Cooking and Warm-Holding: Effect on General Composition and Amino Acids of Kidney Beans (*Phaseolus vulgaris*), Chickpeas (*Cicer arietinum*), and Lentils (*Lens culinaris*)

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The effect of two widely used techniques in catering services, cooking and warm-holding, on the general composition and amino acid content of three legumes was analyzed. Cooking produced a decrease in carbohydrate content and an increase in the protein content of kidney beans and chickpeas as well as in the mineral content of lentils. No changes in the total amount of dietary fiber were observed except for lentils. Warm-holding did not significantly change the composition of cooked legumes. Cooking led to a significant decrease in all amino acids in kidney beans, especially in methionine, tyrosine, and threonine. Lysine was the only essential amino acid that was affected by the cooking of chickpeas. For lentils a decrease in the content of isoleucine, leucine, and valine and a significant increase in lysine, phenylalanine, and tyrosine were observed. Lentils were the legume most affected by warm-holding.

Keywords: *Cooking; kidney beans; chickpeas; lentils; technological process*

INTRODUCTION

The catering industry makes an important contribution to nutrient intake in developed countries and therefore needs to consider the impact of the food it provides on the nutritional intake of consumers (Glew et al., 1987). WHO (1990) has pointed out the importance of the nutritional, social, and culinary aspects of the catering services.

The nutrient content of foodstuffs provided by a caterer may differ from a well-prepared home-cooked meal both because the preparation, storage, and cooking methods differ and also because of the choice and composition of available ingredients and supplies (British Nutrition Foundation, 1987).

In traditional systems, large-scale preparation and cooking of foodstuffs are followed by a period of holding at warm temperature prior to service. To ensure microbiological safety, the temperature must be controlled so that the food is maintained at 65 °C or above, during 3 h. This process is known as warm-holding and is used by a large number of enterprises. Cooking and even warm-holding could change the composition of food and as a result its nutritional value. This fact was demostrated in previous works (Candela et al., 1996, 1997).

Legumes are an important component of the diets elaborated by dieticians for these food services. They are, together with cereals, fruits, fish, and olive oil, one of the principal components of the Mediterranean diet. Legumes are an excellent source of protein, carbohydrates, fiber, minerals, and other nutrients (Ruiz et al., 1996). However, several antinutritional factors are found in the raw seed (Gupta, 1987; Savage and Deo, 1989), which can be eliminated or reduced by cooking or with other simple tehnologies (Nestares et al., 1993; Vidal-Valverde et al., 1994; Urbano et al., 1995). Cooking significantly improves the protein digestibility of some types of legumes (Jood et al., 1989; Estévez et al., 1991). The importance of grain products as suppliers of protein is often ignored, particularly in populations ingesting diets rich in animal products. Legumes are the vegetable food with the highest level of protein and can supply an average of 16−20% of the total protein intake. They are known as "poor people's meat" (Cervera, 1995). The process of cooking and warm-holding carried out by catering services may lead to changes in the amino acid composition of legumes. Some studies have been carried out to evaluate the biological quality of legume protein, but relatively few works have studied the impact of processing on the amino acid content of legumes.

The objetive of this study was to evaluate the effects of cooking and warm-holding carried out by a catering system on the nutritional value of kidney beans, chickpeas, and lentils and in particular to provide data on amino acid composition.

MATERIALS AND METHODS

Materials. Chickpeas (*Cicer arietinum*), kidney beans (*Phaseolus vulgaris*), and lentils (*Lens culinaris*) were obtained from local supermarkets.

Sample Preparation. The legumes were allowed to imbibe water and hydrate at room temperature for 12 h. The water was drained, and the legumes washed in water. The water-soaked legumes were cooked by a catering industry firm following the usual process. Soaked seeds were placed, together with sunflower oil and salt, in a pot filled with water and were boiled for 3 h. Each type of cooked legume was divided into two batches. One was homogenized and immediately analyzed, and the other was introduced into a Thermos used by the company for distribution. The internal temperature of food was 65 °C. After 3 h, the second batch was also homogenized and analyzed. Similar weights of raw samples were homogenized and analyzed in the same way. The analyses of the cooked and warm-held legumes were performed without the cooking water being drained. The complete process was repeated four times for each legume to ensure the reproducibility of the data.

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Analytical Procedures. Total fat was determined with an extraction technique with petroleum ether, prior to hydrolysis (ISO 1443, 1973).

The methods used for crude protein and ash determinations were those of the AOAC (1990 and 1923, respectively). The factor 6.25 was used for conversion of nitrogen to crude protein. For the analysis of carbohydrates the Clegg anthrone method was used (Osborne and Vooght, 1978).

Amino acids were determinated by HPLC analysis. Total amino acids were identified and quantified by reversed-phase high-performance liquid chromatography with prior precolumn derivatization with phenyl isothiocyanate. To analyze the profile of the total amino acids, the fat was removed with petroleum ether (Soxhlet method) and the samples were subsequently subjected to acid hydrolysis with 6 N HCl (110 °C/22 h). The hydrochloride acid was then evaporated, and the hydrolyzed samples were dissolved in 0.1 N HCl. Phenylthiocarbamil derivates of the different amino acid types were obtained according to the method of Yang and Sepulveda (1985). They were injected into a Perkin-Elmer (PE Nelson) high-performance liquid chromatograph equipped with a Rheodyne manual injector with a 20μL loop, a Series 200 LC pump quaternary version, and a diode array detector operating at 255 nm. A Nova-Pak column C_{18} (3.9 × 300 mm) from Waters was employed. The pump and the detector were connected to a Series 600 link, and the conditions were controlled by a Turbochrom Navigator program (PE Nelson). Resolution of the peaks was accomplished by using a gradient elution with the mobile phase in pump A consisting of 2.5% acetonitrile in pH 6.4, 70 mM sodium acetate 3-hydrate buffer and that in pump B of acetonitrile/water (3:2). The analysis was carried out at 46 °C, and the flow rate was 1.0 mL/min. The mobile phase began at 0% B, increased to 46% B over 36 min, then further increased to 100% B over 1 min, and finally was held at this ratio for 5 min. At the end of the isocratic period the percentage of B was lowered to 0%. Amino acids were identified by comparison of their retention times with those of standards from Sigma and were quantified according to the internal standard method with l-norleucine (Sigma).

The method of Van Soest and Wine (1967) with prior hydrolysis of starch accorindg to the method of Mongeau and Brassard (1982) was used to determine insoluble fiber.

The method of Mongeau and Brassard (1986) was used to determinate soluble fiber.

Total fiber was obtained by totaling insoluble and soluble fiber.

Statistical Analysis. Data analysis was carried out with one-way ANOVA and a Tukey's posteriori test (Statgraphics 4.0). Differences were studied at the $p \leq 0.01$ level.

Results Expresion. The general composition of the studied legumes was expressed as dry matter to compare the effects of different technological process. Amino acid composition was expressed as grams per 100 g of wet sample to further determine the contribution of these legumes to diet.

RESULTS AND DISCUSSION

Carbohydrates, dietary fiber, and proteins constituted the main components (Table 1). Carbohydrate content in the analyzed raw legumes was similar to that shown in food tables (Souci et al., 1989; Holland et al., 1991). With cooking, a significant decrease of carbohydrate content was observed. Vidal-Valverde et al. (1992, 1993) also found considerable decreases in the amount of carbohydrates, which could be partly explained by solubility during the soaking and boiling steps. Furthermore, by analyzing different fractions of carbohydrates, they found that during the soaking period of lentils there was an acute decrease in the galactosidases and an increase in glucose and fructose.

Warm-holding did not significantly affect the carbohydrate content. Vidal-Valverde et al. (1993) found a reduction of α-galactoside content when legumes were warmed for 5 h at 35 °C.

Table 1. General Composition (Percent)[a]

	raw	cooked	warm-held
Kidney Beans			
protein	$23.33^{a} \pm 0.24$	$28.16^{b} \pm 0.36$	$27.44^{b} \pm 0.98$
fat	$3.50^{a} \pm 0.05$	$3.91^{ab} \pm 0.05$	$4.41^{b} \pm 0.35$
carbohydrates	$43.24^{a} \pm 0.85$	$37.64^{b} \pm 0.71$	$34.09^{b} \pm 0.48$
ash	$4.87^{a} \pm 0.08$	$5.65^{a} \pm 0.12$	$5.15^{a} \pm 0.24$
dietary fiber	32.11	32.26	33.98
soluble fiber	$4.93^{a} \pm 0.45$	$11.05^{b} \pm 0.64$	$10.73^{b} \pm 0.75$
insoluble fiber	$27.18^{a} \pm 1.30$	$21.21^{a} \pm 0.00$	$23.15^{a} \pm 0.91$
Chickpeas			
protein	$19.15^{a} \pm 0.23$	$23.66^{b} \pm 0.58$	$23.67^{b} \pm 0.89$
fat	$5.75^{a} \pm 0.05$	$5.22^{a} \pm 0.14$	$5.50^{a} \pm 0.02$
carbohydrates	$50.54^{a} \pm 1.69$	$43.34^{ab} \pm 0.35$	$40.84^{b} \pm 1.58$
ash	$4.26^{a} \pm 0.13$	$3.62^{a} \pm 0.16$	$3.57^{a} \pm 0.16$
dietary fiber	27.81	29.64	27.57
soluble fiber	$4.29^{a} \pm 0.13$	$4.55^{a} \pm 0.00$	$4.32^{a} \pm 0.02$
insoluble fiber	$23.52^{a} \pm 0.77$	$25.09^{a} \pm 0.55$	$23.15^{a} \pm 0.03$
Lentils			
protein	$26.69^{a} \pm 0.13$	$25.30^{a} \pm 0.33$	$26.35^{a} \pm 0.47$
fat	$3.59^{a} \pm 0.03$	$10.11^{b} \pm 0.51$	$10.70^{b} \pm 0.20$
carbohydrates	$33.77^{a} \pm 0.63$	$27.18^{b} \pm 0.98$	$30.66^{ab} \pm 0.39$
ash	$3.21^{a} \pm 0.04$	$6.12^{b} \pm 0.01$	$5.34^{c} \pm 0.06$
dietary fiber	35.11	24.38	26.04
soluble fiber	$3.75^{a} \pm 0.54$	$7.65^{ab} \pm 0.00$	$10.21^{b} \pm 0.04$
insoluble fiber	$31.36^{a} \pm 0.88$	$16.63^{b} \pm 0.24$	$15.83^{b} \pm 0.02$

[a] All values are referred to dry matter. Values in the same row bearing different letters are significantly different ($p \leq 0.01$).

Mineral loss during preparation of legumes has been investigated (Borade et al., 1984; López and Willians, 1988; Rincón et al., 1993). Although a significant loss with cooking was observed in the percentage of ash calculated on the basis of wet weight, data from dry weight showed different behaviors depending on the type of legume. For kidney beans and chickpeas the amount of total ash did not change significantly ($p < 0.01$) with soaking and cooking processes. Certain minerals are bound to nonsoluble or less soluble substances, and their movement out of the bean is restricted (Reddy et al., 1978; Sathe et al., 1984; Lombardi-Boccia et al., 1991). However, for lentils, we observed a significant increase ($p < 0.01$) in the ash content of cooking seeds. The reverse process, in which the foods absorb minerals from water or equipment, may be of great significance in certain instances (Lee et al., 1982). This increase is probably due to use of regular drinking water or water contamination with minerals from the equipment used by the catering industry, from which they diffuse during soaking process (El-Nahry et al., 1977).

Lignin, cellulose, and some hemicelluloses typically constitute the insoluble dietary fiber portion (Olson et al., 1987). The insoluble fraction was found at much higher quantity than the soluble fraction; in raw legumes these percentages were 31.4% in lentils, 27.2% in kidney beans, and 23.5% in chickpeas. Insoluble fiber did not change significantly with cooking and warm-holding for kidney beans and chickpeas. However, cooking caused a significant decrease in the insoluble fraction for lentils. Vidal-Valverde et al. (1992) found that cooking and prior soaking of lentils brought about a considerable decrease in hemicellulose content, while celullose and lignin increased significantly. The major loss of hemicellulose in lentils could explain the decrease in insoluble fiber. The decrease in insoluble dietary fiber content was similar to results reported for a series of legumes by Augustin and Klein (1989). The major component of the soluble fraction is pectic substances. Results obtained for this fraction showed an increase

Table 2. Amino Acid Composition of Kidney Beans (Grams per 100 g of Wet Sample)

	raw	cooked	warm-held
Essential Amino Acids			
histidine	$0.30^{a} \pm 0.02$	$0.24^{a} \pm 0.01$	$0.31^{a} \pm 0.01$
isoleucine	$0.54^{a} \pm 0.00$	$0.36^{b} \pm 0.00$	$0.37^{b} \pm 0.00$
leucine	$0.72^{a} \pm 0.01$	$0.46^{b} \pm 0.00$	$0.50^{b} \pm 0.00$
lysine	$0.83^{a} \pm 0.00$	$0.50^{b} \pm 0.00$	$0.63^{c} \pm 0.00$
methionine	$0.23^{a} \pm 0.01$	$0.08^{b} \pm 0.00$	$0.17^{ab} \pm 0.00$
phenylalanine	$0.69^{a} \pm 0.00$	$0.42^{b} \pm 0.01$	$0.54^{c} \pm 0.01$
tyrosine	$0.45^{a} \pm 0.01$	$0.22^{b} \pm 0.01$	$0.32^{b} \pm 0.01$
threonine	$0.26^{a} \pm 0.01$	$0.09^{b} \pm 0.00$	$0.18^{ab} \pm 0.01$
valine	$0.65^{a} \pm 0.01$	$0.45^{b} \pm 0.00$	$0.46^{b} \pm 0.01$
Nonessential Amino Acids			
proline	$0.38^{a} \pm 0.00$	$0.23^{b} \pm 0.00$	$0.24^{b} \pm 0.00$
aspartic acid	$1.36^{a} \pm 0.01$	$0.64^{b} \pm 0.01$	$0.84^{c} \pm 0.00$
serine	$0.61^{a} \pm 0.00$	$0.20^{b} \pm 0.01$	$0.46^{c} \pm 0.00$
glutamic acid	$1.88^{a} \pm 0.01$	$1.17^{b} \pm 0.00$	$1.23^{b} \pm 0.01$
glycine	$0.43^{a} \pm 0.01$	$0.24^{b} \pm 0.00$	$0.31^{b} \pm 0.00$
alanine	$0.30^{a} \pm 0.00$	$0.21^{b} \pm 0.00$	$0.21^{b} \pm 0.00$
arginine	$0.42^{a} \pm 0.01$	$0.21^{b} \pm 0.00$	$0.28^{b} \pm 0.01$

[a] Values in the same row bearing different letters are significantly different ($p \leq 0.01$).

Table 3. Amino Acid Composition of Chickpeas (Grams per 100 g of Wet Sample)

	raw	cooked	warm-held
Essential Amino Acids			
histidine	$0.24^{a} \pm 0.01$	$0.15^{a} \pm 0.00$	$0.21^{a} \pm 0.01$
isoleucine	$0.36^{a} \pm 0.00$	$0.37^{a} \pm 0.00$	$0.37^{a} \pm 0.00$
leucine	$0.48^{a} \pm 0.00$	$0.48^{a} \pm 0.00$	$0.48^{a} \pm 0.00$
lysine	$0.91^{a} \pm 0.00$	$0.53^{b} \pm 0.00$	$0.55^{b} \pm 0.00$
methionine	$0.12^{a} \pm 0.00$	$0.11^{a} \pm 0.00$	$0.14^{a} \pm 0.00$
phenylalanine	$0.42^{a} \pm 0.00$	$0.46^{a} \pm 0.01$	$0.47^{a} \pm 0.01$
tyrosine	$0.19^{a} \pm 0.01$	$0.18^{a} \pm 0.01$	$0.25^{a} \pm 0.01$
threonine	$0.06^{a} \pm 0.00$	$0.11^{a} \pm 0.00$	$0.06^{a} \pm 0.00$
valine	$0.38^{a} \pm 0.00$	$0.38^{a} \pm 0.01$	$0.41^{a} \pm 0.00$
Nonessential Amino Acids			
proline	$0.24^{a} \pm 0.00$	$0.28^{a} \pm 0.00$	$0.26^{a} \pm 0.00$
aspartic acid	$0.58^{a} \pm 0.00$	$0.78^{b} \pm 0.00$	$0.65^{c} \pm 0.00$
serine	$0.12^{a} \pm 0.00$	$0.28^{b} \pm 0.00$	$0.15^{a} \pm 0.00$
glutamic acid	$1.67^{a} \pm 0.01$	$1.14^{b} \pm 0.00$	$1.21^{b} \pm 0.01$
glycine	$0.26^{a} \pm 0.00$	$0.27^{a} \pm 0.00$	$0.27^{a} \pm 0.00$
alanine	$0.26^{a} \pm 0.00$	$0.21^{b} \pm 0.00$	$0.25^{ab} \pm 0.00$
arginine	$0.48^{a} \pm 0.00$	$0.32^{b} \pm 0.01$	$0.33^{b} \pm 0.00$

[a] Values in the same row bearing different letters are significantly different ($p \leq 0.01$).

in kidney beans with no significant effect in chickpeas and lentils.

Several authors (Kon, 1968; Varriano Marston and De Omana, 1979; Van Buren, 1985; Vidal-Valverde et al., 1992) have found increases in the soluble fraction with cooking. It has been established that in fact during the soaking period there must be a conversion of insoluble pectinates to soluble pectins, with no change in the total amount of dietary fiber. Acevedo et al. (1994) also concluded that the thermal treatment did not affect the total content of fiber.

This was corroborated with the results obtained for kidney beans and lentils, for which a decrease in insoluble fiber and an increase in soluble fiber were found with no significant changes in the supply of total dietary fiber. However, no effect was found in chickpeas with cooking. This means that the interconversion between insoluble and soluble fractions does not always take place. Warm-holding did not affect dietary fiber content in any way.

The content of fat showed a significative increase with cooking in lentils as a consequence of the oil employed in the cooking. In the other legumes a significative increase of fat was not detected, probably because the amount of employed oil was minor or it was less absorbed by these legumes. Warm-holding did not produce any change in the lipidic fraction of legumes.

As for protein content, few quantitative variations were observed. A significant increase with cooking was observed in kidney beans and chickpeas. This increase in protein content was also observed in cooked chickpeas and faba beans (Fernández et al., 1996; Nestares et al., 1996). According to Vidal-Valverde et al. (1993) and Savage and Thompson (1993), the increase in protein content of soaked and cooked chickpeas could be due to the solubility of carbohydrates in the soaking and cooking liquids. The study of the protein fraction was completed with the analysis of amino acids.

Cooking led to a significant decrease in both essential and nonessential amino acids in kidney beans (Table 2). Ziena et al. (1991) reported that almost all essential amino acids of faba beans were induced after different cooking treatments. Tyrosine was included as an essential amino acid as, under special circumstances (e.g., in premature infants or in people with liver damage), this amino acid, which is not normally essential, may become so because of impaired conversion from precursors (Horowitz et al., 1981). The major reduction of essential amino acids affected methionine, tyrosine, and threonine with reductions percentages of 65.2%, 51.1%, and 48.8%, respectively.

The only essential amino acid that was affected by soaking and cooking of chickpeas (Table 3) was lysine. Geervani and Theophilus (1980) also found a decrease in methionine, threonine, and lysine when chickpeas were cooked by using different methods, including boiling. Analysis showed an important content of lysine in the raw sample, but it diminished in the cooked sample. An explanation for this could be the Maillard reaction. This reaction involves condensation between amino groups of amino acids in the protein (or in peptide linkage or even free amino acids) with glycosidic sugars. The first relatively stable compound formed in the Maillard reaction appears to be a 1-deoxy-2-ketose (lysine-fructose), which is not hydrolyzed by the digestive enzymes, so the lysine is biologically unavailable. Acid hydrolysis (used in the digestion process) liberates half of the lysine, forming 20% furosine and 10% pyridosine (Hodge, 1953; Finot, 1973). Raw chickpeas showed an important content of nonessential glutamic acid, but cooking involved a significant reduction together with alanine and arginine. However, aspartic acid and serine increased significantly.

Table 4 shows the amino acid profile of lentils. A decrease in the content of isoleucine, leucine, and valine was observed, but data showed a significant increase in lysine, phenylalanine, and tyrosine. Morcos et al. (1976) reported that cooking whole lentils resulted in slight losses of all amino acids except for lysine, which showed slight gains. Glycine and arginine were the only nonessential amino acids that did not change significantly. Proline, glutamic acid, and alanine diminished, but aspartic acid and serine showed significant increases.

In a study on the effect of different baking methods in nitrogenous constituents of potatoes, Klein and Mondy (1981) deduced that these methods may lead to compositional changes in these components depending on the mechanism of heat transfer and the particular tissue under investigation.

Our review of the literature found no information on the effects of holding cooked legumes at 65 °C on their

Table 4. Amino Acid Composition of Lentils (Grams per 100 g of Wet Sample)

	raw	cooked	warm-held
Essential Amino Acids			
histidine	$0.18^{ab} \pm 0.00$	$0.23^{a} \pm 0.01$	$0.16^{b} \pm 0.00$
isoleucine	$0.50^{a} \pm 0.00$	$0.37^{b} \pm 0.01$	$0.30^{b} \pm 0.01$
leucine	$0.63^{a} \pm 0.00$	$0.54^{b} \pm 0.00$	$0.43^{c} \pm 0.01$
lysine	$0.32^{a} \pm 0.00$	$0.66^{b} \pm 0.00$	$0.51^{c} \pm 0.01$
methionine	$0.05^{a} \pm 0.00$	$0.08^{a} \pm 0.00$	$0.05^{a} \pm 0.00$
phenylalanine	$0.26^{a} \pm 0.00$	$0.48^{b} \pm 0.01$	$0.35^{a} \pm 0.01$
tyrosine	$0.15^{a} \pm 0.00$	$0.26^{b} \pm 0.01$	$0.20^{ab} \pm 0.01$
threonine	$0.18^{a} \pm 0.01$	$0.12^{a} \pm 0.00$	$0.04^{b} \pm 0.00$
valine	$0.76^{a} \pm 0.00$	$0.40^{b} \pm 0.00$	$0.34^{b} \pm 0.01$
Nonessential Amino Acids			
proline	$0.37^{a} \pm 0.01$	$0.28^{b} \pm 0.00$	$0.18^{c} \pm 0.01$
aspartic acid	$0.22^{a} \pm 0.00$	$0.81^{b} \pm 0.01$	$0.43^{c} \pm 0.01$
serine	$0.01^{a} \pm 0.00$	$0.30^{b} \pm 0.00$	$0.09^{c} \pm 0.00$
glutamic acid	$2.23^{a} \pm 0.01$	$1.41^{b} \pm 0.01$	$1.01^{c} \pm 0.00$
glycine	$0.35^{a} \pm 0.00$	$0.31^{a} \pm 0.00$	$0.21^{b} \pm 0.00$
alanine	$0.61^{a} \pm 0.00$	$0.22^{b} \pm 0.00$	$0.17^{b} \pm 0.00$
arginine	$0.41^{a} \pm 0.01$	$0.36^{a} \pm 0.00$	$0.24^{b} \pm 0.01$

[a] Values in the same row bearing different letters are significantly different ($p \leq 0.01$).

amino acid content. Warm-holding had little effect on the amino acid profile of cooked kidney beans and chickpeas. Nonessential amino acids of chickpeas changed significantly, and only lysine and phenylalanine increased slightly for kidney beans. Aspartic acid and serine were nonessential amino acids that changed in both cases, although in different ways, increasing for kidney beans and decreasing for chickpeas.

Lentils were the legumes most affected by warm-holding. Histidine, leucine, lysine, phenylalanine, threonine, and valine decreased significantly. Also, proline, aspartic acid, serine, glutamic acid, glycine, alanine, and arginine decreased.

In summary, cooking can produce changes in the composition of raw legumes that must be taken into account to estimate their nutritional value. On the other hand, warm-holding did not significantly change the composition of cooked legumes. As for amino acids, a general pattern could not be established as the effect depended on the amino acid and legume concerned.

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