NEW INFORMATION ON THE CHEMICAL, PHYSICAL AND BIOLOGICAL PROPERTIES OF DRY BEANS

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INTRODUCTION

Basic studies on the physical, chemical and biological properties of dry beans during the past 15 years (1-5, 8, 12) have been indispensable to the evolution of a new process for preparing dry beans as human food; and the generation of a series of more acceptable products from commercial varieties of legumes (6, 7, 9-11). One dividend of the basic work has been the accumulation of new knowledge relevant to a variety of problems concerned with bean processing.

Chemical studies on whole dry, raw water-soaked, and processed quick-cooking beans, as well as their cooked counterparts, established a rational basis for improving bean processing methods and at the same time provided data on bean nutrients and nutritional properties. The latter data will be useful in preparing to comply with new FDA recommendations for nutritional labeling.

Visual and scanning electron microscopy have been employed to determine the influences of soaking, processing and cooking on the morphology of cells in large Lima bean cotyledons. Critical changes in cotyledon proteins, during processing and cooking, have been characterized by polyacrylamide gel electrophoresis. Electrophoretic characterization of bean proteins promises to provide a completely new basis for distinguishing closely related legume varieties. Only a fraction of a single seed may be used to distinguish hybrid strains and thereby conceivably minimize the need for seasonal agronomic evaluations.

Animal studies have shown that the protein quality of different bean types may vary over a relatively broad range. Improvements in the protein quality of bean products has been accomplished by supplementation with animal proteins containing higher proportions of methionine. Several highly acceptable protein-enriched bean products have been developed by blending precooked, quick-cooking beans with small amounts of meat and cheese. These formulations have been used in the preparation of low cost frozen and/or canned casseroles especially suitable for School Lunch programs.

Integration of the results of various basic studies has been directly responsible for the evolution of a new generation of more convenient, more wholesome, more economical and more acceptable foods prepared from dry beans. Physical, chemical and biological evaluations of quick-cooking products compared with beans prepared in the conventional way, have shown that no deleterious effects are induced during processing. In addition, the processed, cooked products have a more uniform texture, an enhanced natural flavor, improved appearance, at least equal protein quality, and lower flatulence activity.

Within the present text, it is not possible to present complete detailed comparisons between standard and quick-cooking beans. However, examples will serve to illustrate the practical rewards derived directly from basic investigations.

PHYSICAL PROPERTIES

The scanning electron microscope has been employed to study the influence of cooking on the morphology of individual cells in the cotyledons of large Lima bean preparations (12). A consistent sequence of physical changes occurred during cooking of both standard and quick-cooking beans. However, the primary difference between the two types of bean products was the rate at which these changes occur. The standard beans required more than six times as long to cook although there were no major, apparent differences in physical characteristics of the heated cells (Fig. 1). On the basis of these and related optical microscopy studies, the cooking process was characterized, for the first time, as dispersion of the middle lamella which separates adjacent cells, accompanied by denaturation of proteins and gelatinization of starch granules within individual whole bean cells.

Disc gel electrophoresis studies have been conducted on the proteins extracted from raw, dry standard, water-soaked and processed (salt-soaked) large Lima and blackeye beans. Gel electrophoresis patterns of these products have shown that salt solution, used to process quick-cooking beans, has a pronounced effect on bean proteins. Dry beans and standard water-soaked beans had identical electrophoretic patterns. However, a clear difference was observed between water-soaked and quick-cooking beans. In addition, it was been demonstrated that cooking modifies, similarly, the proteins in both standard and quick-cooking beans (Fig. 2). These studies corroborate the microscopy investigations which suggested that both types of cooked beans were essentially identical.

CHEMICAL PROPERTIES

The chemical properties of beans are of interest for several reasons. Analytical values provide nutrient and nutritional data which relate to recent proposals by the Food and Drug Administration for nutritional labeling. Analytical data are also useful to dieticians and home economists in preparing general and special purpose menus. Our interest in the chemical properties of dry beans has been based on the need for data comparing the composition of standard bean products with those prepared from quick-cooking beans.

The proximate composition of raw, dry large Lima beans, garbanzo, pink and blackeye beans are presented in Table 1. The apparent protein content (N X 6.25) of different bean varieties ranged from 18% to 26%. Raw garbanzo beans contained about five times as much fat as the other three varieties. There were no apparent differences in protein content of analogous pairs of cooked standard and quick-cooking beans (Table 2). Slightly higher ash values were found in the cooked, quick-cooking beans than in beans prepared in the usual way. More detailed studies on the mineral composition of both types of cooked beans indicated that quick-cooking beans contained slightly higher levels of sodium chloride (salt). The increased salt content, acting as a flavor potentiator, may be responsible for the enhanced natural flavor of the cooked, processed beans. Variations were also noted in the phosphorous, calcium and magnesium content of raw, dry large Lima, blackeye, pink and garbanzo beans (Table 3). Only minor differences in these elements were found in cooked samples of standard and quick-cooking beans (Table 4).

BIOLOGICAL PROPERTIES

The nutritional quality of bean protein is an important factor in the use of dry beans and other legumes for food. The Protein Efficiency Ratio (PER) is an accepted, although somewhat arbitrary, measure of protein quality. The milk protein, casein, is generally used as a primary standard and assigned a PER value of 2.5. It is well known that raw beans do not promote growth of weanling rats used in PER studies. For unknown reasons, heat treatment employed in cooking rehydrated beans, is required to activate nutritional properties. PER estimations conducted on samples of standard and quick-cooking large Lima beans indicated that both types of cooked products had PER values of about 1.9 (Table 5). Cooked Lima bean protein was only about 75% as effective as casein for promoting growth of young rats, whereas the uncooked preparation did not permit the animals to grow and survive. Small, but probably significant differences in PER values were observed for other varieties of cooked beans (Table 6). However, there were no apparent differences between the PER values obtained for cooked standard and quick-cooking samples of pink, blackeye and garbanzo beans.

Supplementation of large Lima beans with specific, small amounts of animal proteins, such as meat and cheese, blended into a highly acceptable food product, raised the PER level significantly (Table 7).

Gastrointestinal distress and flatulence due to the formation of intestinal gases, presumably of microbiological origin, is a major defect which opposes more extensive utilization of dry bean products for food. Previous studies on the flatulence activity of large Lima beans, using both human and microbiological assay techniques, indicated that cooked, drained quick-cooking beans had only about half the activity of standard beans combined with their own cook water (9). These studies suggested that the cook water contained a significant portion of the flatulence activity and that a larger proportion of the activity was extracted into the cook water from quick-cooking beans than from standard beans.

In order to establish the utility of the Rat Hydrogen technique for estimating flatulence activity (2), samples of several varieties of cooked, drained standard and quick-cooking beans were evaluated for apparent flatulence activity. Individual values, obtained in each of two or three replicate assays of each sample, were highly variable. However, it was of interest that the average value found for each of the samples of quick-cooking beans was lower than the average value obtained from analogous samples of standard beans (Table 8). In general, the assays suggested that the quick-cooking beans contained only about 80% of the apparent flatulence activity of standard beans. These results are consistent with the results obtained for similar samples using a microbiological assay technique (9).

CONCLUSIONS

The close relationship between basic studies on the physical, chemical and biological properties of dry beans and the development of new and improved process and products, clearly illustrates the urgent need for continuation, if not acceleration, of basic investigations on all dry bean varieties. In addition to the immediate and direct benefits of basic research, the bank of basic knowledge which accumulates provides a platform for further work on the utilization of dry beans.

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TABLE 1

PROXIMATE ANALYSES OF RAW DRY BEANS[a]

Name		Protein[b]	Lipid	Fiber	Ash	Carbohydrate[c]
Common	Scientific	%	%	%	%	%
Garbanzo	_C. arietinum_	18.3	7.8	3.3	3.0	67.6
Large Lima	_P. lunatus_	20.9	1.3	5.9	6.6	63.6
Blackeye	_V. sinensis_	24.9	1.6	3.2	3.7	66.6
Pink	_P. vulgaris_	26.4	1.6	4.6	4.5	62.9

[a] Calculated to a moisture free basis

[b] Nitrogen x 6.25

[c] By difference

TABLE 2

PROXIMATE ANALYSES OF STANDARD AND QUICK-COOKING BEANS[a]

Variety	Type	Protein[b] %	Lipid %	Fiber %	Ash %	Carbohydrate[c] %
Large Lima	Standard	20.8	1.9	7.4	4.9	65.0
	Quick-cooking	20.4	1.5	5.9	5.3	64.9
Blackeye	Standard	25.4	2.2	3.5	2.8	66.1
	Quick-cooking	24.7	2.4	3.6	4.4	64.9
Pink	Standard	26.6	1.7	4.7	3.8	63.2
	Quick-cooking	26.5	1.6	4.9	4.0	63.0

[a] Cooked, drained beans. Calculated to a dry weight basis

[b] Nitrogen x 6.25

[c] By difference

TABLE 3

MINERALS IN RAW DRY BEANS[a]

Variety	Phosphorous mg %	Calcium mg %	Magnesium mg %	Iron mg %	Copper mg %
Garbanzo	340	140	120	7	2
Large Lima	410	60	180	3	2
Blackeye	530	70	220	10	2
Pink	610	120	230	7	2

[a] Calculated to a dry weight basis

TABLE 4

MINERALS IN STANDARD AND QUICK-COOKING BEANS[a]

Variety	Type	Phosphorous mg %	Calcium mg %	Magnesium mg %	Iron mg %
Large Lima	Standard	370	40	150	9
	Quick-cooking	450	30	120	8
Blackeye	Standard	510	60	170	6
	Quick-cooking	640	40	170	6
Pink	Standard	530	100	150	8
	Quick-cooking	530	100	120	10

[a] Cooked, drained beans. Calculated to a dry weight basis.

TABLE 5

PROTEIN QUALITY

OF

CALIFORNIA LARGE DRY LIMA BEANS[a]

Condition	Protein Efficiency Ratio[b]	
	Raw	Cooked
Water-soaked	0.00	1.83
Quick-cooking	0.00	1.91

[a] Ventura, SCFS
[b] Relative to casein (2.50)

TABLE 6

PROTEIN QUALITY OF WATER-SOAKED AND QUICK-COOKING

CALIFORNIA DRY BEAN VARIETIES

Variety	Protein Efficiency Ratio[a]	
	Water-Soaked	Quick-Cooking
Pinto	1.2	1.3
Pink, Sutter	1.2	1.2
Blackeye	1.5	1.5
Large Lima, Ventura	1.5	1.5

[a] Cooked beans relative to casein (2.50)

TABLE 7

EFFECTS OF NATURAL SUPPLEMENTS ON PROTEIN QUALITY OF QUICK-COOKING LARGE DRY LIMA BEANS[a]

Condition	Material	Protein Efficiency Ration	Digestibility, %	
			Whole Diet	Nitrogen
Raw	Lima Beans	0.00	83	
Cooked	Lima Beans	1.4	90	76
Cooked	Lima-meat casserole	2.1	96	92
Cooked	Lima-meat casserole + milk protein	2.5	96	92
Control	Casein	2.5	96	92

[a] Ventura variety, UCD, 1971

TABLE 8

AVERAGE RELATIVE RAT HYDROGEN PRODUCTION

WATER-SOAKED VS QUICK-COOKING

COOKED, DRAINED BEANS

Variety	Water-soaked	Quick-cooking	Ration QC/WS
Blackeye	.83	.78	.94
Pink	.87	.60	.69
Lima, large	.87	.72	.82
Pinto	.80	.56	.70
Average	.84	.67	.79

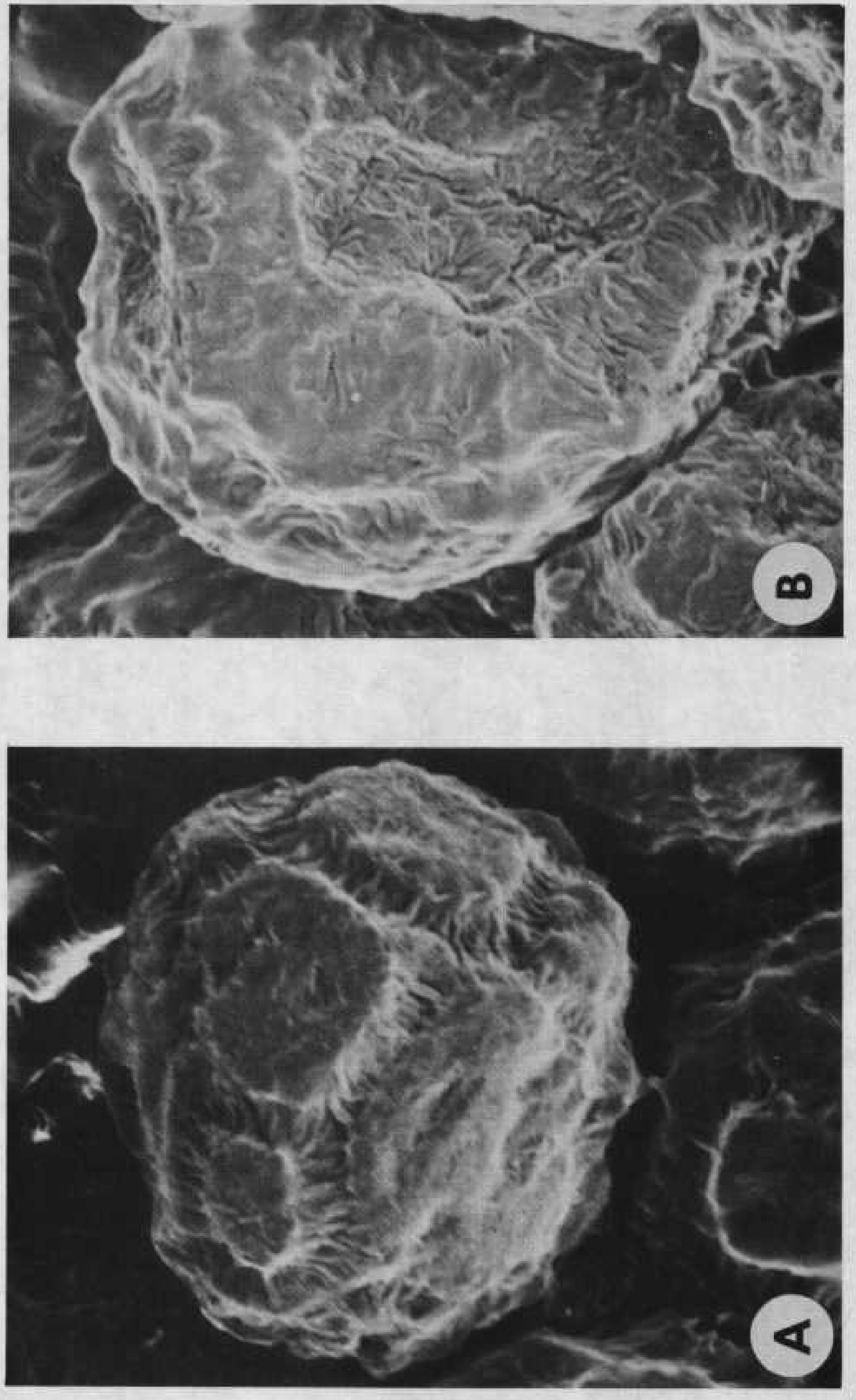
Gumbmann, April, 1973 (unpublished data).

FIGURES

1. Scanning electron photomicrographs of cooked bean cells in cotyledons of (A) water-soaked and (B) salt-soaked, quick-cooking large dry Lima beans.

2. Polyacrylamide gel disc electrophoresis patterns of proteins in dry beans:

   A. Raw, water-soaked large Lima beans.
   B. Raw, salt-soaked, quick-cooking large Lima beans.
   C. Cooked, water-soaked or salt-soaked, quick-cooking large Lima beans.
   D. Raw, water-soaked, blackeye beans.
   E. Raw, salt-soaked, quick-cooking blackeye beans.
   F. Cooked, water-soaked or salt-soaked, quick-cooking blackeye beans.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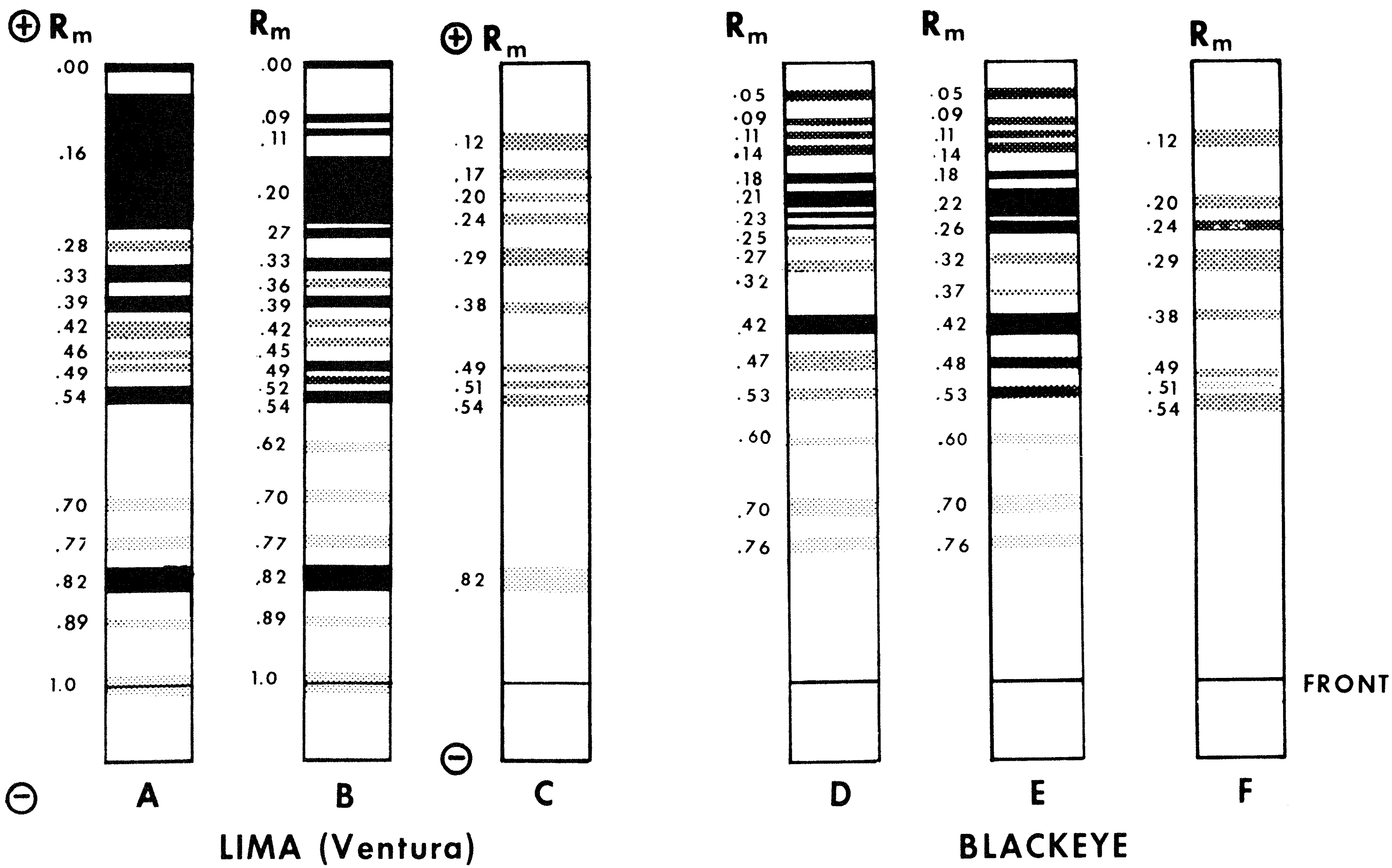
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