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Research needs to up-grade the nutritional quality of common beans (Phaseolus vulgaris)*

RICARDO BRESSANI

Division of Food and Agricultural Sciences, Institute of Nutrition of Central America and Panama (INCAP), Guatemala, C.A.

Abstract. Beans are important sources of nutrients in diets based on cereal grains and starchy foods. The paper reviews briefly some of the factors of nutritional importance which are relatively well defined and which may serve as a basis for recommendations for further study and for establishing nutritional objectives for breeding.

Introduction

Common beans constitute the main source of supplementary protein to the cereal and starchy food diets of large segments of the Latin American population [1]. Their nutritional value is, therefore, of the greatest importance, particularly in view of the fact that consumption is relatively low and less than desirable, particularly for those population groups requiring more and better balanced diets [2, 3, 4].

This paper will review briefly some of the available information on factors in common beans which have direct or indirect nutritional relevance, and which are relatively well established to serve as the basis of recommendations for further research.

Table 1 presents some of the principal well known nutritional characteristics of common beans. These have been divided for purposes of this document into positive and limiting factors. The positive factors are their high protein and lysine content and their excellent nutritional supplementary effect to cereal grains [5]. The limiting factors include those of a physical nature which are of importance in determining acceptability by the consumer [6]; and the antiphysiological and nutritional factors which are of importance in relation to the more efficient biological utilization of the nutrients in beans [5]. The significance of those factors will be expanded in the following Tables and Figures. The basis for the positive nutritional factors in beans is shown in Figure 1. Protein content in beans average about 24% with a reported range of 19 to 31%. The lysine content averages 464 mg/g N with values ranging from 207 to 607 mg/g N.

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Table 1. Principal nutritional characteristics of common beans (Phaseolus vulgaris)

1. Positive factors:
   a. High protein content
   b. High lysine content
   c. Excellent supplementary protein to cereal grains
2. Limiting factors
   a. Physical factors
      a.1 Hard-to-cook
   b. Antiphysiological substances
      b.1 Trypsin inhibitors
      b.2 Hemagglutinins
      b.3 Polyphenolic compounds
      b.4 Flatulence factors
      b.5 Phytic acid
   c. Nutritional factors
      c.1 Sulfur amino acid deficiency
      c.2 Low protein digestibility

Bressani, 1981.

The effect of these two factors is evident in the results, shown graphically in Figure 1, on the protein quality of various mixtures between beans and corn. As reported before, there is a significant complementary effect for the 70/30 mixture by weight, due to the lysine contribution of bean protein to corn and the methionine contribution of corn to beans [7]. As far as we know, very little use has been made of this finding in applied nutrition programs.

Among the limiting factors, the first to be discussed is shown in Figure 2 for physical factors, of which the hard-to-cook condition is of practical significance [8, 9]. This condition becomes more important as beans are stored and is characterized by a slow water absorption process, increased cooking time, development of off-flavor and other physical, chemical and structural changes still not well established [10, 11, 12].

The effect of storage time on hardness in beans and its effect on cooking time is shown on the left of Figure 1. In this particular case, red colored beans were stored for 0, 3, and 9 months at 35 °C and 80% Relative Humidity. Hardness was measured by cooking beans at atmospheric pressure in water added in a 1 to 3 bean to water ratio. Samples withdrawn at the specified times were assayed for hardness using an Instron Texturometer and values expressed as g-force. A value of around 90 g-force was chosen as the hardness acceptable by consumers, shown in the Figures as the horizontal line [13].

As shown, cooking time for the same hardness increases with storage time. This condition is probably dependent on the structural characteristics and chemical composition of the variety, the effects of storage conditions, and possible interactions between these factors [14, 15, 16, 17]. The resistance of hard beans to cooking has three important considerations. First, hardness implies significant economic losses of beans because consumers do not purchase them, and often they have to be used for animal feeding or

POSITIVE NUTRITIONAL FACTORS OF COMMON BEANS

A. High protein content: Ave. 24o/o Range: 19-31o/o

B. High lysine content: Ave. 464 mg/g N Range: 207-607 mg/g N

C. Excellent supplementary protein to cereal grains

Example: Corn/beans

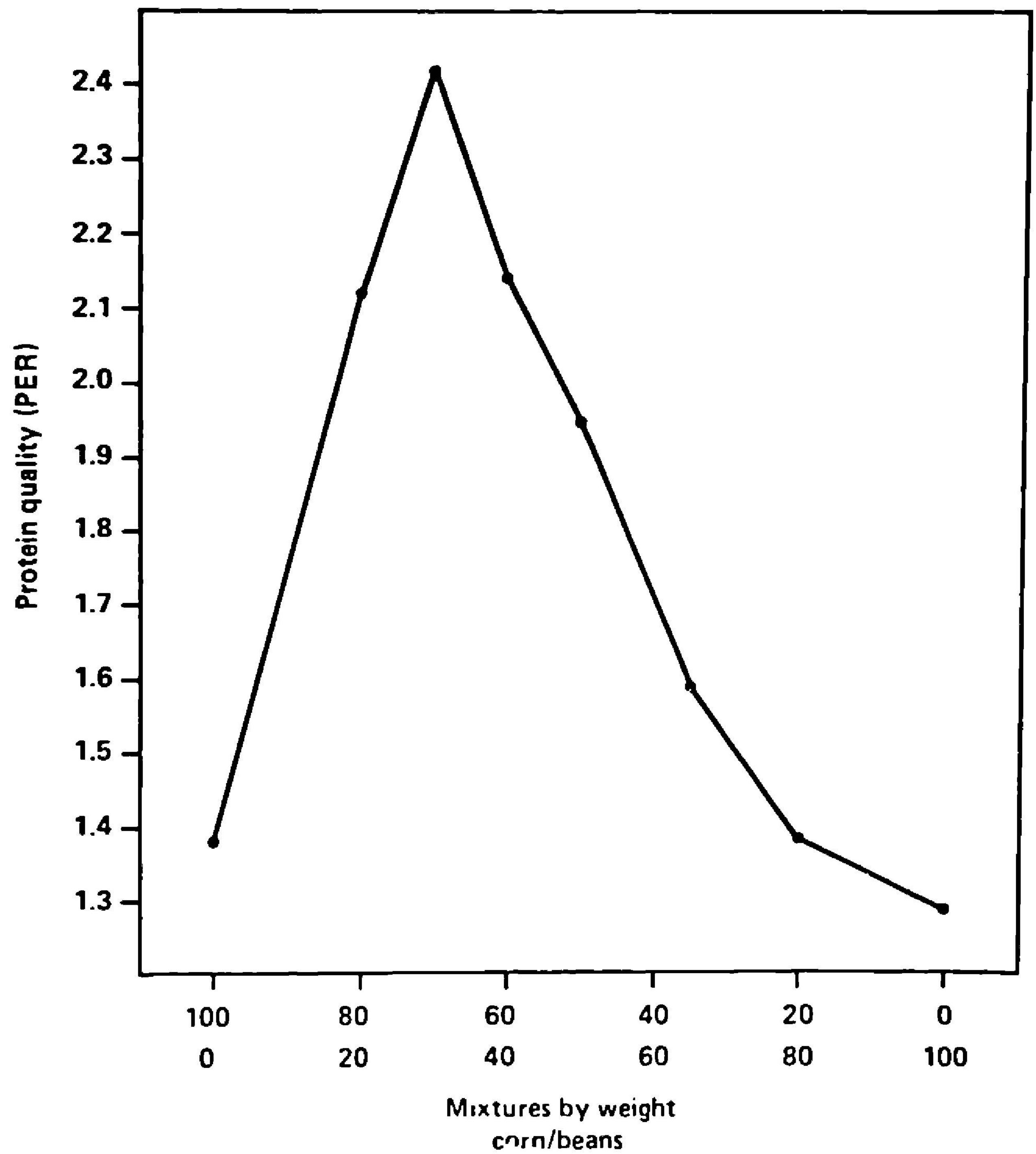


Figure 1. Positive nutritional factors of common beans. A. High protein content: Ave. 24%. Range: 19–31%. B. High lysine content: Ave. 464 mg/gN. Range: 207–607 mg/gN. C. Excellent supplementary protein to cereal grains.

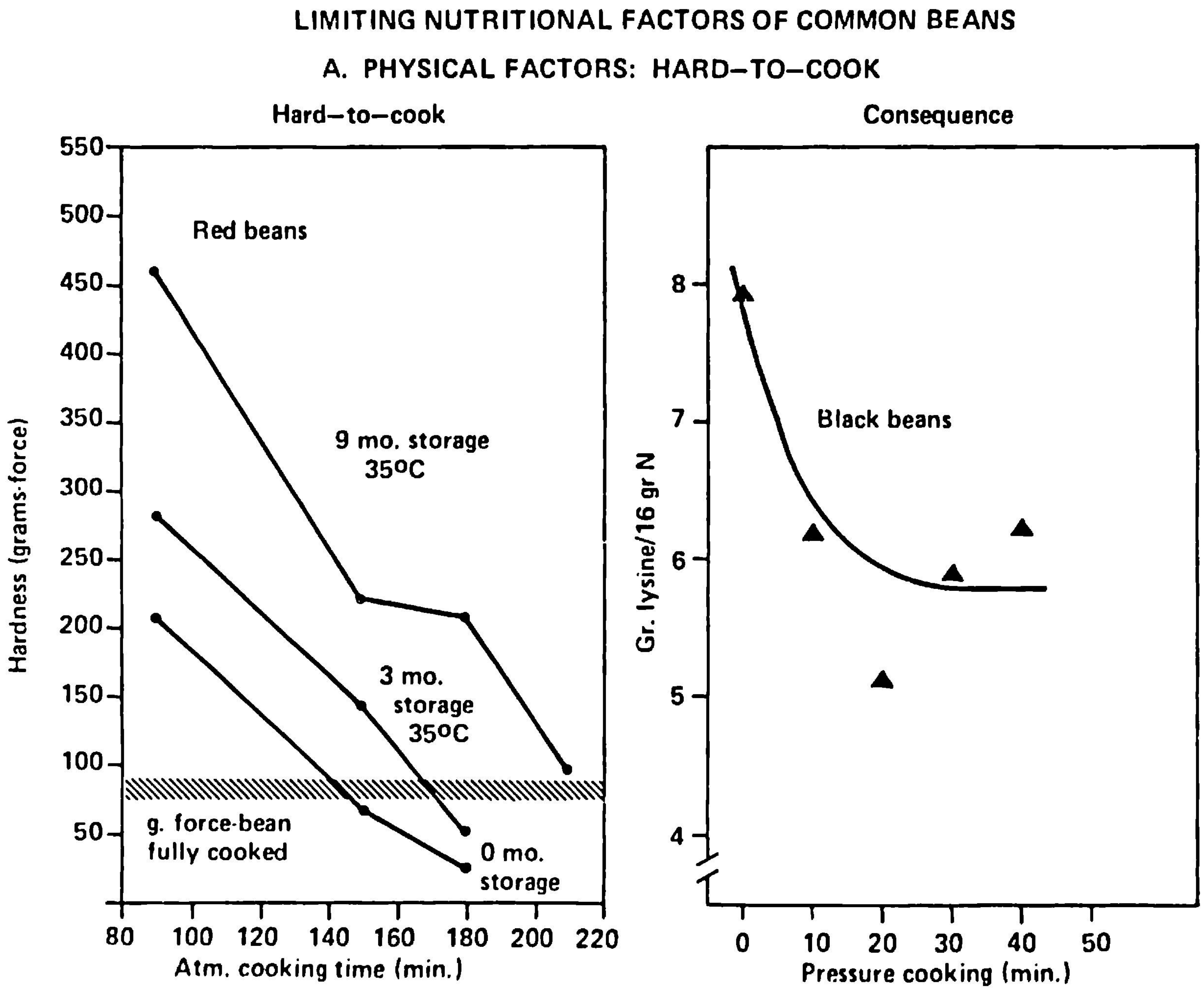


Figure 2. The effect of hardness in beans developed through storage on cooking time and available lysine.

otherwise destroyed. Secondly, hardness implies higher cooking time with higher expenditures of fuel energy, a factor of economic importance to the consumer, particularly for those using wood for cooking. Furthermore, if cooking time is excessive, it causes a decrease in the protein quality of beans and therefore in the supplementary effect to cereal grain, as suggested by the loss of lysine shown in Figure 1 where available lysine was plotted against cooking time, for cooking conducted at 15 pounds pressure and 121 °C [18], although loss of lysine is much less pronounced when cooking is carried out at atmospheric pressure.

With respect to other limiting factors, the presence of antiphysiological substances in common beans has been known for some time. Much attention has been given to the trypsin inhibitors, lectins and the flatulence factors and more recently to the polyphenolic compounds [19, 20, 21]. On the graph in the left side of Figure 3, the changes in trypsin inhibitors, hemagglutinins, and polyphenolic compounds with respect to cooking time at atmospheric pressure are shown. In this case, 500 g of black coated beans were placed in 1500 cc of boiling water and small samples were withdrawn at specific times, freeze-dried and chemically analyzed. Neither trypsin inhibitors nor hemagglutinins are detectable after about 90 minutes of heating; however, although decreasing with time, significant levels of polyphenolic compounds are still observed after cooking for 150 minutes. Relatively high amounts are found in the cooking liquor, equivalent to around 20% of the total. The significance of this is still not well known but indirect evidence suggests that polyphenolic compounds decrease protein digestibility and quality [20]. The beneficial effect of heat on the desctruction of the trypsin inhibitors and lectins is shown in the figure to the right by a significant increase in protein quality. Again, excessive heating markedly decreases the quality of bean protein.

The significance of other limiting nutritional factors in beans is shown in Table 2. The data in this Table demonstrates the deficiency of sulfur amino acids in bean protein. The Table in the upper part shows that the importance of the methionine in beans when consumed with cereal grain is associated to the proportion in which both protein sources are consumed [7, 27].

When corn predominates, methionine addition has no nutritional importance; however, some importance is evident when the amount of beans in the mixture increases, as shown in the values of the Table below. With respect to other food consumption systems, such as the one shown in the graph below, for mixtures of cassava and beans, methionine plays a more significant role as indicated by the amount of beans with and without methionine needed to induce weight increases in rats. This is about 15% when no methionine is added to beans and 10% when 0.2% methionine is added [1, 6, 21, 22].

Finally, one of the most important nutritional problems is the low protein

LIMITING NUTRITIONAL FACTORS OF COMMON BEANS

B. ANTIPHYSIOLOGICAL SUBSTANCES – Trypsin inhibitors
– Hemagglutinin compounds
– Polyphenolic substances

Effect of cooking
Atmospheric conditions

Nutritional
consequence

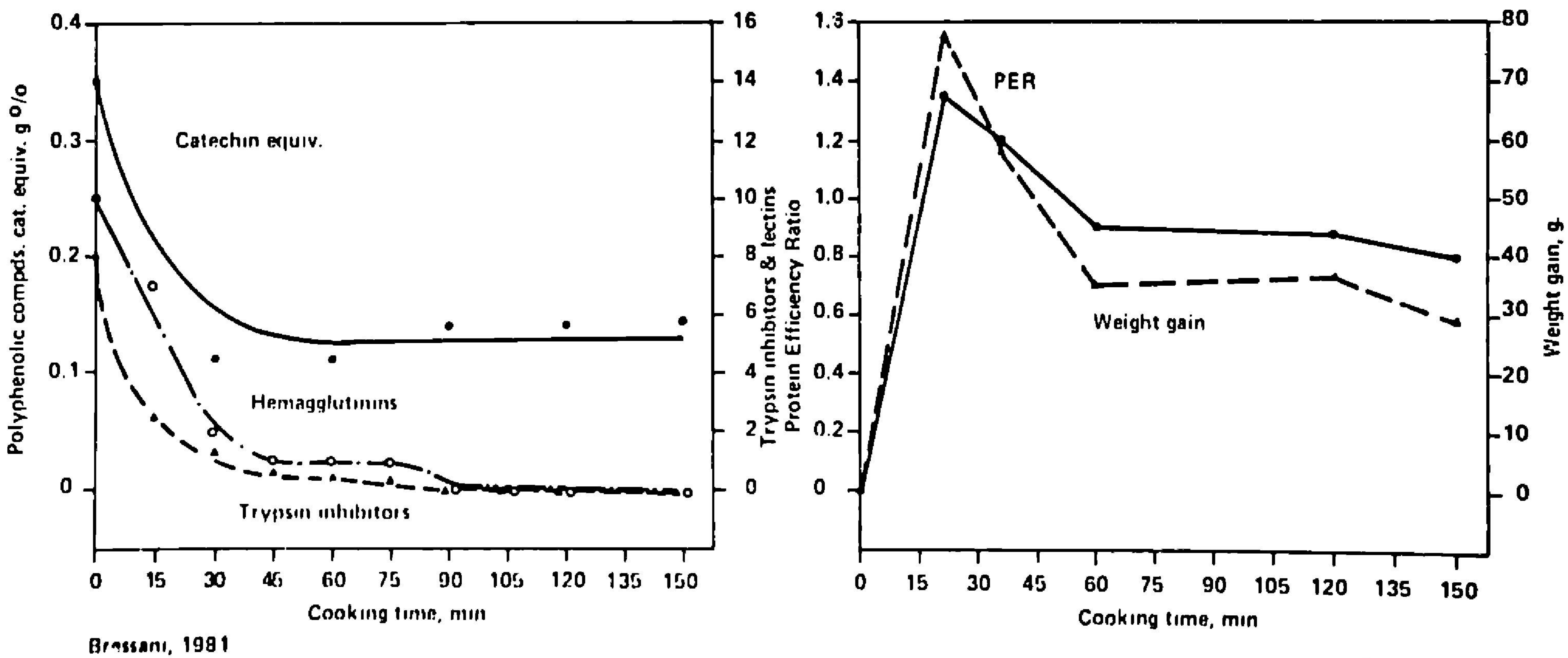


Figure 3. The effect of cooking on the inactivation of antiphysiological factors and improvement in protein quality.

Table 2. The significance of the sulfur amino acid content of beans in food consumption systems based in cereal grains and on tubers

LIMITING NUTRITIONAL FACTORS OF COMMON BEANS

C. SULFUR AMINO ACID DEFICIENCY. Ave. 125 mg/g N

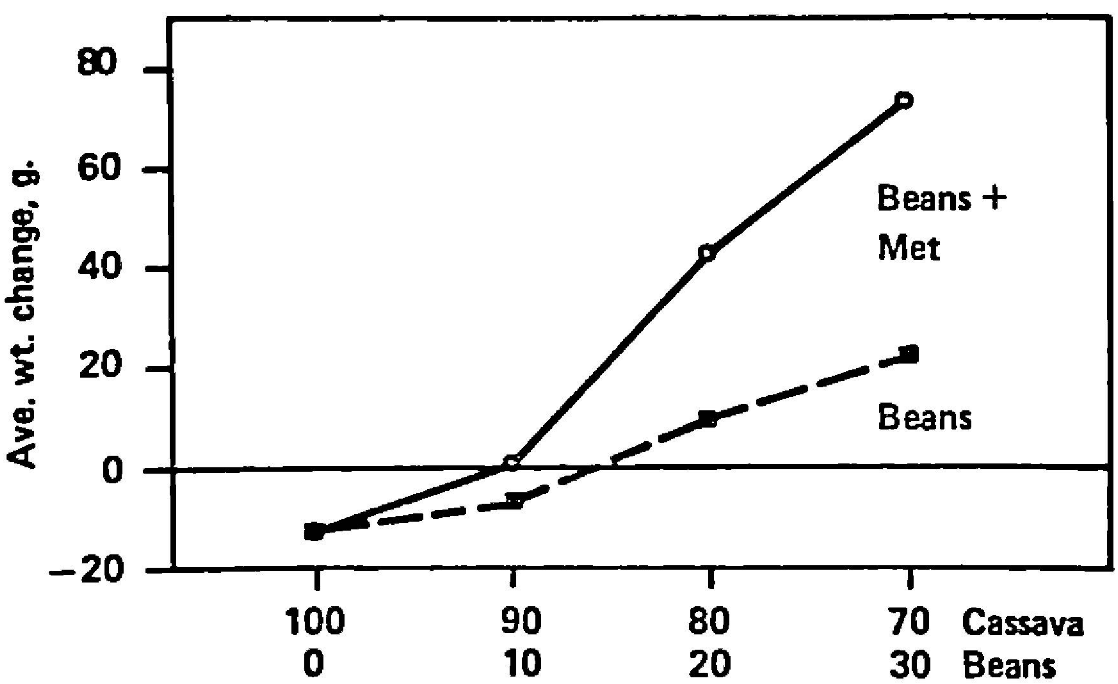
Range: 49–239 mg/g N

Significance: Some for cereal/bean mixtures
High for tuber/bean mixtures

CEREAL/BEAN FOOD CONSUMPTION SYSTEM

	PER
Corn (87) + beans (13) = Basal	2.11
Basal + Lys + Try	2.64
Basal + Met	1.93
Basal + Lys + Try + Met	2.69
Corn (70) + Beans (30) = Basal	2.41
Basal + Lys	2.35
Basal + Met	2.60

CASSAVA/BEAN FOOD CONSUMPTION SYSTEM



Bressani, 1981

Incap 81–342

Table 3. Protein digestibility of common beans in adult human subjects

Cooked	Form fed	No. of subjects	Apparent Prot. Digest. %	Ref.
Black beans	Mashed	6	60.0 ± 2.0	(23)
Black beans:	Whole	8	54.6 ± 4.1	(23)
	Ground	9	57.8 ± 3.4	(23)
	Sieved	9	48.4 ± 4.8	(23)
Ground meat	–	5	86.0 ± 1.2	(23)
	–	5	82.1 ± 2.7	(23)
Red beans	Mashed	12	55.7 ± 4.6	
White beans	Mashed	12	62.1 ± 2.9	
Black beans (I)*	Mashed	12	53.4 ± 2.1	
Black beans (J)**	Mashed	12	49.6 ± 2.9	
Cheese	–	12	76.2 ± 1.4	

* Origin of sample: Ipala
**Origin of sample: Jalpatagua
Bressani, 1981.

digestibility of beans. Some information from adult human studies is shown in Table 3. These results summarize various digestibility trials in which beans were cooked at 15 psi for 30 minutes before feeding as the sole source of dietary protein. In one study the bean preparations offered were whole cooked, ground and sieved, which represents the main forms in which beans are consumed in Latin America. The values found range from 48.4 to 62.1 for apparent digestibility as compared to values for animal protein sources which for cheese was 76.2 and for meat 82 to 86%. Information is still not available which could explain this low digestibility, and its significance in terms of protein quality is still to be measured, although it is logical to assume that it would increase if digestibility increased [23, 24, 25].

Based on the information presented, Table 4 shows some recommendations with respect to some nutritional standards for the up-grading of beans [26]. First of all, yield must be increased or should remain stable since trends seem to indicate decreases in per capita intake. The increases in yield should not be at the expense of protein or lysine content. Furthermore, higher level of sulfur amino acids would be desirable for some diets. Research is needed to determine whether or not low protein digestibility

Table 4. Recommendations

1. Increase yield of accepted varieties
2. Maintain or increase protein and lysine content
3. Increase sulfur amino acid content
4. More research needed with respect to polyphenols
5. Improve cooking characteristics and storage stability of dry seeds

Bressani, 1981

is realted to the amount of polyphenolic compound present. Finally, attention must be given to cooking characteristics and storage stability in breeding programs in order to ensure high consumer acceptability.

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