Journal of Food Research; Vol. 12, No. 4; 2023
ISSN 1927-0887 E-ISSN 1927-0895
Published by Canadian Center of Science and Education

Effect of Pinto Bean Starch Fortification on Bread Texture and Expected Glycemic Index

Courtney Simons[1]

[1] Wright State University – Lake Campus, Celina Ohio, USA

Correspondence: Courtney Simons, Wright State University Lake Campus, 7600 Lake Campus Drive Ohio 45822, USA. Tel: 419-586-0313

Received: August 9, 2023 Accepted: September 13, 2023 Online Published: September 15, 2023

doi:10.5539/jfr.v12n4p11 URL: https://doi.org/10.5539/jfr.v12n4p11

Abstract

Pulse starches are known to have a low glycemic index due to their unique starch conformation and high amylose content. Hence, pinto bean starch (PBS) was extracted from pinto beans and added to bread formulations at 0% (control), 5%, 10%, and 15% concentrations. Texture profile analysis (TPA) on the loaves was completed 24 hours after baking. Following TPA, the breads were analyzed to determine their starch hydrolysis profiles and expected glycemic index (eGI). TPA results showed that inclusion of native PBS in bread did not significantly alter textural characteristics (hardness, springiness, and chewiness), except for cohesiveness which was significantly lower in the bread loaves containing PBS (0.52 – 0.54) compared to the control (0.61). The addition of native PBS (eGI = 37.5) significantly reduced eGI in bread loaves by approximately 2%. However, the final eGI was still within the range considered to be high GI (>70). The findings demonstrated that pinto bean starch may be added to bread to reduce eGI without significantly altering textural properties.

Keywords: starch, bean starch, resistant starch, starch hydrolysis, glycemic index, bread texture, low glycemic index bread

1. Introduction

White bread is one of the most consumed food products (Cust et al., 2009; Pot et al., 2015). As with other refined and simple carbohydrates, white bread digests rapidly and contributes to an increase in postprandial glucose. Several negative outcomes correlate with the rapid glucose release associated with over consumption of simple carbohydrates, including type 2 diabetes, obesity, and cardiovascular disease (Brand-Miller et al., 2009; Ceriello and Colagiuri, 2008; Jenkins et al., 2002; Liu et al., 2023). The popularity of white bread, despite these challenges, is likely due to its sensory properties (Pot et al., 2015). In order to maintain the highly acceptable sensory properties of white bread while improving its nutritional quality, food manufacturers have added commercially available resistant starch (RS) to bread formulations (Arp et al., 2018; Barros et al., 2018; Eerlingen et al., 2003; Korus et al., 2009; Ozturk et al., 2009; Sarawong et al., 2014; Tekin and Fisunoglu; 2023).

Resistant starch is that portion of starch that escapes digestion in the small intestine and is fermented in the colon by bacteria. Hence RS is classified as a dietary fiber (CODEX, 2019). Health outcomes of RS include body weight control and improved gut health (Bindels et al., 2015; Bird et al., 2010; Birt et al., 2013; Higgins and Brown, 2013; Lockyer and Nugent, 2017; Alfilasari et al., 2021; Sajilata et al., 2006, Yuan et al., 2018). Resistant starch is classified into five categories, as follows: RS1: Physically entrapped starch such as those found in whole or partially milled grain; RS2: Native resistant starch that is physically inaccessible due to its unique starch conformation such as high amylose corn; RS3: Retrograded starch; RS4: Chemically modified starch; and RS5: Starch that is chemically bound to lipids (Eerlingen et al., 1995; Englyst, et al., 1992).

RS2 and RS3 are the most popular RS ingredients in commercial bread making. They are effective in reducing the glycemic index of bread while retaining its organoleptic properties (Roman and Martinez, 2019). RS3 offers some advantage over RS2 due to its superior ability to resist breakdown of its crystalline structure during baking, and hence maintaining its RS property (Haralampu, 2000; Jacobs and Delcour, 1998; Klucinec and Thompson, 1999; Matalanis et al; 2009; Ratnayake and Jackson, 2008; Reddy and Haripriya, 2015; Roman et al., 2019; Sajilata et al, 2006).

Roman and Martinez (2019) summarized findings of in-vitro studies in commercially available RS2 and RS3 sources as ingredients to increase RS content in bread. Total resistant starch in the bread formulations ranged from 29.5% to 83.2% and was mostly from maize. Other RS sources were tapioca, wheat, green plantain, and green banana flour. They found that the incorporation of starch up to 20% significantly reduced the expected glycemic index (eGI) and did not affect consumer acceptability. The overall bread quality was maintained, although there was a general reduction in cohesiveness, specific volume, and hardness as RS substitution increased.

Maize was the most common RS starch source in the studies they investigated. This is likely due to its high amylose content (50-70%) and highly crystalline structure which makes it difficult to be gelatinized and hydrolyzed by alpha-amylase (Borchers, 1962; Sandstedt, et al. 1962).

The addition of commercial RS in bread may drive up cost due to processing and isolation. Using native starch may be a cheaper option while still achieving acceptable sensory and health outcomes. A suitable starch source to achieve this, other than corn is pulse crops. Pulses are high in amylose (11.6 to 88%) and possess a crystalline structure that inhibits alpha-amylase digestion. They can be processed to produce a high yield of high-amylose starch (18-49%). Hence, in this study, PBS was utilized in bread making with a goal to lower glycemic index, while maintaining texture.

2. Materials and Methods

2.1 Starch Extraction

Starch was extracted from pinto beans based on a procedure by Simons et al. (2018). Briefly, pinto beans were soaked in distilled water overnight and blended in a kitchen blender at high speed to reduce particle size. The pulp was then strained through a series of Tyler sieves of 20 – 80 mesh. The starch precipitate was solubilized with 0.2% NaOH to remove proteins, followed by neutralization with 2N HCl. The starch was dehydrated in a convection oven and passed through a centrifugal mill equipped with a 0.5 mm sieve to remove starch aggregates.

2.2 Baking

Exactly 250 g of warm water (50^{o}C) was added to a bread maker machine (Oster BM-1; model CKSTBRTW20) followed by 30 g canola vegetable oil, 30 g table sugar, and 400 g wheat flour-pinto starch mix containing 0%, 5%, 10% and 15% PBS respectively. A well was then made in the flour and 6 g Fleischmann’s bread machine instant yeast was added. The loaves of bread were baked for 58 minutes by selecting the “Express Bake” menu (menu 5). After baking, the bread pans were removed from the bread machine and allowed to cool for 10 minutes before emptying from the pans and cooling for another 24 hours in a kitchen oven at room temperature. The baking procedure was done in triplicate.

2.3 Texture Profile Analysis

Texture Profile Analysis (TPA) was accomplished using a Brookfield CT3 Texture Analyzer (Brookfield Engineering Laboratories, Inc., Middleboro, MA) fitted with a TA4/1000 probe following test method: target, 10.0 mm; hold time, 0 s; trigger load, 50.0 g; test speed, 1.00 mm/s; return speed, 1 mm/s; number of cycles, 2.0.

2.4 Milling and Drying

Following TPA, the loaves of bread were dried in a convection oven (VWR International, Radnor, PA) at 50^{o}C for 20 hours and then milled in a Retsch ZM200 centrifugal mill (Retsch GmbH, Haan, Germany), fitted with 0.5-mm sieve, and rotated at 10,000 rpm.

2.5 Expected Glycemic Index

The eGI was determined based on the procedure by Simons et al. (2012). In brief, PBS and bread flours were digested (in duplicate) with alpha-amylase from a Megazyme resistant starch kit (Megazyme International, Ireland) for 30, 60, 90, 150, and 180 minutes at 37^{o}C. The amount of glucose released from the starch at each interval was then determined spectrophotometrically using a glucose oxidase/peroxidase (GOPOD) reagent in the RS kit.

2.6 Statistical Analysis

SPSS version 23 statistics software (IBM Corp., 2015) was used to subject TPA and eGI data to the analysis of variance (ANOVA) and means comparison using Tukey’s test ($p < .05$).

3. Results and Discussion

3.1 Dough Behavior

The addition of PBS caused stickiness during dough mixing at the 15% treatment level (Figure 1). The stickiness was likely due to damaged starch that may have been created during starch milling to remove aggregates. Damaged starch increases water absorption and stickiness in bread dough (Sluimer, 2005). The problem could be eliminated by avoiding the milling step. Alternatively, the starch could be milled at a much lower speed.

Figure 1. The addition of pinto bean starch at 15% caused stickiness during dough mixing (left) compared to addition at 10% and below (right)

3.2 Texture Profile Analysis

The texture profile of bread containing pinto bean flour was similar to the control (100% WF) (Figure 2).

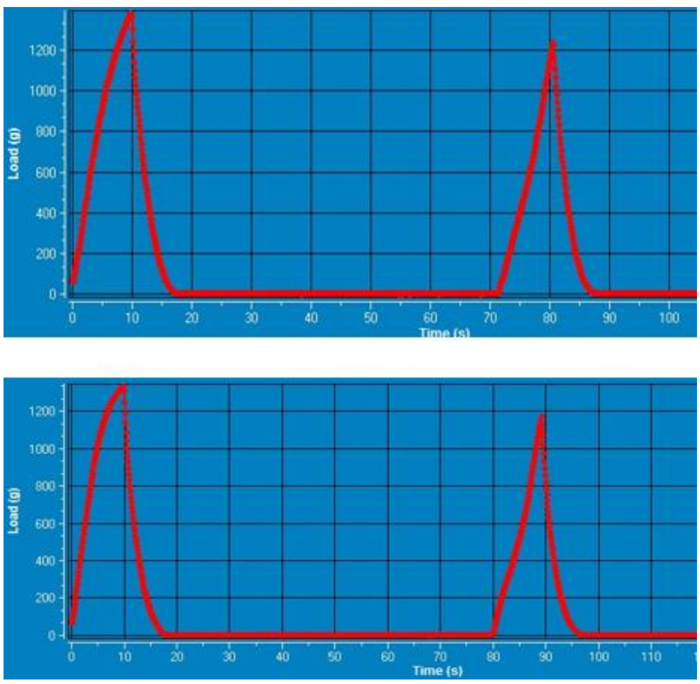

Figure 2. Texture profile of wheat bread with 0% pinto bean starch (top) and 15% pinto bean starch (bottom)

PBS had no significant effect on bread hardness, springiness, and chewiness but reduced cohesiveness significantly (Table 1).

Table 1. Texture profile of bread loaves

Treatment	Hardness (g)	Cohesiveness	Springiness (mm)	Chewiness (mJ)
100% WF Bread	1,547.17 ±197.58	0.61 ±0.03[a]	9.02 ±0.13	82.57 ±7.51
5% PBS Bread	1,734.25 ±168.80	0.54 ±0.02[b]	9.04 ±0.05	82.49 ±10.71
10% PBS Bread	1,427.42 ±468.25	0.52 ±0.02[b]	8.48 ±0.3	61.50 ±22.14
15% PBS Bread	1,273.83 ±42.86	0.54 ±0.01[b]	7.48 ±2.03	58.80 ±3.58

WF = wheat flour, PBS = pinto bean starch. Values with different superscripts in each column indicate significant difference ($P<0.05$)

Arp et al. (2018) also observed a reduction in cohesiveness in bread as starch substitution increased from 0 to 30%. The ability of bread to retain most of its textural properties is likely due to the ability of starch to interact with gluten to create a stable network that can retain gas and prevent dough collapse during baking and cooling (Delcour and Hoseney, 2009).

3.3 Starch Hydrolysis and Expected Glycemic Index

The starch hydrolysis rate for native PBS was lower than the hydrolysis rate of all flours made from bread. As expected, 100% WF (the control) bread was hydrolyzed the fastest (Figure 3).

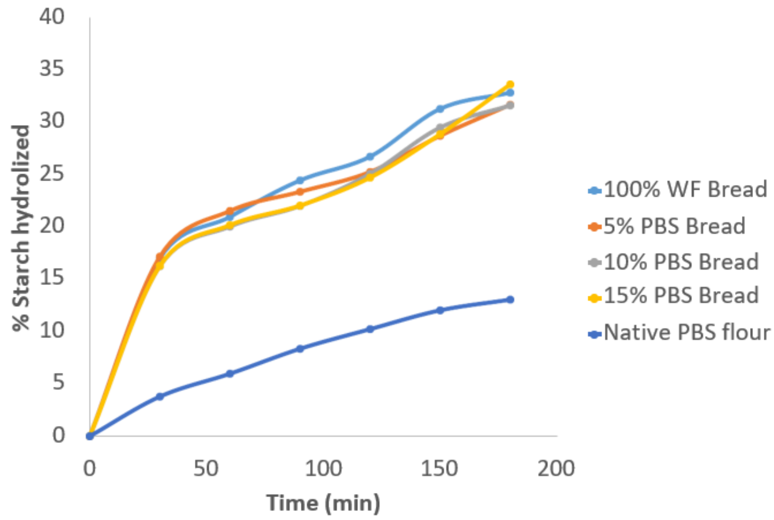

Figure 3. Starch hydrolysis of bread treatments

The eGI of PBS was 37.5. This was close to the eGI of 33.65 found in PBS by Ovando-Martinez et al., (2011). The value obtained in this study may be higher due to a higher concentration of damaged starch produced by milling the starch to remove aggregates. Bread treatments containing 5% pinto bean had a high glycemic index of 91.4 (Table 2). This value dropped significantly when the PBS concentration increased to 10% and 15% but the eGI was still high (89.2 and 89.7, respectively). The resulting high eGI indicates easy accessibility of amylase to break down starch. The high accessibility was likely facilitated by significant starch gelatinization due to damaged starch (Zhang et al. 2006).

Table 2. Expected glycemic index of bread treatments and native PBS

Treatment	**eGI**
5% PBS Bread	91.4 ±0.6[a]
10% PBS Bread	89.2 ±0.0[b]
15% PBS Bread	89.7 ±0.6[b]
Native PBS Flour	37.5 ±0.0[c]

WF = wheat flour, PBS = pinto bean starch. Values with different superscripts in each column indicate significant difference ($P<0.05$)

The eGI of bread treated with PBS could be reduced by avoiding the final milling step in the preparation of the starch. This will reduce the possibility of increasing damaged starch and extensive gelatinization during baking. Another consideration should be to convert native PBS to RS3 before adding it to bread. There are currently no commercial RS ingredients made from pulses. To create RS3 from pinto bean, PBS could be cooked, followed by cooling for several days to increase retrogradation. The retrograded starch could then be digested to remove soluble starch and in the process, concentrating the RS (Simons et al., 2018).

4. Conclusion

The potential to use a pulse starch in bakery products as an ingredient to reduce eGI was investigated. The bread loaves maintained their overall texture after baking with a slight reduction in cohesiveness. The eGI in the bread treatments decreased with the addition of PBS, but not low enough to classify them in the low glycemic index category. Hence, the addition of native pinto bean starch is not an effective method to reduce the glycemic index of bread. This finding is important for researchers and food manufacturers who are interested in improving the nutritional benefits of bread by lowering glycemic index. To better achieve this outcome, researchers should focus their attention on adding resistant starch directly to bread formulations, including exploring opportunities to develop novel commercial resistant starches from pulse flours.

Competing interests

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal’s policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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