DEHYDRATED FOODS

Chemical and Histological Properties Of Dehydrated Meat

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Studies on commercially dehydrated meat produced prior to and during World War II are reviewed. More recent work has investigated some of the basic histological and histochemical changes that occur during dehydration and rehydration of beef muscle tissue. When slices of raw beef were dehydrated at 65° C. under vacuum or at 70° C. in air there were a reduction in muscle fiber diameter, disappearance of longitudinal striations, a decrease in distinctness of cross striations, "merging" of individual muscle fibers, and movement of potassium to the periphery of muscle fibers. The dehydrated slices did not rehydrate satisfactorily. Meat precooked at 140°, 170°, and 200° F. and then dehydrated gave similar products. Frozen-dried meat rehydrated satisfactorily to a condition almost indistinguishable from that of fresh raw meat. If the frozen-dried product remains stable under adverse storage conditions, it may be feasible to freeze-dry raw steaks and chops on a commercial basis.

From the theoretical standpoint, meat, like other food products, should be preserved effectively by dehydration. This method of preservation becomes particularly desirable when the maximum amount of food must be transported and stored under adverse conditions. Consequently, interest in dehydrated meat (and other dehydrated foods) has been greatest in times of national strife, and dehydrated meat was extensively investigated immediately prior to and during World War II. Since the end of the war only a very limited amount of study has been devoted to the product. This paper reviews briefly the chemical and histological studies made on dehydrated meat during the past 15 years.

Criteria for Satisfactory Dehydrated Meat

Before discussing the properties of dehydrated meat it is perhaps well to define the characteristics that are necessary if the product is to be considered acceptable.

1. The meat must be an acceptable food—that is, the dehydrated product must rehydrate readily to a food which has no undesirable odor or flavor; it should resemble very closely the original fresh product in all organoleptic characteristics.

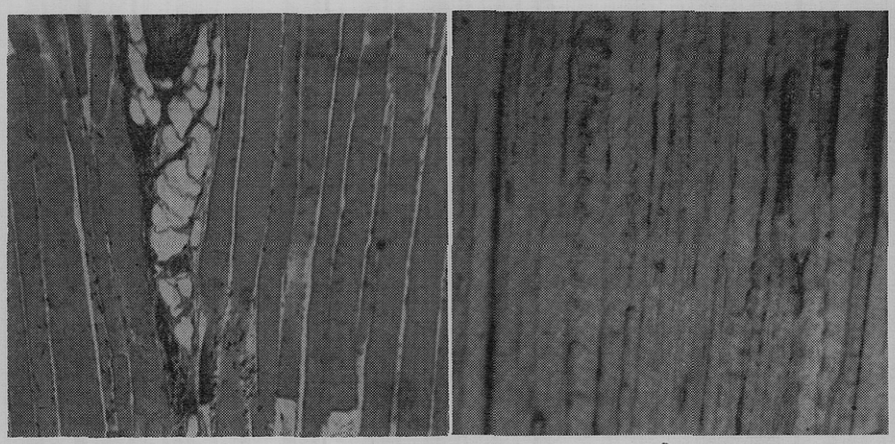
2. The dehydrated meat should retain most of the essential nutritive elements present in fresh meat.

3. The product must be stable for considerable periods of time under adverse storage conditions. No undesirable odors or flavors should develop on storage and there should be little or no loss of essential nutrients.

4. For certain specialized uses (arctic rations) the dehydrated meat should be an acceptable, palatable, nutritious food without rehydration.

Dehydrated Meat Products Of World War II

The commercially dehydrated meats produced prior to and during World War II fulfilled many, but not all, of the requirements listed above. Naturally, the characteristics of the dehydrated meat products depended to a considerable extent upon the methods used for dehydration. These have been outlined by Kraybill (*11*), Hankins *et al.* (*7*), Dunker *et al.* (*5*), and Bate-Smith (*1*). Regardless of the method used, the best products were obtained by cooking, grinding, and drying as rapidly as possible at temperatures below 70° C. Small particle size, low (165° to 212° F.) precooking temperatures, and low fat content contributed to rapid drying and high rehydratability of the dehydrated prod-



A B

Figure 1. Longitudinal sections (×75) of raw (A) and dehydrated (B) *Biceps femoris* muscle

From Wang *et al.* (19)

uct. However, Hankins and Hetzer (*9*) reported that the most satisfactory dehydrated meat reabsorbed water only to the extent of 60 grams per 100 grams of dried meat under their rehydration conditions (1 hour at 28° to 30° C.). Bate-Smith *et al.* (*3*) reported higher reabsorption values, but their conditions for the determination were somewhat less critical. It may be safely stated that none of the precooked, ground, dehydrated beef or pork produced commercially during World War II would rehydrate to the moisture level of the precooked meat.

Despite this, however, the freshly dehydrated products after reconstitution and cooking were satisfactory foods. Bate-Smith *et al.* (*2*) stated that such products were practically indistinguishable from cooked fresh minced meat. Data presented by workers in this country (*4*) were not quite so favorable from this standpoint.

The gross chemical composition of meat on a moisture-free basis (beef, pork, mutton) was apparently little changed by dehydration. Hankins *et al.* (*8*) reported that dehydrated pork contained less fat and more protein than calculatd from the composition of the raw meat. This was apparently due to mechanical loss of fat during processing. Macara (*14*) reported analyses of a considerable number of dried meat samples, and proposed a method for calculating the raw meat equivalent of dried meat from the fat and moisture content of the dried sample. His data indicated that there was little loss of any of the gross chemical constituents during dehydration if the cooking liquors were reincorporated in the dried product. When precooking was carried out under pressure, soluble phosphorus and noncoaguable nitrogen in the final product were increased. Grau (*6*) found that the loss of water-soluble nitrogen compounds during dehydration increased with higher drying temperature. He attributed loss of flavor during dehydration to conversion of these water-soluble compounds to insoluble compounds.

From a nutritive standpoint the only significant loss during dehydration of meat was in thiamine and pantothenic acid (*1, 4, 16, 18,*). Biological value and digestibility of the protein were not adversely affected by dehydration of meat (*1, 10*).

The storage of dehydrated meat produced prior to and during World War II usually resulted in loss of palatability (particularly flavor) and thiamine (*13, 15, 17, 21*). Deterioration in storage was greater at higher temperatures and higher moisture content and in the presence of oxygen. Thiamine retention was improved by the incorporation of cereal products in the dehydrated meat (*15, 17*). Although dried meat stored in the presence of a plentiful supply of oxygen absorbed relatively large amounts of oxygen and rapidly became rancid (*13*), particularly at low moisture content and high temperature, dehydrated meat stored in airtight containers did not become rancid (*12, 13*) even after several months at room temperature and above. Although oxygen was absorbed and carbon dioxide formed by stored dehydrated meat, no aldehydes or α-carbonyl groups were formed during storage and, in airtight containers, the peroxide value of the fat did not increase (*12*). Thus, it would appear that flavor deterioration during storage of dehydrated meat in airtight containers is not due to the development of oxidative fat rancidity. As the amount of soluble nitrogen and the amount of free α-amino nitrogen increased greatly in samples of dried meat stored at 135° F. for 6 months (*12*), it may be postulated that flavor deterioration in storage is associated with changes in the protein fraction of dehydrated meat.

Recent Studies on Dehydrated Meat

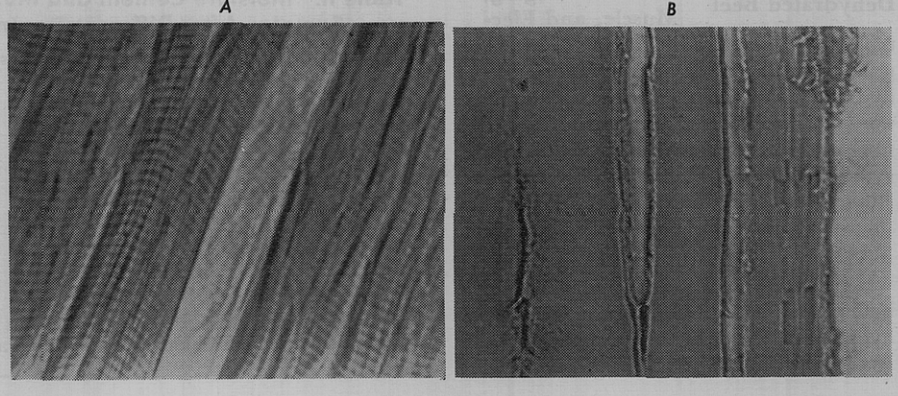
Careful study of the researches on dehydrated meat reported above points out several important considerations: The only satisfactory type of dehydrated meat products produced commercially are those prepared by precooking, mincing, and dehydrating (experimentally satisfactory dehydrated raw meat has been prepared by freezer-drying (*4*). Although these products could be rehydrated and used in any dish that would normally contain ground fresh meat, rehydration characteristics were far from ideal; there were appreciable losses of certain nutrients and flavor during processing and storage of the dehydrated product.

The importance of dehydrated meat as an item in military rations and for civilian consumption would be greatly enhanced if steaks, chops, etc., could be dehydrated satisfactorily, stored under adverse conditions for long periods without appreciable loss of nutrients or flavor, and rehydrated to a condition nearly identical with that of fresh undried meat. Basic information on the structural and chemical changes occurring during dehydration was needed before the technological production of such products could be undertaken. The authors began such investigations in 1950 and the research is still in progress.

Materials and Methods. Most of the techniques used in this study have been described (*19, 20*). Slices (ca. $2\frac{1}{2} \times 1 \times \frac{1}{4}$ inches) or cylinders (2 inches × $\frac{1}{2}$-inch diameter) of beef muscle tissue were dehydrated at 70° C.

Figure 2. Longitudinal sections (×730) of raw (A) and dehydrated (B) *Biceps femoris*

Showing change in potassium location as result of dehydration. Potassium appears as dark staining areas. From Wang *et al.* (19)



A B

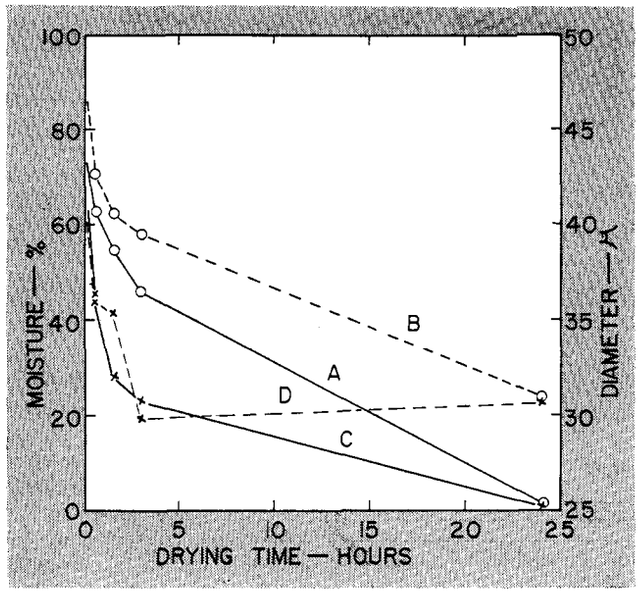


Figure 3. Progressive change in moisture content (——) and muscle fiber diameter (– – –) in raw (A and B) and precooked (C and D) transverse slices of *Biceps femoris* dehydrated at 70° C.
From Wang *et al.* (19)

in a mechanical convection air oven, at 65° C. under 25 inches of mercury or more vacuum, or frozen-dried in a laboratory lyophilizer after being frozen at ca. −80° C. In some experiments the meat was precooked before dehydration. Some samples were electrolyzed to remove inorganic cations prior to dehydration.

Preliminary Experiments (19). When slices of raw *Biceps femoris* were dehydrated at 70° C. in an air oven, there was a reduction of muscle fiber diameter, disappearance of longitudinal striations, decrease in the distinctness of cross striations in muscle fibers, and "merging" of individual muscle fibers (Figure 1). Similar changes were observed in meat dehydrated at 65° C. under vacuum and in precooked meat dehydrated at either 65° C. under vacuum or 70° C. in air. During dehydration potassium moved to the periphery of the muscle fibers (Figure 2). Moisture loss and reduction in muscle fiber diameter were parallel during the dehydration of raw meat, but muscle fiber shrinkage was comparatively more rapid than moisture loss during the early stages of dehydration of precooked *Biceps femoris* (Figure 3). In no case did the dehydrated samples absorb appreciable amounts of moisture when held in water at 70° C. for 15 minutes.

Properties of Dehydrated Beef

Influence of Carcass Grade, Aging, Muscle, and Electrolysis Pretreatment (20). Carcass grade and extent of aging prior to dehydration had no significant effects on the moisture relationships or muscle fiber diameter of dehydrated (at 70° C.) raw *Biceps femoris* and *Rectus femoris* (Figure 4). The histological organization of the dehydrated meat was similar to that reported above. If the raw meat was subjected to electrolysis prior to dehydration, the dehydrated product rehydrated to a very high degree (Table I). In a few cases with the *Rectus femoris* muscle the muscle fibers actually returned to essentially their original normal condition with muscle fiber diameter, cross striations, and nuclei and connective tissue elements similar to those in undehydrated raw meat (Figure 5). Potassium (and probably other soluble inorganic ions) was essentially absent from this tissue and the acidity was increased from the normal pH 5.5 to pH 2.8.

Influence of Precooking. Cylinders ($^1/_2$-inch diameter) of *Biceps femoris* from a commercial grade carcass were precooked to internal temperatures of 140°, 170°, and 200° F. in a beef tallow bath and dried for 16 hours at 45° C. under vacuum and at 70° C. in an air oven. Duplicate cylinders were electrolyzed after precooking and prior to dehydration. The nonelectrolyzed samples dehydrated to 15 to 25% moisture and rehydrated to 25 to 35% moisture in water at room temperature for 30 minutes. The electrolyzed samples dehydrated to a lower level and rehydrated to a moisture content of 45 to 65%. Cooking in larger blocks (300 to 400 grams) and then removing the cylinders for subsequent treatment gave results similar to those obtained for precooked cylinders, except that the samples dehydrated to a lower moisture content. Although differences were not great, the data indicated that precooking at 170° F. followed by dehydration at 70° C. gave the better product from the standpoints of low moisture content of the dehydrated product, the extent of rehydration of the dehydrated product, and the increase in muscle fiber diameter with rehydration. There was some loss of potassium during cooking, but in general the same potassium distribution pattern was present in the cooked samples as in the raw samples studied previously. The data do not indicate any marked advantages for dehydrating cooked meat rather than raw meat.

Properties of Frozen-Dried Meat

Slices of raw meat frozen at −80° C. and then dried in a laboratory lyophilizer under a vacuum of 10 to 100 microns of mercury were almost completely dehydrated in 9 hours. The meat rehydrated rapidly to the original moisture content and in gross physical characteristics was almost indistinguishable from fresh raw meat. Similar results were obtained when meat was removed from the

Table I. Moisture Content and Muscle Fiber Diameter of *Rectus femoris* from Unaged Carcasses of Different Grades

(From Wang *et al.* (20))

	Carcass Grade					
	Prime		Good		Commercial Cow	
	Moisture, %	Fiber diameter, microns	Moisture, %	Fiber diameter, microns	Moisture, %	Fiber diameter, microns
Raw, untreated	71.3	33.7	75.4	36.7	73.6	38.8
Electrolyzed	72.2	38.2	79.0	35.9	76.2	46.1
Dehydrated	−12.1[a]	21.3	−35.0[a]	23.6	−19.0[a]	29.0
Rehydrated	60.6	25.2	81.1	28.3	78.0	35.4

[a] Negative values probably are result of solids loss during electrolysis treatment.

Table II. Moisture Content and Muscle Fiber Diameter of *Biceps femoris* Samples After Different Treatments Involving Freeze-Drying

(10 or more samples for each treatment)

Treatment	Moisture, %	Fiber Diameter	
		Core, μ	Periphery, μ
1. None	73.7	35.2–37.8	35.2–37.8
2. 3 hours freeze-drying	7.7–37.0	34.9–36.6	21.5–25.0
3. 3 hours freeze-drying, 3 hours at 45° C.	−4.3[a]–6.5	22.8–31.1	20.7–24.5
4. 9 hours freeze-drying	−5.5[a]–4.0	. . .	23.7–26.5
5. Rehydrated (3)	49.3–71.4	28.0–34.2	32.1–37.8
6. Rehydrated (4)	59.1–62.1	. . .	33.1–40.4

[a] Negative values indicate greater weight loss than that obtained on duplicate sample ground and dried for 16 hours at 65° under vacuum.

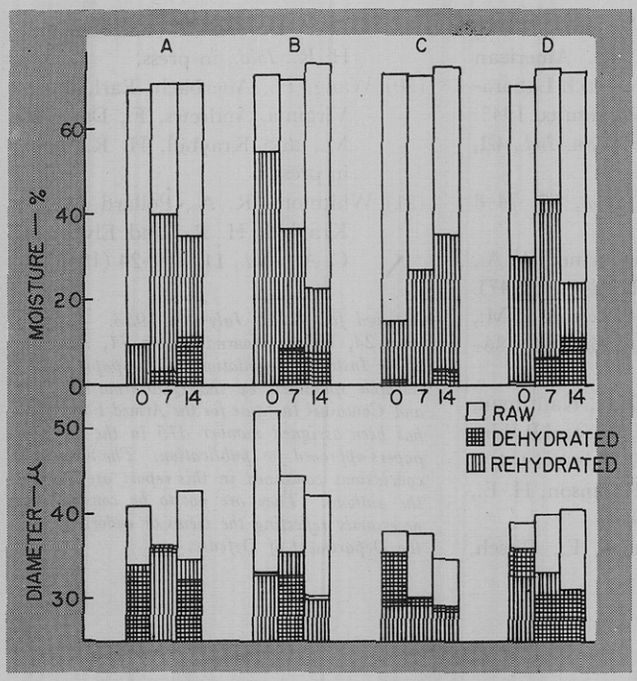


Figure 4. Moisture content and fiber diameter changes during dehydration and rehydration of slices of *Biceps femoris* from heavy U. S. prime (*A*), heavy U. S. good (*B*), light U. S. good (*C*), and U. S. commercial cow (*D*) carcasses after 0, 7, and 14 days' aging

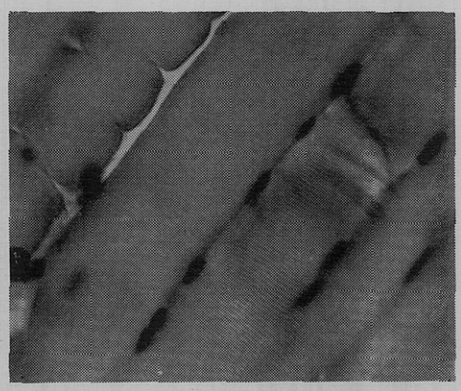


Figure 5. Longitudinal section (×590) of a rehydrated slice of *Rectus femoris* muscle subjected to electrolysis prior to dehydration

Note distinct cross striations and dark-staining nuclei

lyophilizer after 3 hours and drying completed under vacuum at 45° C. for 6 hours. Muscle fiber diameter changes paralleled the moisture changes closely (Table II), which shows that the meat dried by either technique reconstituted in the true sense. The histological organization of frozen-dried raw beef was somewhat different from that of undried raw meat, but after reconstitution the two were almost identical (Figure 6). The potassium distribution pattern for frozen-dried and for frozen-dried reconstituted samples was indistinguishable from that in fresh undried beef muscle, which indicates that no movement of inorganic salts occurred during moisture removal from the frozen state.

If further experiments confirm these preliminary results, and if the frozen-dried product proves stable under adverse conditions, it may be feasible to freeze-dry raw steaks and chops on a commercial basis.

Summary

Commercially dehydrated meat produced prior to and during World War II was a fairly satisfactory food. There was some loss of thiamine and pantothenic acid during dehydration and the flavor was somewhat impaired by dehydration. The biological value of the protein was not significantly affected. During storage in airtight containers there was further loss of thiamine and development of undesirable flavors. Only cooked ground dehydrated meat was produced.

To develop necessary fundamental information needed before satisfactory dehydrated steaks or chops can be produced, the authors have investigated some of the basic histological and histochemical changes that occur during dehydration and rehydration of beef muscle tissue. When the slices of raw meat were dehydrated at 65° C. under vacuum or at 70° C. in air there was a reduction in muscle fiber diameter, disappearance of longitudinal striations, a decrease in distinctness of cross striations, "merging" of individual muscle fibers, and movement of potassium to the periphery of the muscle fibers. The dehydrated samples did not rehydrate to any appreciable extent.

Carcass grade and the extent of aging the meat prior to dehydration had little effect on the moisture relationships or muscle fiber diameter of raw *Biceps femoris* and *Rectus femoris*. Electrolysis prior to dehydration resulted in a dehydrated product that rehydrated to a very high degree. In a few cases the muscle fibers of electrolyzed *Rectus femoris* muscle returned essentially to their original normal condition after rehydration.

Beef precooked at 140°, 170°, and 200° F. in a beef tallow bath and then dehydrated at 70° C. in air or at 45° C. under vacuum gave results similar to those obtained with raw meat as far as histological characteristics and moisture relationships are concerned.

Slices of raw meat that had been completely frozen-dried, or partially frozen-dried and then dried at 45° C. under vacuum, could be almost completely rehydrated and exhibited almost complete return to the normal histological organization. No movement of potassium occurred during moisture removal from the frozen state or during reconstitution of frozen-dried samples.

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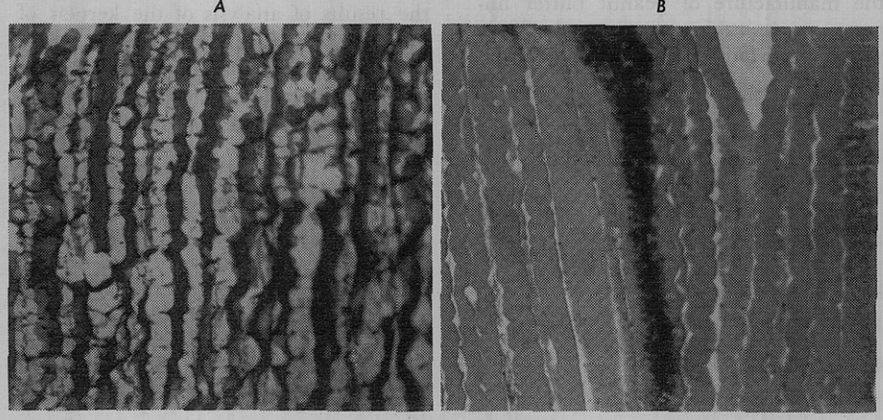
Figure 6. Longitudinal sections (×75) of frozen-dried (*A*) and reconstituted (*B*) *Biceps femoris*

Note shriveled condition of muscle fibers in dehydrated sample but nearly normal condition of rehydrated sample



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PEANUT COMPOSITION

Relation to Processing and Utilization

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The chemical composition of peanut kernels, hearts, and skins is reviewed in relation to the processing and edible use of peanuts. The changes that may occur as a result of roasting include volatilization, degradation, and chemical interactions, some of which contribute to the improvement of the flavor and aroma of peanut products.

PEANUTS ARE AN EXCELLENT SOURCE of food, oil, and protein. The roasting process employed in preparing them for use as salted and roasted nuts, in candies and bakery products, and in the manufacture of peanut butter imparts a desirable aroma and flavor which contribute to consumer acceptance. A thorough knowledge of the composition and characteristics of the constituents of the peanut kernel is basic to improving the quality of peanut products for edible uses.

The kernel consists of two cotyledons and the heart (germ) enveloped in a thin skin (testa). These portions of the kernel differ markedly in chemical composition.

Composition of Kernels

The literature reports a large number of analyses of kernels. The ranges and average values of the constituents tabulated in Table I are the results of the work of a number of investigators (*15, 23, 39, 41, 42, 44, 57, 65, 67*). The average of the results of analysis of the kernels of Spanish, Runner, and Virginia peanuts from the 1942 domestic crop (*67*) are given in Table II. These data indicate that on a dry basis peanut kernels contain approximately 50% oil and nearly 30% protein.

Like most edible vegetable oils, the oil of peanuts consists of the glycerides of long-chain fatty acids. As shown in Table III (*24, 25, 30, 66*), the fatty acids present include oleic, linoleic, palmitic, stearic, arachidic, behenic, and lignoceric.

The phosphatides, lecithin, and cephalin (*19, 23*), occur in the sludge which settles out of the crude oil. Though the peanut oil phosphatides have not been thoroughly investigated, Rewald (*55*)

Table I. Composition of Peanut Kernels

Constituent	Range, %	Average, %
Moisture	3.9–13.2	5.0
Protein	21.0–36.4	28.5
Lipides	35.8–54.2	47.5
Crude fiber	1.2– 4.3	2.8
Nitrogen-free extract	6.0–24.9	13.3
Ash	1.8– 3.1	2.9
Reducing sugars	0.1– 0.3	0.2
Disaccharide sugar	1.9– 5.2	4.5
Starch	1.0– 5.3	4.0
Pentosans	2.2– 2.7	2.5