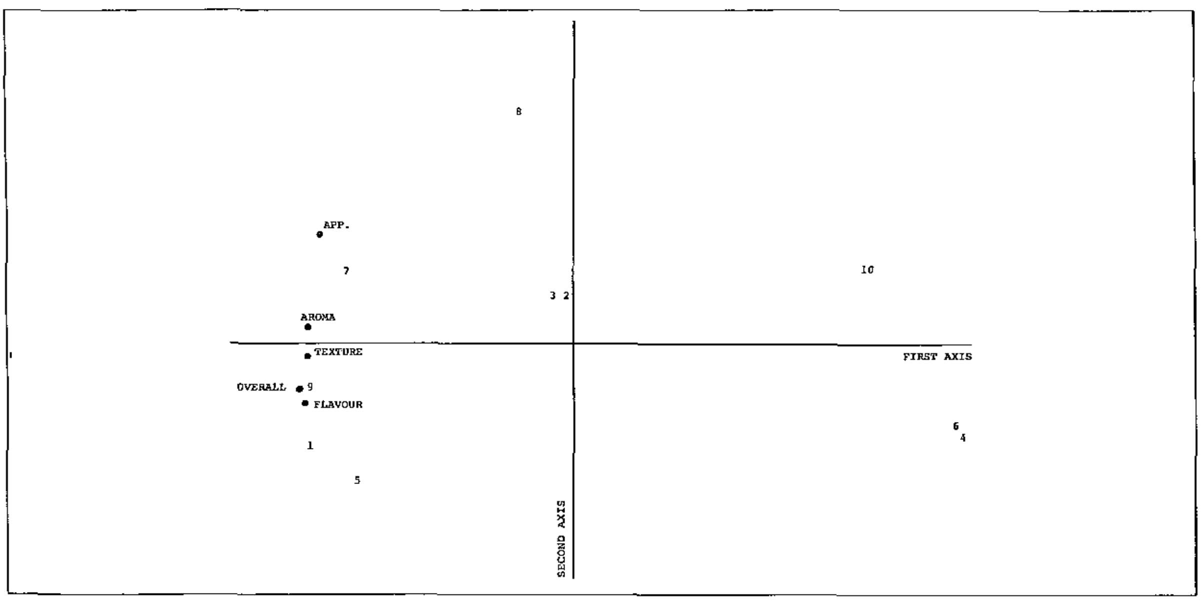


Fig. 1 (above). Scores for the various ham and correlations of the attributes of the sensory profile relative to the first two components of the Principal Components Analysis.

Fig. 2 Scores for the various ham and correlations of the acceptability ratings relative to the first two components of the Principal Components Analysis.



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Oat Bran & Plasma Cholesterol: An Assessment of Recent Evidence

David Oakenfull

CSIRO Division of Food Processing, North Ryde, NSW 2113

During the past couple of years only a hermit could have remained unaware of the claims, both in the scientific and the popular media, that oat bran lowers plasma cholesterol. Are these claims still scientifically justified? They are now being questioned and it is being suggested that oat bran is really no more effective than any other source of dietary fibre in reducing the risk of heart disease.

A recent article in The New England Journal of Medicine (NEJM) (Swain *et al.* 1990) has concluded that 'oat bran has little cholesterol-lowering effect'. So has the oat bran bubble finally burst? The answer appears to be 'no', and for two reasons. Firstly, there are good scientific grounds on which to challenge the way in which the authors of the NEJM article interpret their results. Secondly, in science in general, and particularly in the area of nutrition, a single experiment is not in itself enough to prove a point. The cholesterol-lowering activity of oat bran has been established in a large number of independent experiments; a negative result has been reported once only.

The Experimental Evidence

Experiments with Animals

The cholesterol-lowering activity of oats has been repeatedly demonstrated in numerous independent experiments with animals, particularly chicks and rats (see, for example, Oakenfull 1988). At least six independent trials have been carried out and fully reported in the scientific literature. Additionally, by feeding various oat fractions, it has been possible to show that the active principle is present in the bran (Chen *et al.* 1981).

Experiments with Humans

An experiment carried out as long ago as 1963 (de Groot *et al.*) suggested that daily rolled oats could lower plasma cholesterol in a group of healthy

TABLE 1.

Effects of wheat bran, rice bran and oat bran on plasma lipids, lipoprotein lipids and apoproteins in human volunteers. Means and standard deviations are given. (Inge 1989.)

	Baseline	Wheat Bran	Rice Bran	Oat Bran
Total cholesterol (mM)	6.34^a ±0.84	6.39^a ±1.07	6.27^a ±1.01	6.03^b ±0.87
Ratio of HDL to total cholesterol	0.166^a ±0.046	0.171^a ±0.048	0.175^b ±0.051	0.179^b ±0.049
Ratio of apoprotein AI to apoprotein B	1.29^a ±0.29	1.28^a ±0.28	1.33^b ±0.28	1.34^b ±0.27

^{a,b} In each row, values with different superscripts differ significantly.

TABLE 2.

Mean plasma cholesterol levels (mM) in healthy subjects given either oat bran or a low-fibre dietary supplement. (Swain *et al.* 1990.)

Cholesterol	Baseline*	Oat bran	Low-fibre
Total	4.80 ± 0.80	4.44 ± 0.73	4.46 ± 0.64
HDL†	1.40 ± 0.43	1.40 ± 0.39	1.32 ± 0.39
LDL‡	2.96 ± 0.61	2.69 ± 0.63	2.77 ± 0.59
VLD‡	0.44 ± 0.42	0.34 ± 0.27	0.37 ± 0.29

*Before dietary supplement was given.†High density lipoprotein cholesterol - the 'safe' form. ‡Low density and very low density lipoprotein cholesterol - the forms that are associated with increased risk of heart disease.

men. Since then, a least four well-controlled and independent trials have been carried out with human subjects which have confirmed the cholesterol-lowering effect (Oakenfull 1988). Additionally, a recent comparative study of oat bran, wheat bran and rice bran carried out by the CSIRO Division of Human Nutrition (Inge 1989) confirmed that oat bran could lower plasma cholesterol levels (Table 1). In this study, with a group of 24 men with mildly elevated plasma cholesterol levels, the experimental diets provided 22-23g dietary fibre daily, of which 12g was supplied by the respective bran. The diets were otherwise matched for dietary fibre and also fatty acid content and fatty acid profile. The experiment was conducted in three four-week periods in which the three test brans were allocated to each subject in a predetermined random order. Wheat bran and rice bran had no significant effect on the total plasma cholesterol whereas oat bran gave a useful 5% reduction. Additionally, oat bran (and to a lesser extent rice bran) increased the ratio of HDL-cholesterol to total cholesterol and also the ratio of apoprotein A1 to apoprotein B. There are indications from epidemiological studies, in particular the Framingham study, that these ratios are more powerful predictors of heart disease risk than the total plasma cholesterol (Naito 1987).

The NEJM Study

This study (Swain *et al.* 1990) compared the effects of oat bran (87 g/day) with a low-fibre wheat product on the plasma cholesterol levels in a group of 20 healthy subjects. After six weeks of the experimental diet there were no significant differences between the plasma cholesterol levels in the two groups (Table 2).

Although in most respects this study was well designed and carried out, it has a number of features which make the conclusions questionable.

1. The subjects' mean plasma cholesterol levels were already low before the experimental diet was started - well below the level (5.5 mM) that is associated with an increased risk of heart disease. This means that oat bran or any other dietary means of lowering cholesterol would be most unlikely to lower it much further.

2. Their diets ('baseline' in Table 1) were also very low in fat - 30.6% of energy comp-

ared with the Australian average of 35% of energy. Thus, the single most powerful dietary means of lowering plasma cholesterol, a low fat intake, was already in operation. This again implies that oat bran would be unlikely to lower plasma cholesterol much further.

3. The oat bran group consumed a higher proportion of fat (35.4% energy) than the low-fibre group (30.0% energy). This could have at least partly negated any cholesterol-lowering effect from the oat bran.
4. Most of the experimental group were women (16 out of a total of 20) whereas it is men who are most at risk of heart disease (Moore 1989, Mackerras, 1990).

Thus the evidence from the NEJM study does not justify the conclusion that 'oat bran has little cholesterol-lowering effect'. But it does suggest that people with plasma cholesterol concentrations already low, and with low dietary intakes of fat, do not benefit from supplementing their diets with oat bran.

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A New Technique for Statistical Analysis of Consumer Sensory Evaluation & Market Research Data

D.J. Best

CSIRO, IAPP Biometrics Unit, Food Research Laboratory
PO Box 52, North Ryde, NSW 2113

Introduction

One implication of the increased emphasis within CSIRO on working with industry is the need to be more involved in assessing market acceptance of a variety of products. This assessment can partly be made with sensory evaluation or market research trials.

Such trials seek answers to questions like the following:

- Is it possible to 'feel' the difference between woollen and synthetic sweaters?
- Is brand X fragrance really stronger smelling than brand Y?
- What does a taste-test on two cola drinks prove?

Responses from the public or consumer panellists are likely to involve considerable variation and statistical methodology is useful for optimising experimental design, for objective, quantitative analysis and for summary and presentation.

The widespread availability of mainframe or personal computers means new computer-intensive graphics or methods of analysis can now be used. Some new graphics were described in the CSIRO Food Research News, No. 7 (August, 1989). To give a brief introduction to one of the new analysis methods recently developed, consider the following:

Example
Suppose five products have been rated by consumers using a five point scale where the five points or categories are denoted by 'Awful', 'Not Good', 'OK', 'Like' and 'Terrific'. In consumer — as opposed to 'expert' — panel product comparisons, it sometimes makes sense (because it more closely mimics actual marketplace practice) to get only one evaluation per consumer. For the data in Table 1 from Bradley *et al* (1962) we assume only one response per consumer.

These data can be represented graphically in a number of ways. One simple, but effective, method is a dot plot of the raw percentages, as shown in Figure 1. Careful inspection of Figure 1 or Table 1 might suggest the following:

TABLE 1

Response frequency in a consumer taste-testing experiment

	Response category					
Product	Awful	Not Good	OK	Like	Terrific	Total
A	9	5	9	13	4	40
B	7	3	10	20	4	44
C	14	13	6	7	0	40
D	11	15	3	5	8	42
E	0	2	10	30	2	44
Total	41	38	38	75	18	210

Product E is most liked and the consumers agree on this; Product D produced a mixed response, while Product C was least liked.

One of the aims of a statistical analysis is to objectively quantify comments like these which have been obtained by 'eyeballing' the data. The traditional textbook method of analysis for data such as that in Table 1 would be to calculate as x^2 statistic for a 5x5 contingency table. If this is done it is found that X^2=73.8 on 16 degrees of freedom. This is highly significant, but all it tells us is that there are some, unspecified, differences between products. More detail is required of what are the differences between products is required. Using the formulae in the Appendix we can summarise the data of Table 1 in terms of 'mean' and 'variance' parameters as shown in Table 2.

Product E has the highest 'mean' parameter value and the lowest 'variance' parameter value; Product D has the highest 'variance' parameter value and Product C has the least mean parameter value. Thus, the parameter values confirm and quantify the subjective assessment earlier. Further, the parameter estimates in Table 2 are approximate standard normal N(O,l) deviates so that objective assessment is also possible. For example, the 'mean' parameter for C is much smaller than an N(O,l) deviate is likely to be and so we conclude that Product C is significantly disliked.

A FORTRAN computer programme (available on a floppy disk for an IBM PC or compatible) to perform the statistical analysis discussed above is available from the author and more mathematical details are given in Best *et al* (1990).

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TABLE 2

Product effect parameters

Product	'Mean' Parameter	'Variance' Parameter
A	-0.03	0.38
B	1.51	-0.14
C	-3.96	-0.30
D	-1.70	2.25
E	3.96	-2.15

APPENDIX

Calculation of Mean & Variance Parameters

Suppose the data are in the form of Table 2 where there are c(ordered) columns and r rows. Let a_{ij} be the count in the (i,j)th cell of the data table and let::

$$a_{i.} = \sum_{j=1}^{c} a_{ij},\ a_{.j} = \sum_{i=1}^{r} a_{ij},\ a_{..} = \sum_{i,j} a_{ij}.\ \text{Put } p_j = (a_{.j}/a_{..}) \text{ and}$$

calculate g_1 (j) and g_2 (j)

where $g_1 (j) = A((j-1) - Sl)$ and $g_2 (j) = C((j-1)^2 - A^2 Y(j-l) + Z)$

$$\text{where } S_m = \sum_{j=1}^{c} (j-1)^m p_j,$$

$$A = (S_2 - S^2_1)^{-2},\ Y = S_3 - S_1 S_2,\ Z = A^2 Y S_1 - S_2,$$

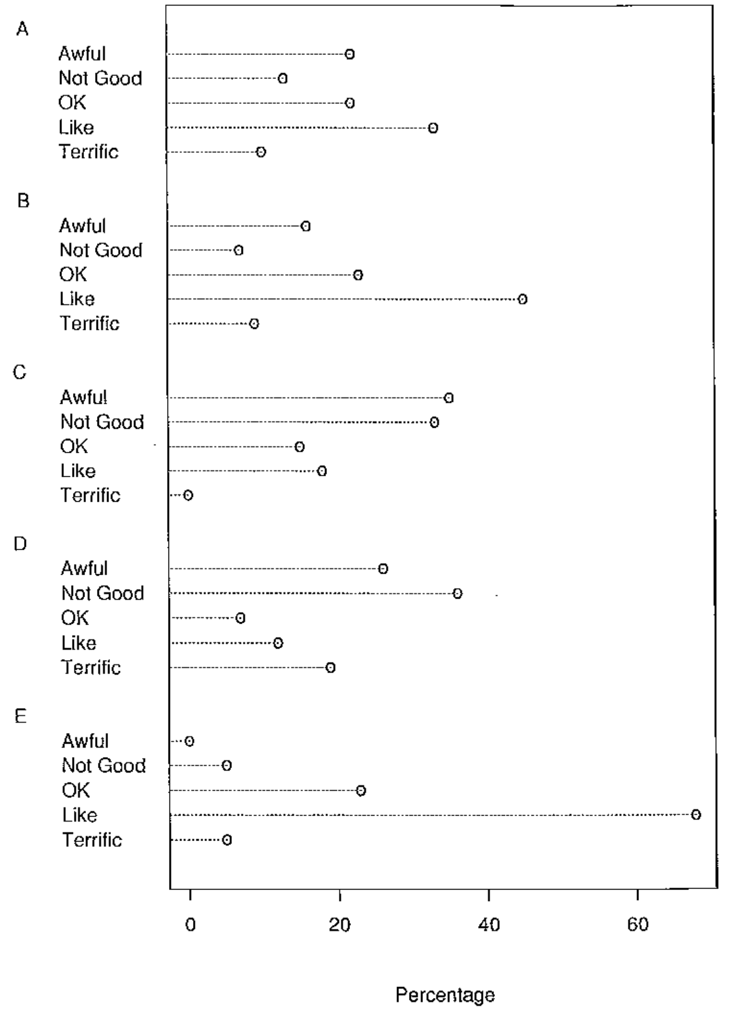
$$C = (S_4 + A^4 Y^2 S_2 + Z^2 - 2A^2 Y S_3 + 2ZS^2 - 2A^2 YZS_1)^{-1/2}.$$

The 'mean' parameter for the ith row is then $a_{i.}^{-1/2} \sum_{j=1}^{c} a_{ij} g_1(j)$

The 'variance' parameter for the ith row is then $a_{i.}^{-1/2} \sum_{j=1}^{c} a_{ij} g_2(j)$

Figure 1

Taste Responses for Products A, B, C, D, E



Opportunities for the Export of Highly Processed Food to Japan

D.J. Walker

Chief, CSIRO Division of Food Processing

The Japan External Trade Organisation (JETRO) is organising a series of study tours for people associated with manufacturing industry from North America, Europe and Oceania. The author was fortunate to be offered an opportunity to join the 3rd Export to Japan Study Program spanning 29 August to 7 September 1990. The program is designed for those who have an opportunity either to directly export because of their personal manufacturing background or who might be able to broadcast widely certain messages about opportunities in Japan.

The composition of the group for the 3rd Study Tour included persons with activities ranging from heavy machinery manufacture to electronics manufacture, software publishing and food manufacturers plus government regulators, journalists and (in the author's case) a research and development specialist.

The superbly organised study tour began with a series of lectures by both Japanese and western expatriates on the following issues:

- Japan's comprehensive import promotion measures.
- The JETRO project for promoting imports from developed countries.
- Case studies of exporting to Japan and advice to newcomers.
- Case studies of Krones (Japan) and SMIS (Japan)—both foreign companies successfully operating in Japan.
- Characteristics of Japanese market distribution systems and points in exporting to Japan (covering examples such as capital goods, machinery and parts, electrical and electronic equipment and parts, and computer software).
- Japanese lifestyle (cultural aspects).
- Import of consumer goods (including furniture and household appliances, fashion apparel and food products and beverages).

This series of lectures gave a good insight into the culture which underlies the Japanese way of doing business and social behaviour. Also included was a strong appreciation of government policy in relation to such matters as employment, protection of certain domestic industries and measures to tackle what is undoubtedly an embarrassing trade surplus. In respect of the latter, government policy is expressed as 'bringing the import and export sectors of the Japanese economy into a harmonious relationship'.

Whilst it is not possible to summarise all that transpired on the Study Tour within the confines of a short article, certain points are well worth recording.

Export Opportunities to Japan

There is no question whatsoever that the Japanese population is both inclined to buy high quality imported manufactured goods and is being urged by its government to do so. Japanese cities have large advertisements exhorting the population to buy imports.

Information provided to the delegates to the JETRO Export to Japan Study Tour showed the relatively rapid decline in manufacturing as part of the total Japanese economy and the concomitant rise in the tertiary sector. Added to this is a very marked shortage of skilled labour in a number of manufacturing industries. Of course, moves by a good many major Japanese corporations to move their manufacturing base offshore means that total Japanese-controlled manufacturing may not be declining in a relative sense as quickly as would appear from purely domestic statistics. Consequently, some imported manufactured goods will certainly continue to be made by Japanese-owned companies.

However, in the processed food sector this does not seem to be a particularly marked trend and in the huge $300 billion food market which is Japan, there has to be a major opportunity for very high quality, very well presented manufactured products.

Facilitation of Export into Japan

JETRO will spend some US$100 million on programs to improve the flow of imports. The program will include the following features:

- Further JETRO-organised export study tours
- The establishment of a products-information database which will define potential markets for imported manufactures and into which foreign companies will be invited to place information on their products. The idea is, of course, to attempt to match *potential products with potential demand in Japan.*
- The sending of buying groups from Japan to small and medium-sized overseas companies with a view to the purchasing of samples of manufactures which, on return to Japan, will be examined for conformity with general standards of Japanese quality requirements and so forth.
- The establishment of a cadre of trade experts in overseas countries. At the present time the proposal is to send 15 to the USA, 1 to Canada, 8 to Europe and only 1 to Oceania. (There is no doubt that this represents the relative economic power residing in each of these regions.).
- Tax incentives for Japanese importers and distributors.
- The establishment of an import loan program. This is for facilitating the setting up of equipment and infrastructure for imported manufactured goods. Loans will be available to foreign companies for this purpose so long as a reasonable proportion of that company's exports go to Japan. We were advised that up to 70% of the funds required can come from this source if all of the exports of the manufacturing company in fact end up in Japan.

Overall this program restresses the strong determination of the Japanese to redress the very large positive balance of trade.

Characteristics of the Japanese Market

Time and again, the immense purchasing power represented *by the Japanese consumer was* stressed to the delegates on the Study Tour.

It is this large and growing purchasing power which is partly responsible for the need to increase imports of manufactures into the country.

It also explains to a great extent the Japanese willingness to pay what we would consider very high prices *provided that the quality* and attractiveness of the goods is adequate.

The Japanese manufacturer's attitude to the consumer is effectively that 'the customer is God'. In satisfying consumer requirements and demand, industry puts great stress on QCDS (Quality, Cost, Delivery *and Service).*

Experience with imported products often shows that faults due to a poor quality control environment at manufacture are responsible for extensive rejections of shipments.

For example, the Study Tour was advised that in one sampling 39% of US processed foods *did not meet analytical standards* required by the Japanese.

Faults included the use of non-permitted food colouring and preservatives, foods which are too highly salted, foods containing poor quality oils, foods containing spices well in excess of that accepted by the Japanese palate and so on.

Special attention also needs to be given to Japanese requirement for the tolerance allowed in stipulating the weight of a product.

A specific presentation on the export of processed foods to Japan concluded with an exhortation that each of the following points must be analysed before the basis for success can be established:

1. Japanese climate
2. History of eating and eating habits
3. The housing situation in Japan
4. The purchasing frequency of the consumer
5. The change in consumer needs
6. The aesthetic sense of the Japanese consumer

In this latter respect, the Japanese consider themselves the most demanding consumers in the world.

A CSIRO Presence

Among other outcomes of the Study Tour, the author has concluded that the potential for a hugely increased export from Australia of processed food to Japan is confirmed. Furthermore, the decision of the CSIRO Division of Food Processing to establish a Sensory Research Group in Tokyo was both timely and wise. This Group, which will study not only the fundamentals of the sensitivity of the Japanese palate, but also assess under contract the acceptability of Australian food products in Japan, is superbly placed to offer some of the most fundamental and important advice that the Australian food processing industry requires.

The author urges any company with the spirit and determination to export to Japan to approach this Division and discover the assistance which can be derived from our body of expertise.

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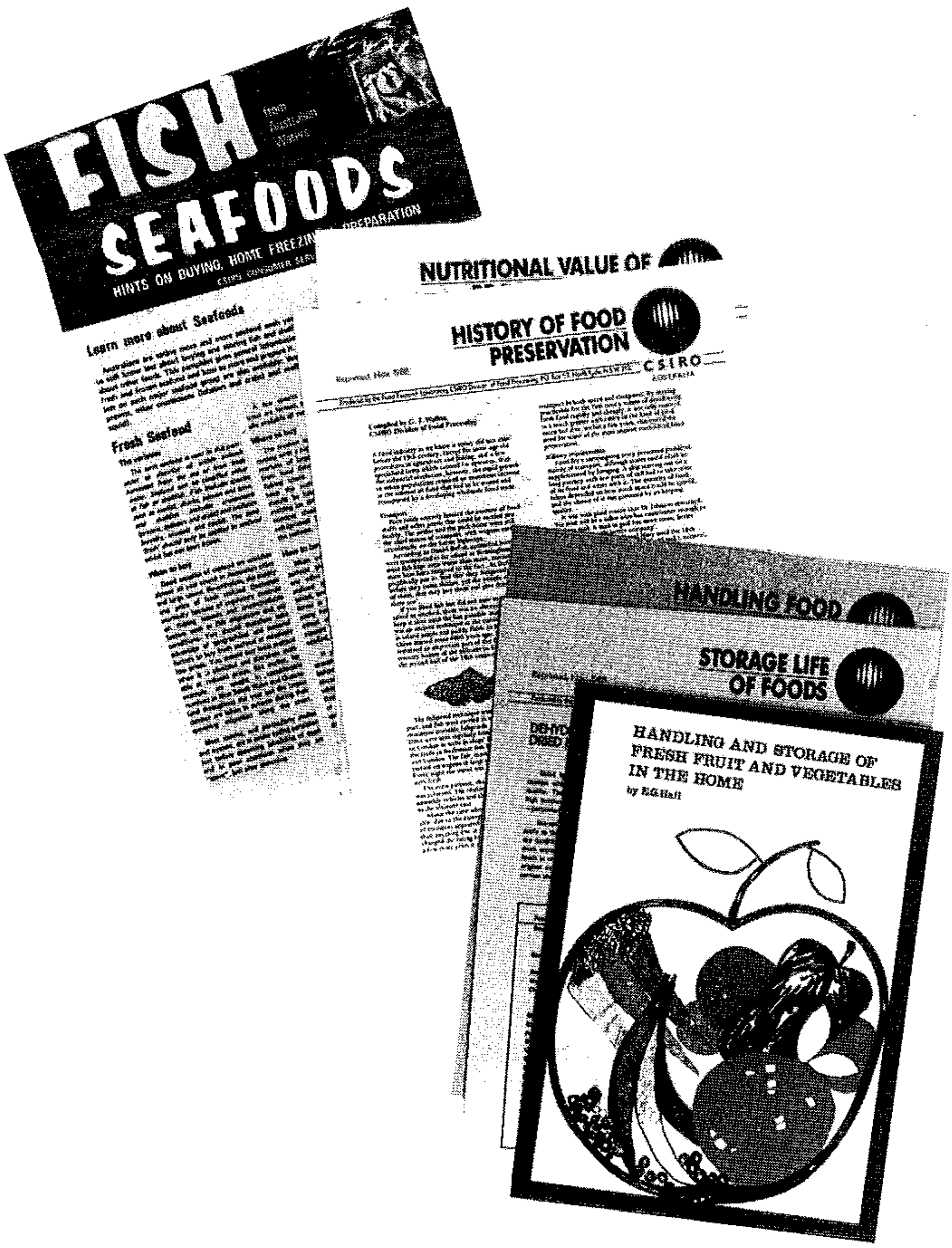

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