Changes in Flesh Lipids and Fill Oils of Albacore (*Thunnus alalunga*) during Canning and Storage

Santiago P. Aubourg, Carmen G. Sotelo, and José M. Gallardo*

Instituto de Investigaciones Marinas del CSIC, Muelle de Bouzas s/n, 36208 Vigo, Spain

Three different parts of the muscle of cooked albacore were canned in soybean oil and stored at room temperature for 11 months. Cans were opened at different times; flesh lipids and fill oils were analyzed for free fatty acid (FFA), sterol (ST), and phospholipid (PL) contents, as well as fatty acid composition. The thermal treatment during the sterilization step produced a decrease in the flesh lipid content and increases in FFA, ST, and PL. Due to canning storage, the lipid content increased significantly after 7–11 months and the FFA and PL amounts decreased. With respect to fatty acid composition, an interaction between the two types of lipids exists. In the flesh lipids a steep increase in fatty acids abundant in fill oil was noticed (18:2, 18:3), and at the same time the characteristic fatty acids of the flesh lipids in fill oil (22:6, 20:5, and others) showed an increase.

Canned fish and other marine species are products of economic importance in many countries. Among the most common species, sardine, herring, albacore, and other tuna fishes, mackerel, anchovy, mussel, etc., can be mentioned (Cheftel and Cheftel, 1976).

It is well-known that the quality of canned products has a very close relationship with their lipid content and composition. Canned fishery products are especially susceptible to flavor and other changes due to the high levels of polyunsaturated fatty acids (Ackman, 1979; Maeda et al., 1985).

Many studies relative to the precooking effect in the quality of the canned product (Slabyj and True, 1978; Joshi and Saralaya, 1982) have been carried out as well as those focusing on the fatty acid and lipid class compositions of canned species (Melva et al., 1982; Hale and Brown, 1983). Changes in quality of canned fish have been investigated as a function of packaging method (Oliveira et al., 1986) and storage temperature (Pirazzoli et al., 1980).

Fatty acid composition of fill oil and flesh muscle and hydrocarbon composition in canned sardines on the Spanish market have been studied by Vall et al. (1983) and Coll et al. (1983), respectively. Nevertheless, there is not enough information about the changes produced from the earlier steps of processing until the end of the canned storage of both fill oil and fish flesh lipids.

In the present work, three different parts of albacore (*Thunnus alalunga*) muscle were separated and canned separately. Lipids of the edible muscle as well as lipids from the fill oil were investigated and compared so as to determine their changes and interactions during canning and storage. Albacore was chosen because of its great commercial significance to the canning industry in northwest Spain.

MATERIALS AND METHODS

Raw Material and Processing. The albacore tuna (*Th. alalunga*) used was caught by a tuna fishing vessel on the Atlantic Ocean (43° N and 27° W) during June 1985. The fish were kept in boxes and transported on ice for 10 days. After arrival to our laboratory, the fish were frozen at −40 °C and stored at −18 °C for 6 months.

Six individual fish were selected. The fish were cooked in our pilot plant according to the following procedure: Whole eviscerated and beheaded fish were cooked (at 102–103 °C) with steam until a final backbone temperature of 65 °C (90 min); the fish were then cooled at room temperature (14 °C) for about 5 h.

After the fish were cleaned, sampling began. The six individual fish were kept in three groups of two; within each group, three different parts of the muscle, known in the commercial literature as back muscle, belly flap muscle, and ventral muscle, were separated. As a result, three batches of each muscle part were obtained for statistical purposes.

Once each batch was homogenized, lipids from these cooked samples were isolated according to the Bligh and Dyer method (1959).

At the same time, portions of 90 g of each homogenized batch were placed in OL-120 cans (105.1 × 64.7 × 28.8 mm) and soybean oil (30 mL) and salt (2 g) added. The cans were vacuum-sealed and sterilized in a retort at 115 °C for 60 min. The cans were stored at room temperature until required for analysis.

From the catch of the fish until the end of processing, the procedure employed in this work simulated the method used in commercial canneries.

Preparation of the Lipid Samples. The cans were opened and analyzed at different times of storage (5 days and 3 and 11 months for the back muscle; 7 months for the belly flap muscle; 3, 7, and 11 months for the ventral muscle).

After the cans were opened, the liquid part was drained off carefully and lipids were extracted from the fish flesh following the Bligh and Dyer method (1959).

The fill oils of the cans were dried with anhydrous Na_2SO_4 and analyzed the same way as the flesh lipid extracts.

Spectrophotometric Methods. The free fatty acid (FFA) content was determined by the Lowry and Tinsley method (1976), based on a complex formation with $(AcO)_2Cu$–pyridine.

Sterols (ST) were determined by the method of Huang et al. (1961), based on the Liebermann and Buchardt reaction.

Phospholipids (PL) were determined according to the method of Raheja et al. (1973), based on a complex formation with ammonium molybdate.

Transesterification of Lipid Extracts and Determination of Fatty Acids. Lipid extracts were transesterified with use of the BF_3–MeOH complex according to Morrison and Smith (1964).

Fatty acid methyl esters (FAME) were analyzed on a Varian Vista 6000 gas chromatograph equipped with a 30-m flexible capillary column with SP-2330 (Supelco) as stationary phase. The operating conditions were isothermal separation at 190 °C, with an injector temperature of 220 °C and detector at 230 °C. Carrier gas used was nitrogen flowing with a linear velocity of

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Table I. Lipid (g/100 g Muscle), Free Fatty Acid, Sterol, and Phospholipid (g/100 g Lipid Extract) Contents[a,b] for the Cooked Samples, Initial Oil, and Canned Samples (Flesh and Oil Considered Separately)[c]

sample		storage time	LC	FFA	ST	PL
BM-C			4.9 ± 0.1	6.2 ± 0.5	1.2 ± 0.1	6.9 ● 0.4
BFM-C			14.0 ± 0.6	3.7 ± 0.3	0.6 ± 0.2	2.3 ± 0.3
VM-C			3.9 ± 0.1	7.4 ± 0.5	1.3 ± 0.1	8.5 ± 0.5
INO				0.1 ± 0.1	0.2 ● 0.1	ND[d]
BM-1	flesh	5 days	1.3 ± 0.1	12.4 ± 0.7	1.9 ± 0.2	13.8 ± 0.8
	oil			0.1 ± 0.1	0.4 ± 0.1	ND
BM-2	flesh	3 months	1.2 ± 0.1	11.9 ± 0.7	2.0 ± 0.2	13.5 ± 0.8
	oil			0.3 ± 0.1	0.4 ± 0.1	ND
BM-3	flesh	11 months	1.7 ± 0.1	8.9 ± 0.6	1.6 ± 0.2	10.5 ± 0.7
	oil			0.3 ± 0.1	0.5 ± 0.1	ND
BFM	flesh	7 months	3.1 ± 0.1	5.0 ± 0.4	0.8 ± 0.1	6.3 ± 0.6
	oil			0.4 ± 0.1	0.5 ± 0.1	ND
VM-1	flesh	3 months	1.6 ± 0.1	9.1 ± 0.6	1.7 ± 0.2	12.4 ± 0.8
	oil			0.5 ± 0.1	0.4 ± 0.1	ND
VM-2	flesh	7 months	2.0 ± 0.1	8.2 ± 0.6	1.5 ± 0.2	8.7 ± 0.6
	oil			0.4 ± 0.1	0.4 ± 0.1	ND
VM-3	flesh	11 months	2.2 ± 0.1	7.4 ± 0.5	1.4 ± 0.2	9.2 ± 0.6
	oil			0.5 ± 0.1	0.5 ± 0.1	ND

[a] Abbreviations: lipid, LC; free fatty acid, FFA; sterol, ST; phospholipid, PL; cooked samples, BM-C, BFM-C, VM-C; initial oil, INO; canned samples, BM-1, BM-2, BM-3, BFM, VM-1, VM-2, VM-3. [b] Mean of three determinations ± standard deviation. [c] Abbreviations used for the three parts of the muscle: BM, back muscle; BFM, belly flap muscle; VM, ventral muscle. [d] ND = not detected.

18 cm/s. The individual FAMEs were identified by comparison of the retention times with those of standard methylic esters mixtures including PUFA no. 1, Marine Source (Supelco), and by semilogarithmic plots of retention times against carbon chain lengths (Ackman, 1969).

RESULTS AND DISCUSSION

The comparison of cooked (BM-C, BFM-C, VM-C) and canned samples (see Table I) shows a general reduction in lipid contents for the latter due to the sterilization and storage steps. The low level showed by sample BM-1 (analyzed after 5 days of storage) indicates that the decrease in lipid contents has been produced during sterilization. For the back and ventral muscles a slight increase during storage is observed, which becomes significant in both muscle parts at the 11th month.

Due to the thermal treatment of sterilization, a high increase in the FFA and PL contents was attained. This is better illustrated by comparing the FFA and PL contents of the samples of a shorter storage time (BM-1, BFM, VM-1) with the content of the cooked samples. During storage, a major decrease in the FFA and PL contents was obtained at the 11th month of storage for the back and ventral muscles.

ST content showed the same tendencies as for the two other groups; but increases during the sterilization step were only significant in the case of the back and the ventral muscles. Furthermore, there were no major reductions in these two parts of the muscle during the canned storage.

For the fill oil composition, values were very low and no significant variations were attained for the FFA and ST contents. PLs were not detected after the sterilization step or the canned storage.

Table II shows the fatty acid compositions from the various muscle parts of cooked flesh fish and the initial oil employed in canning. Fatty acids having a low content (<1.0%) have been grouped as others. Tables III and IV show the fatty acid composition of the canned flesh lipids from the different samples.

In the case of the belly flap muscle, an increase in fatty acids coming from the fill oil (18:2, 18:3) was observed in flesh after sterilization and 7 months of storage; this was accompanied by proportional reductions in other fatty acids (14:0, 16:0, 22:1, 20:5, 22:6).

Table II. Contents (%) of Fatty Acids in the Lipid Extracts of Cooked Samples and in the Initial Oil Employed for Canning[a,b]

FA	BM-C	BFM-C	VM-C	INO
14:0	3.5 ± 0.2	3.6 ± 0.3	3.7 ± 0.3	0.3 ± 0.1
15:0	1.7 ± 0.4	1.5 ± 0.4	1.7 ± 0.2	0.4 ± 0.1
16:0	17.6 ± 0.8	19.2 ± 0.4	18.3 ± 0.6	10.1 ± 0.4
17:0	2.0 ± 0.4	2.1 ± 0.2	1.8 ± 0.4	0.6 ± 0.1
18:0	6.3 ± 0.4	6.4 ± 0.2	6.5 ± 0.5	3.9 ± 0.4
total satd	31.1 ± 1.4	32.8 ± 1.1	32.0 ± 1.3	15.3 ± 1.1
16:1	5.6 ± 0.3	6.2 ± 0.2	5.5 ± 0.4	0.8 ± 0.2
18:1	17.8 ± 0.6	19.7 ± 0.4	18.2 ± 0.4	22.2 ± 0.7
20:1	1.6 ± 0.3	1.8 ± 0.2	1.6 ± 0.2	0.4 ± 0.1
22:1	3.5 ± 0.4	3.7 ± 0.4	3.2 ± 0.4	0.5 ± 0.1
24:1	1.0 ± 0.3	1.1 ± 0.1	0.9 ± 0.2	0.6 ± 0.2
total monounsatd	29.5 ± 1.4	32.5 ± 1.1	29.4 ± 1.3	24.5 ± 1.2
18:2	2.2 ± 0.2	2.1 ± 0.2	2.0 ± 0.2	51.5 ± 1.1
18:3	2.0 ± 0.5	2.2 ± 0.4	1.8 ± 0.4	7.5 ± 0.6
18:4	1.1 ± 0.2	1.0 ± 0.1	1.0 ± 0.3	
20:4	1.4 ± 0.3	1.3 ± 0.2	1.3 ± 0.3	
20:5	5.4 ± 0.4	5.1 ± 0.5	5.2 ± 0.3	
22:5	1.4 ± 0.3	1.3 ± 0.3	1.3 ± 0.3	
22:6	20.0 ± 0.6	15.4 ± 0.6	20.2 ± 0.7	
total polyunsatd	33.5 ± 1.5	28.4 ± 1.4	32.8 ± 1.3	59.0 ± 1.3
others	5.2 ± 0.4	4.9 ± 0.3	4.8 ± 0.4	0.4 ± 0.1

[a] Abbreviations as specified in footnote a, Table I. [b] Mean of three determinations ± standard deviation.

As a result of comparing the cooked samples with the canned ones of a shorter storage time of the back and the ventral muscles (BM-1, VM-1), considerable increases in fatty acids from the fill oil (18:2, 18:3) were observed; fatty acids present in the initial flesh muscle but absent in the fill oil suffered variable reductions in most cases (16:0, 16:1, 20:5, 22:6). During storage, increases in 18:1, 18:2, and 18:3 acids for the back muscle and in 18:2 and 18:3 acids for the ventral muscle were accompanied by a decrease in 22:6 acid.

Tables V and VI show the fatty acid compositions of the fill oils. For the belly flap muscle, there was a migration of fatty acids from the muscle to the fill oil (initial composition in Table II) leading to significant increases in 20:5 and 22:6; at the same time, a major reduction in 18:2 was attained.

Concerning the back muscle and ventral muscle, the same pattern was observed. There has been an interaction between the fish lipids and the fill oil. The most

Table III. Contents (%) of Fatty Acids in the Flesh Lipids of the Canned Back Muscle and the Belly Flap Muscle[a,b]

FA	BM-1	BM-2	BM-3	BFM
14:0	1.7 ± 0.4	1.6 ± 0.2	1.6 ± 0.2	1.9 ± 0.3
15:0	0.6 ± 0.2	0.4 ± 0.2	0.4 ± 0.1	0.8 ± 0.2
16:0	14.6 ± 0.7	15.7 ± 0.6	15.2 ± 0.5	14.6 ± 0.7
17:0	1.1 ± 0.2	1.0 ± 0.2	0.9 ± 0.1	1.2 ± 0.2
18:0	6.0 ± 0.4	6.0 ± 0.4	5.7 ± 0.6	5.4 ± 0.4
total satd	24.0 ± 1.5	24.7 ± 1.5	23.8 ± 1.3	23.9 ± 1.4
16:1	2.9 ± 0.4	3.3 ± 0.4	2.9 ± 0.3	3.9 ± 0.2
18:1	18.0 ± 0.8	18.7 ± 0.7	19.9 ± 0.7	18.9 ± 0.8
20:1	1.7 ± 0.2	1.4 ± 0.2	1.5 ± 0.3	1.9 ± 0.2
22:1	1.7 ± 0.2	1.5 ± 0.2	1.3 ± 0.2	1.6 ± 0.2
24:1	0.8 ± 0.2	0.4 ± 0.1	1.1 ± 0.2	0.4 ± 0.2
total monounsatd	25.1 ± 1.6	25.3 ± 1.5	26.7 ± 1.5	26.7 ± 1.4
18:2	15.5 ± 0.7	18.1 ± 0.7	20.2 ± 0.8	19.5 ± 0.7
18:3	3.3 ± 0.3	3.0 ± 0.3	3.4 ± 0.3	3.5 ± 0.3
18:4	0.6 ± 0.2	0.3 ± 0.2	0.5 ± 0.2	0.7 ± 0.2
20:4	2.4 ± 0.4	1.9 ± 0.3	2.1 ± 0.3	2.3 ± 0.3
20:5	4.2 ± 0.4	3.6 ± 0.3	3.7 ± 0.3	3.2 ± 0.3
22:5	1.6 ± 0.3	1.2 ± 0.2	1.3 ± 0.2	1.1 ± 0.1
22:6	18.1 ± 0.7	16.8 ± 0.6	15.3 ± 0.7	13.1 ± 0.6
total polyunsatd	45.7 ± 1.8	44.9 ± 1.7	46.5 ± 1.7	43.4 ± 1.7
others	4.2 ± 0.3	3.9 ± 0.3	2.8 ± 0.3	5.3 ± 0.4

[a] Abbreviations as specified in footnote a, Table I. [b] Mean of three determinations ± standard deviation.

Table IV. Contents (%) of Fatty Acids in the Flesh Lipids of the Canned Ventral Muscle[a,b]

FA	VM-1	VM-2	VM-3
14:0	1.6 ± 0.2	1.4 ± 0.3	1.3 ± 0.2
15:0	0.6 ± 0.1	0.5 ± 0.1	0.5 ± 0.2
16:0	14.4 ± 0.6	14.7 ± 0.7	14.2 ± 0.6
17:0	1.0 ± 0.2	1.1 ± 0.1	0.9 ± 0.1
18:0	5.7 ± 0.3	5.6 ± 0.3	5.5 ± 0.4
total satd	23.3 ± 1.3	23.3 ± 1.3	22.4 ± 1.3
16:1	3.6 ± 0.3	2.5 ± 0.2	2.5 ± 0.2
18:1	19.5 ± 0.7	20.5 ± 0.8	20.0 ± 0.6
20:1	1.7 ± 0.2	1.1 ± 0.2	1.3 ± 0.1
22:1	1.6 ± 0.3	1.2 ± 0.2	1.2 ± 0.3
24:1	0.2 ± 0.1	0.3 ± 0.1	0.6 ± 0.1
total monounsatd	26.6 ± 1.5	25.6 ± 1.3	25.6 ± 1.3
18:2	20.5 ± 0.7	25.3 ± 0.6	26.3 ± 0.8
18:3	3.5 ± 0.3	4.0 ± 0.2	4.1 ± 0.2
18:4	0.7 ± 0.1	0.4 ± 0.1	0.5 ± 0.1
20:4	1.9 ± 0.2	1.6 ± 0.2	1.4 ± 0.2
20:5	3.3 ± 0.3	2.8 ± 0.2	2.7 ± 0.2
22:5	1.0 ± 0.2	1.0 ± 0.3	0.8 ± 0.2
22:6	14.7 ± 0.6	13.3 ± 0.7	12.2 ± 0.7
total polyunsatd	45.6 ± 1.6	48.4 ± 1.6	48.0 ± 1.6
others	4.0 ± 0.4	2.3 ± 0.3	3.0 ± 0.3

[a] Abbreviations as specified in footnote a, Table I. [b] Mean of three determinations ± standard deviation.

significant changes when the oil samples of a shorter storage time were compared with the initial oil were the reduction of 18:2 in the ventral muscle and the increase of 22:6 in both muscle types. However, during storage unappreciable differences were observed, except for reductions of 22:6 in the back muscle and of 18:2 in the ventral muscle.

Fatty acid contents in the lipid extracts of the cooked samples and in the initial oil (Table II) are compared with all the lipid samples from cans (flesh lipids and oils; Tables III–VI). It can be concluded that the content of polyunsaturated fatty acids was not altered by processing or storage. Similar results were obtained by Giddings and Hill (1975) during processing of blue crab and by Dudek et al. (1981) during processing of atlantic mackerel and socheye salmon.

It is therefore proven that the use of oil as a packing medium has significant effects on the lipid content and

Table V. Contents (%) of Fatty Acids in the Fill Oil Associated to the Flesh of the Canned Back Muscle and the Belly Flap Muscle[a,b]

FA	BM-1	BM-2	BM-3	BFM
14:0	0.2 ± 0.1	0.4 ± 0.1	0.6 ± 0.1	0.5 ± 0.2
15:0	0.1 ± 0.0	0.2 ± 0.1	0.4 ± 0.2	0.3 ± 0.1
16:0	10.6 ± 0.4	10.1 ± 0.3	10.4 ± 0.5	11.0 ± 0.5
17:0	0.3 ± 0.1	0.2 ± 0.1	0.3 ± 0.1	0.5 ± 0.1
18:0	3.9 ± 0.3	3.8 ± 0.4	4.4 ± 0.3	4.1 ± 0.4
total satd	15.1 ± 1.0	14.7 ± 1.1	16.1 ± 1.1	16.4 ± 1.2
16:1	0.3 ± 0.1	0.4 ± 0.1	0.3 ± 0.1	1.3 ± 0.2
18:1	22.8 ± 0.7	21.9 ± 0.6	21.7 ± 0.5	21.9 ± 0.6
20:1	0.4 ± 0.2	0.3 ± 0.1	0.5 ± 0.1	0.6 ± 0.1
22:1	0.5 ± 0.1	1.6 ± 0.2	0.3 ± 0.1	0.4 ± 0.2
24:1				0.2 ± 0.1
total monounsatd	24.0 ± 1.1	24.2 ± 1.0	22.8 ± 1.1	24.4 ± 1.2
18:2	50.8 ± 1.1	51.5 ± 1.0	51.1 ± 1.2	46.0 ± 0.8
18:3	7.4 ± 0.6	7.5 ± 0.7	6.9 ± 0.6	6.9 ± 0.5
18:4				0.3 ± 0.1
20:4		0.5 ± 0.2		0.4 ± 0.1
20:5		0.3 ± 0.1	0.4 ± 0.2	0.8 ± 0.2
22:5				0.2 ± 0.1
22:6	1.4 ± 0.2	0.8 ± 0.1	0.7 ± 0.1	2.3 ± 0.3
total polyunsatd	59.6 ± 1.6	60.6 ± 1.5	59.1 ± 1.5	56.9 ± 1.5
others	0.5 ± 0.1	0.3 ± 0.1	1.6 ± 0.2	1.9 ± 0.3

[a] Abbreviations as specified in footnote a, Table I. [b] Mean of three determinations ± standard deviation.

Table VI. Contents (%) of Fatty Acids in the Fill Oil Associated to the Flesh of the Canned Ventral Muscle[a,b]

FA	VM-1	VM-2	VM-3
14:0	0.3 ± 0.1	0.6 ± 0.1	0.5 ± 0.1
15:0	0.5 ± 0.2		0.6 ± 0.2
16:0	10.8 ± 0.6	10.5 ± 0.4	10.1 ± 0.4
17:0	0.6 ± 0.1		0.2 ± 0.1
18:0	3.9 ± 0.4	4.2 ± 0.3	3.9 ± 0.4
total satd	16.1 ± 1.2	15.3 ± 1.1	15.3 ± 1.2
16:1	0.7 ± 0.2	0.4 ± 0.2	0.4 ± 0.1
18:1	21.9 ± 0.6	22.7 ± 0.6	21.2 ± 0.6
20:1	0.6 ± 0.2	0.5 ± 0.2	0.4 ± 0.1
22:1	0.4 ± 0.1	0.3 ± 0.1	0.5 ± 0.1
24:1	0.5 ± 0.2		0.7 ± 0.2
total monounsatd	24.1 ± 1.2	23.9 ± 1.1	23.2 ± 1.1
18:2	48.8 ± 0.9	51.6 ± 1.2	51.0 ± 1.2
18:3	8.1 ± 0.6	7.9 ± 0.7	7.6 ± 0.6
20:4	0.3 ± 0.1		
20:5	0.3 ± 0.1		0.3 ± 0.1
22:5	0.3 ± 0.1		0.5 ± 0.1
22:6	1.0 ± 0.2	0.5 ± 0.1	0.6 ± 0.2
total polyunsatd	58.8 ± 1.4	60.0 ± 1.4	60.0 ± 1.5
others	0.9 ± 0.2	0.4 ± 0.1	0.8 ± 0.2

[a] Abbreviations as specified in footnote a, Table I. [b] Mean of three determinations ± standard deviation.

fatty acid profile of the final product. These interactions are manifested by an interchange of lipid molecules as well as the fatty acids attached to these lipids.

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Effect of Germination on the Physical, Chemical, and Sensory Characteristics of Cowpea Products: Flour, Paste, and Akara

Ifendu A. Nnanna,[†] R. Dixon Phillips,*[,‡] Kay H. McWatters,[‡] and Y.-C. Hung[‡]

Department of Food Science and Technology, University of Georgia College of Agriculture, Agricultural Experiment Station, Georgia Station, Griffin, Georgia 30223-1797

Physicochemical and sensory characteristics of products made from cowpeas that were ungerminated (UN) or germinated at 25 or 30 °C for 24 h (G25 and G30, respectively) were assessed. Nitrogen solubilities of UN, G25, and G30 were similar. Electrophoresis revealed minor changes in proteins due to germination. Pastes of G25 or G30 had higher flow consistency (n) and apparent viscosity and possessed better frying characteristics than paste of UN. Germination increased the hardness, elasticity, gumminess, and chewiness of akara (fried cowpea paste) but did not affect cohesiveness. The derived instrumental color function (ΔH) was higher for G25 and G30 flour and akara than for UN products. Among sensory measurements, germination significantly improved the crust color of akara but slightly reduced the ratings for moistness, tenderness, and flavor. Overall acceptability was not reduced by germination.

Cowpea (*Vigna unguiculata*) flour is the principal ingredient in preparing akara (fried cowpea paste), which is popular in West Africa (Dovlo, 1976). Traditionally, cowpea paste is prepared by a manual process that is time-consuming and labor intensive. Technology for producing a ready-to-use flour, intended to reduce labor and encourage expanded cowpea usage, has been developed and is being implemented (Ngoddy et al., 1986; McWatters et al., 1988). Such flour can be directly hydrated to paste.

Germination, which increases the activity and synthesis of hydrolytic enzymes, has been applied to legume seeds to reduce the levels of flatulence-inducing oligosaccharides (Nnanna and Phillips, 1988). This process may also modify the functionality of protein and starch in food systems, depending upon the duration and temperature of germination (Hsu et al., 1982). It is reasonable to expect that the functional behavior of cowpea flour is controlled by the properties of its polymeric components, protein and starch, and further, that these com-

[†] Affiliated with the Department of Nutrition and Food Science, Wayne State University, Detroit, MI.
[‡] Affiliated with the Department of Food Science and Technology, University of Georgia Experiment Station, Griffin, GA.

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