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Research Article

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Bean (*Phaseolus Vulgaris*) Treatments Effect on Starch Digestible Fractions and Consumer Acceptability in the Production of Bean Wheat Cookies

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Abstract

The effect of bean (Phaseolus vulgaris L) treatment (raw bean flour, RBF, soaked bean gruel, SBG, and soaked and cooked bean paste, SCBP) in wheat composite cookie production on starch digestibility and consumer acceptability was evaluated. Cookies were prepared by substituting 50% of wheat flour by beans (dry weight basis). Control cookie was 100% wheat.

More than 80% of trypsin inhibitor and 90% of alfa-amylase activity was destroyed in all bean cookies. Cookies prepared with RBF had the highest value for slow digestible starch (SDS) and resistant starch (RS) ($p<0.05$). The rest of bean cookies have similar amounts for SCBP whereas cookies prepared with SCB had the lowest RS value ($p<0.05$). Consumer acceptability showed that bean cookies were accepted by 68% of consumers and RBF cookies shows the highest level of acceptance. Raw bean flour can be used to increase RS and SDS in composite flour cookies.

Keywords

Consumer acceptance; Functional food; Starch; Bean processing; Resistant starch

Introduction

Common beans (*Phaseoulus vulgaris*) have been a basic food for humans in various regions of the world for millennia. Beans, as other legumes, are an important source of proteins, complex carbohydrates, minerals and vitamins. Also, they are source of poly-unsaturated free fatty acids. Growing evidence suggests several health benefits associated with their consumption. Beans are rich in fiber, compared to other unrefined plant food products [1]. They are considered as a low glycemic index food.

Despite recommendations of health organizations for consumers to increase bean intake, consumption has decreased in bean-consuming countries that have undergone urban lifestyle changes [1-3]. Also, beans are underutilized by people of United States and Northern Europe [1]. Alternative bean products could increase bean utilization, but few exist in the market.

To develop new products using beans as an ingredient is important to evaluate the effect of processing, since some factors influence starch susceptibility to hydrolytic enzymes and, as a result, the starch digestibility will be modified, affecting the characteristics that promote health benefits [4]. Common legume processing includes soaking, boiling and pressure cooking. These treatments affect the *in vitro* starch digestibility in different ways [5]. In some studies, beans has been added at different proportions to corn, rice and wheat flour foods to increased their nutritional and functional value [6,7]. Annealing and heat-moisture treatments has been applied on several bean starches [8,9] to study the effect on starch fractions; although, the effect of processing conditions to keep or improve bean nutritional properties as an ingredient is rarely studied.

A relationship has been established between starch digestion rate and glycemic index response [10,11].

Carbohydrate availability, in terms of rapidly digestible starch, slowly digestible starch and resistant starch, can be evaluated under controlled conditions [10-12]. This determination allows the prediction of *in vitro* starch digestibility.

The objective of this study was to evaluate the effect of different bean treatments on nutritional and sensory impact of cookies prepared with both bean and wheat flour.

Materials and Methods

Bean treatments

Raw bean flour: Raw beans were milled to particles smaller than 2 mm in diameter using a hammer mill.

Soaked raw bean gruel: Beans were soaked for 16 h (3:1 water: beans). Soaking water was discarded and the beans were grounded in a meat grinder.

Cooked bean paste: Beans were soaked for 16 h (3:1 water: beans). Soaking water was discarded and beans cooked (2:1 water: beans) in a pressure cooker (1 MPa, 121°C) for 15 min. Cooked beans were then grounded in a meat grinder.

Cookie preparation

Cookies were formulated from a basic recipe, replacing 50% of wheat flour with beans (dry weight) resulting from three different process (raw bean flour, soaked bean gruel and cooked bean paste). A 100% wheat flour cookie was used as a control. Cookies were baked in a forced convection oven for 17 min at 165°C, cooled on a rack for 25 min, and packed in high-density polyethylene bag, for posterior analysis.

Chemical analysis

Trypsin and alpha-amylase inhibitors were measured in raw beans, wheat flour unbaked mixture and in baked cookies elaborated with wheat flour and beans using the three different treatments previously mentioned. Trypsin inhibitors were measured using the

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method described by Hamerstrand et al. [13], and alpha-amylase inhibitors using the method described by Deshpande et al. [14]. Moisture was determined by the AOAC 925.09 [15] method.

Evaluation of starch digestible fractions

Total starch (TS), rapidly digestible starch (RDS), slowly digestible starch (SDS) and resistant starch (RS) were determined [16].

Experimental design

A completely randomized design with 4 levels of one factor was used [17]. Seven response variables were analyzed: trypsin and alpha-amylase inhibitors, moisture content, total starch content, resistant starch, rapidly digestible starch and slowly digestible starch. Five repetitions were used with a 90% statistical power. The results were analyzed using one-way analysis of variance (ANOVA), $\alpha=0.05$, and the Tukey test used for mean comparison.

Statistical analysis was performed using JMPTM 5.1 statistical software (SAS Institute, Inc. NC, USA).

Consumer acceptability

The degree of liking (DOL) was assessed by 105 cookie consumers: university visitors, students and employees. Subjects included 57 women and 48 men, between the ages of 17 and 50 years old. A structure line scale was used with labels at the beginning for extremely dislike, the middle point for neither like nor dislike and at the end point for extremely like. The three bean cookies were evaluated by each consumer, and water rinses were carried out between samples. Samples were coded with three-digit codes and presented in random, balanced order.

A cluster analysis using Euclidean distances and the average method was used to find consumer segments [18]. ANOVA was applied to each consumer cluster followed by Tukey´s test to determine significant differences among cookie treatments using the statistical program SAS for Windows v 9.1 (SAS Institute, Cary, NC, USA).

Results and Discussion

Alpha-amylase and trypsin inhibitors

As can be seen in Table 1, trypsin inhibitor was destroyed more than 80% in the various treated bean products ($p \leq 0.05$) compared to the unbaked raw bean and wheat flour mixture (3.2 TI mg/g). Baked cookies showed values between 0.3 and 0.6 TI mg/g, with the highest ($p \leq 0.5$) destruction in the cookies prepared with soaked and cooked beans (92%). There was no significant difference noted in the amount of inhibitor present in the cookies prepared with raw bean flour or soaked bean gruel ($p>0.05$). Studies have shown a remnant trypsin inhibitor in soy infant formula of 0.3-2.7 mg/g sample [19]. It has been also reported that boiling dry beans reduces trypsin inhibitor by 80-90%, and boiled beans have been consumed without adverse effects in humans. Amylase inhibitors compared to the unbaked raw mixture of bean and wheat flour (1793 UI μmol/g). The highest level of destruction was obtained in the cookies prepared with soaked and cooked beans (99%) and the lowest level of destruction was found in cookies prepared with raw bean flour (97%). Resulting alpha amylase inhibitor concentration varied from 22 to 56 UI μmol/g. Alpha amylase inhibitors, because of their proteinic nature, are denatured at boiling temperatures. Boiling beans at atmospheric pressure eliminates almost all inhibitory effect [20]. The results show that cookies prepared with raw bean flour, after baking, would have similar residual inhibitory values as cookies prepared with soaked and cooked beans, indicating none of the cookies prepared with beans would have an enzyme inhibitory effect. Baking composite cookies for 17 min at 165°C was an effective heat treatment to inactivate antinutritional factors (80% to 99%). In one study researchers have reported a reduction of a 50% to 100% of trypsin inhibitors in composite corn bean flour submitted to extrusion at 160°C indicating that these materials were safe for human consumption [21].

Total starch: As can be seen from Table 2, total starch (TS) concentration was higher in cookies prepared with 100% wheat (41%) than any of the cookies prepared with 50% bean substitution ($p \leq 0.05$).Total starch concentration did not differ among the cookies prepared with beans ($p>0.05$). The concentration present in cookies prepared with raw bean flour was 34%, with ground soaked bean gruel was 35%, and with cooked beans was 32%. A dilution effect caused by bean addition could explain the lowest value of total starch for the blend between wheat and beans compared to only wheat. Gallegos-Infante [22] found the amount of TS in common bean flour was 35.47%, which is lower than the wheat TS, that generated a higher reduction on total starch with a higher proportion of bean flour on the blend with semolina.

Rapidly digestible starch (RDS), slowly digestible starch (SDS) and resistant starch (RS): Table 2 shows that cookies prepared with 100% wheat flour had the highest RDS value (29%) and the lowest SDS (11%) and RS (1%) values ($p \leq 0.05$). Partial substitution of wheat flour with beans decreased the amount of RDS and increased the amount of SDS and RS ($p \leq 0.05$). Gallegos-Infante et al. [22] found that the addition of common bean flour to spaghetti reflects an important reduction in the available starch content of the product with the perceived decrease in the possible glycemic response after its consumption. Bean flour was only prepared cooking the beans blending them and then drying them. The present study process beans in different ways to decrease the bean RDS and to further improve bean nutritional value.

It can also be seen from Table 2 the effect of bean treatments on the different starch fractions of composite cookies. Higher RDS

Table 1: Trypsin and alpha-amylase inhibitors in cookie formulations using 50% wheat flour and 50% beans (dry base) with different treatments.

Treatment	Trypsin Inhibitor (TI) mg/g$^{(b)}$	Inhibitor Destruction (%)	α-Amylase Inhibitor UI μmol/g$^{(c)}$	Inhibitor Destruction (%)
Raw bean and wheat flour unbaked mixture	3.2^a (0.2)		1793^a (171)	
Raw bean and wheat flour cookies	0.6^b (0.1)	81	56^b (23)	97
Ground soaked bean and wheat flour cookies	0.6^b (0.2)	82	39^{bc} (4)	98
Cooked bean paste and wheat flour cookies	0.3^c (0.1)	92	22^c (20)	99

[a]Mean (± standard deviation) of triplicate analysis. Column followed by the same letter do not differ ($p \leq 0.05$).

[b]Trypsin mg inhibited per g of cookie dry base

[c]Inhibition units express as maltose micromole that is not generated per g of cookie in dry base

Table 2: TS, RDS, SDS, RS and moisture before baking in cookies prepared using wheat flour (100%) or composite flour with 50% wheat substitution for treated bean (dry base).

Cookies n=5	TS (%)	RDS (%)	SDS (%)	RS (%)	Moisture (%)
Wheat flour	4ᵃ (2)	29ᵃ (3)	11ᵇ (3)	1ᵈ (1)	20ᶜ (1)
Raw bean and wheat flour	34ᵇ (3)	5ᵇ (1)	21ᵃ (4)	8ᵃ (1)	19.2ᶜ (0.4)
Ground soaked bean and wheat flour	35ᵇ (7)	15ᶜ (2)	16ᶜ (3)	4ᵇ (1)	37ᵇ (1)
Cooked bean paste and wheat flour	32ᵇ (3)	14ᶜ (1)	16ᶜ (3)	2.2ᶜ(0.4)	45ᵃ (1)

Evaluated parameters were: total starch (TS), rapidly digestible starch (RDS), slowly digestible starch (SDS), resistant starch (RS) and moisture before baking (moisture). Values are means, with standard deviations in parenthesis. Means in a column followed by the same letter do not differ (p≤0.05)

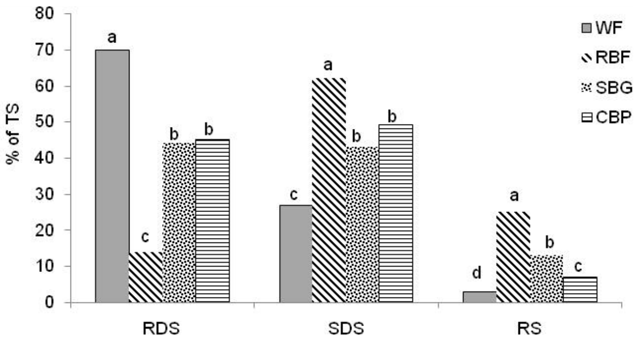

Figure 1: Starch fraction (rapidly digestible starch, RDS; slow digestible starch, SDS and resistant starch, RS) distribution present in the different cookies, expressed as percentage of total starch. Cookies were prepared using wheat flour (WF) (100%) or using 50% bean substitution (dry base) with 3 treatments. Bean treatments were: raw bean flour (RBF), soaked bean gruel (SBG), and cooked bean paste (CBP).

Within the same fraction, means with the same letter do not differ (p ≤ 0.05).

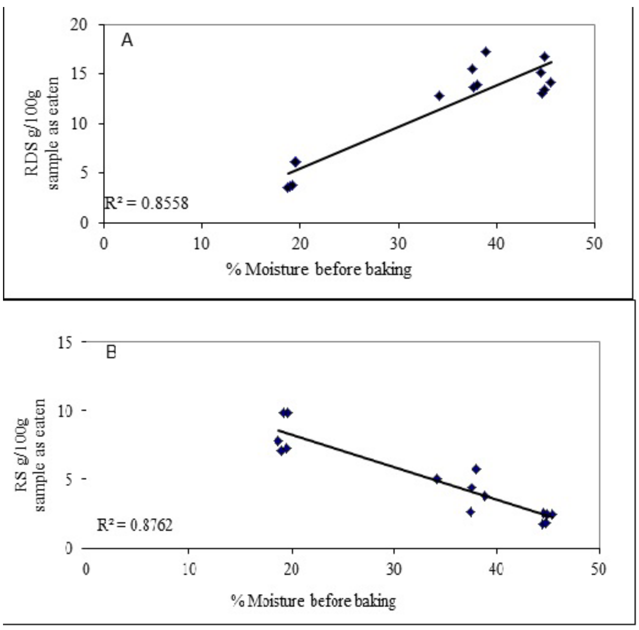

Figure 2: Linear correlation between Rapidly Digestible Starch (RDS) (A) and moisture content before baking of cookies and between Resistant Starch (RS) (B) and moisture content before baking of cookies elaborated with a 50% wheat substitution using beans with different treatments.

values were present while using ground soaked beans (15%) and cooked bean paste (15%) whereas, when using raw bean flour (5%) ($p \leq 0.05$). Cookies prepared with raw bean flour presented the highest value for SDS (21%) and RS (8%) ($p \leq 0.05$). Cookies prepared with ground soaked beans and soaked and cooked bean paste had similar values for SDS, at 16% ($p>0.05$). Those formulated with soaked and cooked bean paste had the lowest RS value, at 2.2%, and those with raw bean flour had the highest value at 8% ($p \leq 0.05$).

Evaluating starch fractions as a percentage of TS, as it can be seen from Figure 1, it was found that cookies with 100% wheat showed the highest fraction (70%) of RDS, and cookies prepared with raw bean flour showed the lowest fraction (14%) ($p \leq 0.05$). Fraction of RDS from TS in cookies prepared with soaked bean gruel (44%) was not significantly different ($p>0.05$) from cooked bean paste cookies (44.7%), while they both were significantly lower than the amount present in TS of wheat flour cookies ($p \leq 0.05$). On the other hand, the SDS fraction was the highest (62%) for cookies prepared with raw bean flour and the lowest for wheat flour cookies (27%) and they were significantly different ($p \leq 0.05$). Cookies formulated with soaked bean gruel and cooked bean paste showed similar SDS values ($p>0.05$), but these values were higher than wheat flour cookies ($p \leq 0.05$).

As can be also seen from Figure 1, RS values only accounts for 3% of TS from wheat flour cookies and it was significantly lower than any composite flour cookie ($p \leq 0.05$). Raw bean flour cookies have the highest percentage of 24% of TS. Soaked bean gruel accounts for 13% RS of TS, and cookies prepared with cooked beans showed the lowest value, 7% of the TS ($p<0,05$), among the cookies with beans added. Bean processing affected *in vitro* digestibility of starch since same proportion of beans was added to the composite cookies. When Gallegos-Infante et al. [22] added different percentages of cooked bean flour *in vitro* digestibility starch changes were not as higher as in the present study.

Moisture content before baking (Table 2) of wheat flour cookies and raw bean flour and wheat cookies does not differ significantly ($p \leq 0.05$). Even though water content is an important factor for starch gelatinization during the process, 100 % wheat cookies had higher value of RDS (29%) and lower values of RS (1%) and SDS (11%) than raw bean composite flour cookies (RDS:5%; RS: 8% and SDS 21%). Higher slow starch digestibility of bean cookies was probably due to higher legume starch amylose content than cereal starches [23] and different morphological characteristics of bean and cereal starches [24,25].

Soaking and cooking the beans before baking the cookies reduces SDS and RS, probably due to the fact that soaked and boiled starch gelatinizes more easily than unsoaked and uncooked starch. Gelatinization makes the starch more available for digestive enzyme attack [5,24].

Figure 2 (A y B) shows the linear correlation between moisture content before baking and resulting RDS and RS of bean cookies. This figure shows bean cookies with higher moisture content before baking had higher values for RDS (with a correlation coefficient of R^2=85%), also higher moisture content produced lower RS values, with a negative determination coefficient of 87%. Sumargo et al. [6]

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described that rapidly digestible starch decreased and resistant starch increased as bean processing moisture increased in an extruded brown rice and pinto bean composite flours.

The differences found for SDS, RDS and RS could be attributed to the different bean treatments and water content before baking [5,10].

Cookies with a 50% substitution of beans instead of wheat flour have potential as a product with health benefits due to the increase in RS and SDS. Resistant starch is receiving a lot of attention recently due to its physiological effects, which include colon cancer prevention, hypoglycemic action, reduction of gallstone formation, hypocholesterolemic effect, and obesity control [25,26].

SDS is also getting attention for product development because of its potential health benefit, influencing satiety, physical performance, glucose tolerance enhancement and blood lipid level reduction [27].

Consumer acceptance

Consumers were grouped in four clusters according to their degree of liking (DOL). Analyzing data by clusters have the advantage of identifying consumers with similar preferences [28-30], which is a good strategy for new product development [27,30].

Cluster 1 was the largest group, with 54% of the tested consumers. Cluster 3 represented 19% of consumers, cluster 2 represented 15% and the smallest was cluster 4 with 12% of the consumers.

There was no relationship between DOL and gender or age among the four clusters, since the ratios of men to women were similar in all groups, and consumers of all ages (17-50 years old) were found in each group as well. It is possible to say that most of the differences in DOL among cookies were due to the sensory characteristics resulting from the bean treatments tested.

Figure 3 shows mean acceptability for each cookie per cluster. It is important to mention that Cluster 1 represented more than half of the consumers tested. Acceptability for Cluster 1 consumers was the highest ($p \leq 0.05$) for raw bean cookies and there were no significant differences in DOL between the other two cookies. Consumers in Cluster 2 did not present significant differences among their DOL for the three cookies ($p>0.05$). This cluster showed high acceptability scores in general, meaning that they liked the cookies regardless of the bean treatment. For Cluster 3, no significant differences were found between DOL of cookies with raw bean flour and with cooked bean paste cookies, with scores close to "neither like nor dislike." The DOL of soaked bean gruel cookies was significantly lower than the other

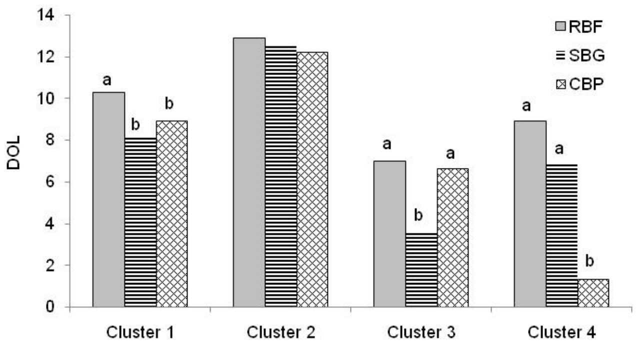

Figure 3: Degree of liking for cookies prepared with 50% wheat flour and 50% beans with different treatments: raw bean flour (RBF), soaked bean gruel (SBG), and cooked bean paste (CBP). Among each cluster, means with the same letter do not differ ($p \leq 0.05$).

two cookies ($p \leq 0.05$) and was not acceptable. This cluster comprised consumers who did not like the bean cookies.

Cluster 4 provided the highest acceptability evaluation for raw bean flour cookies and soaked bean gruel cookies ($p \leq 0.05$) and the lowest for cooked bean paste cookies.

The raw bean flour cookie presented the highest DOL among all consumer clusters evaluated, while DOL for soaked bean cookies and cooked bean paste cookies was variable. This variability in all treatments may be due to intrinsic cookie factors such as appearance, texture, flavor and taste, besides general consumer likes and preferences [32,33]. Some consumers offered comments at the end of the DOL evaluation, mentioning that some cookies had lumps; this is due to non-homogenous ingredient mixing mostly in soaked bean cookies and cooked bean paste cookies. The homogenization problem in these cookies came from the dough texture, which made them very hard to mix.

Consumers of clusters 1 and 2 liked bean cookies. Since the highest DOL score in Cluster 1 was assigned to raw bean flour cookies, and in Cluster 2 all cookies received high DOL scores, it was concluded that raw bean flour cookies will satisfy 68.6% of total consumers. The other groups that presented low acceptance scores were not considered target groups and were excluded from the conclusions. Zucco et al. [7] prepared cookies with partial replacement of wheat flour by pulses flours (navy bean, pinto bean, green lentil and commercial yellow pea) finding that incorporation of fine flours remarkably increased cookies' hardness and decreased spread while coarse flours were of unacceptable structure and were sticky to handle. Sumargo et al. [6] found that incorporating bean flour into extruded snacks can negatively affect physical attributes (hardness, density, and expansion). Processing bean to generate a modified bean ingredient may help reducing negative bean impact on physical and sensory characteristics according to the high DOL of bean cookies found in the present study.

Conclusion

Processing beans can alter their properties. The traditional way beans were prepared (soaked and boiled) reduces their RS and SDS. For industrial bean products special attention should be exerted to maximize or keep health properties. Cookies prepared with wheat flour and raw beans show good potential as a functional food, because of their lower RDS values and higher SDS and RS than the values present in wheat cookies reduces their value. Since higher values of SDS and RS and lower values of RDS are related to low glycemic index, it could be predicted that the bean cookies would have a low glycemic index. Moreover, bean cookies showed very good consumer acceptability in the evaluations carried out. For industrial purpose it is recommended to use raw bean flour to increase bean nutritional benefits without detriment on DOL.

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