Ocimum tenuiflorum seeds and Salvia hispanica seeds: mineral and amino acid composition, physical properties, and use in gluten-free bread

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ABSTRACT

The aim of this study was to compare mineral, amino acid composition, physical properties and use in gluten-free bread of seeds of holy basil (Ocimum tenuiflorum) with those of chia seeds (Salvia hispanica). Holy basil and chia seeds have variable chemical compositions. Holy basil is a valuable source of calcium, manganese, and iron and contains significantly more methionine sulfone and tryptophan. However, higher levels of asparagine, threonine, serine, glutamic acid, proline, glycine, alanine, valine, isoleucine, leucine, phenylalanine, and lysine were found in chia seeds compared to holy basil seeds. With regard to energy consumption during grinding, holy basil appears to be more cost-efficient. The addition of both whole and ground O. tenuiflorum and S. hispanica had a favorable effect on bread crumb texture. Holy basil and chia swell intensely in water and can be used as hydrocolloid replacements in gluten-free bread.

1. Introduction

For several centuries, plants have been used for medicinal purposes. Extracts and essential oils from plant leaves have numerous therapeutic applications. The holy basil (Narasimhulu & Vardhan, 2015) and chia (Harvey, 1991) are examples of such plants. Chia seeds are increasingly valued and used in the production of bread, including gluten-free bread; however, little is known about the application of holy basil seeds.

Holy basil (Ocimum tenuiflorum), of the Lamiaceae Lindl (dead nettles) family, is a plant that has been worshiped for over 3,000 years (Gupta, Prakash, & Srivastava, 2002), and is considered holy (Pattanayak, Behera, Das, & Panda, 2010) due to the considerable therapeutic potential of its leaves. The holy basil has a highly complex chemical structure and comprises numerous biologically active compounds (Rastogi et al., 2015). The extract of holy basil leaves was shown to have anti-carcinogenic and antioxidant properties (Devi, 2001). Moreover, holy basil contains vitamins and minerals, which can increase the nutritional value of foods (Anabarasu & Vijayalakshmi, 2007). Kaur, Dhull, Sandhu, Salar, and Purewal (2018) study confirmed the flour from O. tenuiflorum seeds could be used in preparation of various pharmaceuticals/food products, analysis also proved the presence of four pharmacological important compounds (gallic acid, cinnamic acid, catechol and ascorbic acid).

Salvia hispanica, known as Chia of the Lamiaceae Lindl family, has a long history of plant–human interactions. In the pre-Columbian Mesoamerica, chia played a significant role in the fight for survival, and it overshadowed even corn by its nutritious seeds (Harvey, 1991).

Chia seeds comprise proteins (15–25%), fats (30–33%), carbohydrates (26–41%), dietary fiber (18–30%), and ash (4–5%). Moreover, they contain high amounts of antioxidants (Ixtaina, Nolasco, & Tomas, 2008) and are considered a rich source of fat, dietary fiber, protein, and mucus (Ayerza, 2013).

Chia seeds contain 25–40% oil, of which 60% contains ω-3-alpha linolenic acid and 20% contains ω-6-linoleic acid. Human beings require both of these fatty acids for health and they cannot be synthetically manufactured. An advantage of chia seeds is that they do not contain gluten (Bueno et al., 2010).
Scientific research has demonstrated that biochemical components of *S. hispanica* seeds help maintain serum lipid levels, increase the satiety index, prevent cardiovascular diseases, inflammation, nervous system disorders, and diabetes (Guevara-Cruz et al., 2012; Jin et al., 2010).

Chia seeds have been proposed as a potential component for wheat bread production (Romankiewicz et al., 2017; Steffolani, Martínez, Leon, & Gomez, 2015; Svec & Hruskova, 2015; Verdu et al., 2015; Zettel, Kramer, Hecker, & Hitzmann, 2015). Furthermore, research on the use of chia seeds (Steffolani, De la Hera, Perez, & Gomez, 2014) or flour in gluten-free bread has shown promising results (Costantini et al., 2014; Huerta, Alves, Franco, Kubota, & Severo, 2016; Sandri, Santos, Fratelli, & Capriles, 2017; Verdu, Barat, & Grau, 2017).

A gluten-free products diet is a therapeutic necessity in patients diagnosed with gluten-related disorders such as nonceliac gluten sensitivity, celiac disease, wheat allergy (Leonard, Sapone, Catassi, & Fasano, 2017). Currently, the gluten-free diet is popular not only among patients with disorders associated with gluten, but also among people who believe that it has a beneficial effect on alleviating the symptoms of other diseases (Jones, 2017). Therefore, the popularity of gluten-free products and their perception as health-promoting are increasing (El Khoury, Balfour, & Joye, 2014).

In addition to the abovementioned chia additive, various recipes for gluten-free bread have been proposed so far, but there is a lack of research on bread with the participation of holy basil seeds, therefore we propose the enrichment of gluten-free bread with these seeds. In the literature, only sweet basil seeds have been utilized for baguette production (Rezapour, Ghiasi Tarzi, & Movahed, 2016), and gum extracted from basil (*Ocimum basilicum*) has been proposed for use in wheat bread production (Israr et al., 2017). There are no data on the use of holy basil seeds for gluten-free bread; moreover, the chemical composition of the seeds, including their mineral and amino acid content, remains unknown. Therefore, this study was conducted with an aim to compare holy basil seeds and chia seeds; their ability to swell in the aqueous medium; their chemical composition; the contents of minerals and amino acids; physical properties; and, furthermore, suitable grinding processes and the use of those seeds as the ingredients in gluten-free bread production.

2. Materials and methods

2.1. Materials

Seeds of *O. tenuiflorum* obtained in India (TRS Tukmaria, India) and *S. hispanica* obtained in Mexico (NatVita, Poland) were used for analysis. For gluten-free bread, rice flour (100% Melvit, Warsaw) was used. This flour was characterized by the following composition: carbohydrate, 79.2 ± 3.4%; protein, 7 ± 0.2%; ash, 0.29 ± 0.01%; and fat, 0.7 ± 0.02%. Dried instant yeast (Instaferm, Lallemand Iberia) and salt (Klodawa salt mine, Poland) were also used for making the bread.

2.2. Measurement of the swelling of seeds

The selection of raw material for the research was dictated by its specific swelling properties, therefore these seeds were proposed as a substitute for hydrocolloids. In the preliminary studies, various seeds were compared, among others, *Plantago psyllium* and *Plantago ovata* the suitablity of which was previously proven (Ziemichód, Wójcik, & Różyło, 2019). In this paper we proposed *Ocimum tenuiflorum* seeds and compared them with *Salvia hispanica* seeds. For the determination of the swelling index of seeds, 10 g seeds were added to a 100-mL measuring cylinder and it was filled with 100 mL distilled water at predetermined temperatures ranging from 20°C to 100°C. The swelling index was determined based on the Eq. 1 (Ziemichód et al., 2019):

\[
S_I = \frac{V_m - V_0}{V_0} \cdot 100\% 
\]

Where, \(S_I\) is the swelling index; \(V_m\) is the volume of seeds after swelling; and \(V_0\) is the initial volume of seeds (before swelling).

2.3. Analysis of chemical composition

Kjeldahl method (ISO 20483, 2013 (Kjeltec 2300, Foss) was used for protein determination. For determination of the total fat content in the seeds, we employed the Soxhlet method (ISO 659, 2009 (hexane C6H14, 3 hours) on the Soxtec 2050 (Foss) system. For the estimation of sugar content, we used the Luff–School method (Egan, Kirk, & Sawyer, 1981). The total dietary fiber (TDF) was determined (Asp, Johansson, Hallmer, & Siljestrom, 1983) after enzymes such as thermostable α-amylase, pepsin, and pancreatin were used for the digestion of the test sample.

2.4. Determination of trace elements

Flame atomic absorption spectrometry (FAAS) was used for the quantitative analysis of the trace elements found in the seeds of *O. tenuiflorum* and *S. hispanica*. Based on the previous mineralization of the sample, the contents of zinc, copper, and iron (EN 13804, 2003; Jorhem & Engman, 2000) as well as sodium and magnesium (EN 15505, 2008) were specified.

2.5. Determination of amino acid composition

The composition of amino acids was determined following protein hydrolysis. Acidic protein hydrolysis was carried out as described by Davis and Thomas (1973) (6N HCl, 110°C, 20 hours, hydrolyzer thimble; Ingos, Prague, Czech Republic). According to Schramm, Moor, and Bigwood (1954), protein hydrolysis is undertaken for the separation of sulfuric amino acids. Cysteine was oxidized to cysteic acid, and methionine to methionine sulfone, by using performic acid.

The sample was subject to alkaline hydrolysis (with Ba(OH)2, 110°C, 20 hours) to determine the tryptophan content. Subsequently, the sample was acidified with 6 N HCl, and Na2SO4 solution was added.

The samples thus prepared were loaded onto an amino acid analyzer column (AAA 400; Ingos, Prague, Czech Republic). Amino acid identification using ion-exchange chromatography was carried out via a photometric detector (ninhydrin) at a wavelength of 570 nm for all amino acids and, for proline, at 440 nm. The following four buffers were applied for separation: 1, pH 2.6; 2, pH 3.0; 3, pH 4.25; and 4, pH 7.9.
The limiting amino acid index (Eq. 2) was the quotient of the amino acid in the tested product and its reference value in the standard protein (hen’s egg).

\[ CS = \frac{a_p}{a_w} \]  

(2)

### 2.6. Measurement of physical properties of seeds

Using calipers, the micrometric method was used for the measurement of seed size – that is, the length, width, and thickness of the seeds. The grain densimeter was used for evaluation of the bulk density of the seeds (PN-ISO 7971–2; Sadkiewicz Instruments, Bydgoszcz, Poland).

### 2.7. Grinding of seeds

The *O. tenuiflorum* and *S. hispanica* seeds were ground in a hummer mill (POLYMIX-Micro-Hammermill MFC) with a 1.5-mm sieve. The grinding energy was measured and calculated by using specialized computer software according to the method described by Dziki and Laskowski (2010, 2014).

### 2.8. Analyses of particle size distribution of ground seeds

Particle size analyses of ground seeds were undertaken in triplicate in Mastersizer 3000 (Malvern Instruments Ltd., Great Britain) by using dry dispersions equipment (Aero S) as showed before (Ziemichód et al., 2019).

### 2.9. Color measurements

The color measurements of whole and ground seeds were undertaken in a colorimeter (4Wave CR30-16; Planeta, Tychy, Poland) as showed before (Ziemichód et al., 2019). The color of the bread crumb was measured from the center of the slice (L*\(a^*b^*\) – International Commission on Illumination) with a colorimeter (Precise Color Reader, 4Wave CR30-16) where the probe was directly applied to the surface of the slice.

### 2.10. Baking and characterization of gluten-free bread

#### 2.10.1. Baking procedure of gluten-free bread

Using a single-phase method (Różyło et al., 2015), we developed a process for baking gluten-free bread in the laboratory.

Breads were prepared using a mixture of rice flour and *O. tenuiflorum* or *S. hispanica* whole and ground seeds and other ingredients (Table 1; expressed on 100 g flour). The flour mixture (500 g), dry yeast, salt, and water were mixed for 5 minutes (Kitchen Aid, St. Joseph, MI, USA). The dough was placed into three molds (300 g) and left for 40 minutes to prove (30°C, 75% RH) in a fermentation chamber (Sadkiewicz Instruments, Bydgoszcz, Poland). The laboratory oven was used for baking (230°C, 45–50 minutes).

#### 2.10.2. Measurement of bread volume

Millet seeds were used to measure the bread volume, wherein the volume of millet grains displaced by bread was determined. By dividing the volume by weight of the loaf [cm\(^3\)/g], the specific volume of the bread was determined.

### 2.10.3. Measurement of bread texture

Texture measurements were undertaken on bread samples (30 × 30 × 20 mm\(^3\)) cut from the center of the bread loaf. These measurements were determined for the crumb on days 1 and 3 after baking. The texture profile analysis (TPA) test used double compression at a speed of 1 mm/sto a depth of 50% using ZWICK Z020/TN2S apparatus (Różyło, Dziki, Laskowski, Skonecki, et al., 2014; Różyło, Dziki, & Laskowski, 2014). The texture measurements were done in 9 replications (3 samples of each bread).

### 2.10.4. Sensory evaluation of bread

Sensory evaluation of bread was made according to a nine-point hedonic scale, where 1 means dislike extremely, 5 means neither like nor dislike, 9 means like extremely. During the assessment, the scores for taste, aroma, texture and overall acceptability of breads were evaluated (Lim, Park, Ghafoor, Hwang, & Park, 2011). The panel of 63 untrained consumers (22–49 years old, 34 females and 29 males) rated the breads.

### 2.11. Statistical analysis

The data was collected in triplicate (except texture and sensory), the results were presented in mean±SD. The ANOVA (analysis of variance) was done to determine if there are differences between variables. However, in order to determine between which variables there are differences, the post hoc Tukey test was performed. Statistical analysis was conducted at a significance level of α = 0.05 using Statistica 6.0 (Statsoft software).

### 3. Results and discussion

The swelling characteristics (Figure 1) show that both holy basil and chia can be classified as rapidly swelling seeds, with a substantial volume increase of these seeds that can be observed as early as 1 minute after soaking. Similar results were previously obtained for *Plantago psyllium* and *Plantago ovata* seeds (Ziemichód et al., 2019). This selection of raw material was dictated by its specific swelling properties, therefore these seeds were proposed as a substitute for hydrocolloids. It was based on extensive studies of available scientific literature and preliminary research. *O. tenuiflorum* swells at a higher rate in higher temperatures (i.e., 60–100°C) whereas *S. hispanica* swells best at 20°C and 100°C, although

### Table 1. Ingredients of gluten-free breads.

| Ingredients                  | Control formulation | Enriched gluten-free bread formulations |
|------------------------------|---------------------|----------------------------------------|
| Rice flour (g)               | 100                 | 95                                     |
| Amount of ingredient (whole or ground seeds) (g) | 0                    | 5                                      |
| Dry yeast (g)                | 1                   | 1                                      |
| Salt (g)                     | 2                   | 2                                      |
| Water (mL)                   | 100                 | 125                                     |
| SH, bread with whole seeds of *Salvia hispanica*; SHG, bread with ground seeds of *Salvia hispanica*; BA, bread with whole seeds of *Ocimum tenuiflorum*; BAG, bread with ground seeds of *Ocimum tenuiflorum* | 95        | 120                                     |
| SH, pan con semillas enteras de *Salvia hispanica*; SHG, pan con semillas molidas de *Salvia hispanica*; BA, pan con semillas enteras de *Ocimum tenuiflorum*; BAG, pan con semillas molidas de *Ocimum tenuiflorum* | 95        | 145                                     |
the swelling at 20°C progressed at a lower rate. The highest swelling values in the duration from 5 to 15 minutes were observed for basil, whereas chia seeds were found to swell at a lower rate. For both seeds, the swelling intensity was higher at higher temperatures.

Salgado-Cruz et al. (2013) noticed that chia mucilage is characterized by great water-holding capacity and viscosity (Muñoz, Aguilera, Rodriguez-Turienzo, Cobos, & Díaz, 2012). Holy basil seeds also possess great binding potential (Naji-Tabasi & Razavi, 2017); thus, there exists a need to understand their behavior in the aquatic environment and at different temperatures. In our studies seeds at different temperatures in the range between 20 and 100°C swells with varying intensity. Analyzing the swelling time up to 15 minutes, significant differences occurred for the swelling seeds at 100°C and other temperatures. In the case of basil, the seeds swells most intensively at 100°C and at least at 40°C. Between 20, 60 and 80°C there were no significant

Figure 1. Swelling of Ocimum tenuiflorum and Salvia hispanica seeds in water at various temperatures.

BA, 20°C, 40°C, 60°C, 80°C, and 100°C represent seeds of Ocimum tenuiflorum soaked in water at the specified temperatures. SH, 20°C, 40°C, 60°C, 80°C, and 100°C represent seeds of Salvia hispanica soaked in water at the specified temperatures.

Figura 1. Hinchazón de semillas de Ocimum tenuiflorum y Salvia hispanica en agua a varias temperaturas. BA, 20°C, 40°C, 60°C, 80°C y 100°C representan semillas de Ocimum tenuiflorum remojadas en agua a las temperaturas indicadas. SH, 20°C, 40°C, 60°C, 80°C y 100°C representan semillas de Salvia hispanica remojadas en agua a las temperaturas indicadas.
differences. In the case of chia, the seeds swell the least at 20 and 60°C and most at 80 and 100°C. After 60 minutes of swelling the basil seeds swell the most at 20°C significantly less at 100°C and the least at 40°C while the chia seeds swell the most at 20, 40, 80 and 100°C and the least at 60°C. Other studies (Li & Yeh, 2001) showed that the swelling powers of 10 kinds of starches from cereals, roots, tubers, and peas increased with temperature from 55°C to 95°C. Differences between seeds can be associated with different gelatinisation temperatures (Madriga et al., 2014), particularly important in the initial phases of swelling.

Holy basil and chia are characterized by similar protein content (21.5% and 19.1%, respectively); chia seeds had a markedly higher fat content (32.2%) compared to basil (24.4%; Table 2), whereas holy basil seeds had a higher fiber (45.9%) and sugar content (41.4%). Da Silva et al. (2014) reported the following content for chia seeds: protein level, 25.3%; fat, 30.2%; and fiber, 37.5%. Reyes-Caudillo, Tecante, and Valdivia-Lopez (2008) indicated that, in addition to the high fat content, chia seeds are a good source of protein and fiber.

Data on the composition of holy basil seeds are absent in the available literature. Sweet basil seeds had the following content: protein 20.4% and fat 16.6% (Rezapour et al., 2014; Tecante, and Valdivia-Lopez, 2008). Holy basil and chia seeds did not differ substantially with regard to the content of individual amino acids (Table 3). Higher levels of asparagine, threonine, serine, glutamic acid, proline, glycine, alanine, valine, isoleucine, leucine, phenylalanine, and lysine were detected for chia seeds compared to holy basil seeds. Research conducted by Weber, Gentry, Kohlhepp, and McCrohan (1991) showed that threonine was the first limiting amino acid in chia seed, whereas lysine and leucine were the other limiting amino acids. With regard to the content of amino acids, Ayerza (2013) showed that different genotypes of chia seeds did not significantly differ. Glutamine content was the highest, followed by arginine and asparagine, respectively. Both tryptophan and methionine were present in small amounts. Similarly, Weber et al. (1991) demonstrated the protein quality of chia to be higher than that of common cereals and oil seeds.

The literature lacks reports on the amino acid composition of holy basil seeds. Basil seeds contained significantly more methionine sulfone and tryptophan. We found no significant differences in the content of cysteic acid, tyrosine, histidine, and arginine for those two seed types. Table 4 presents the basic geometric and physical properties of chia and holy basil. Micrometric measurements of seed lengths of both the tested seed types did not differ significantly. Seeds of the holy basil and chia were measured from 2.0 to 2.2 mm in length. The width of the holy basil seed was significantly lower than that of the chia seed, although holy basil seeds were significantly thicker than chia seeds. The raw materials were characterized by variable bulk density, which for holy basil and chia were 710 and 670 kg/m³, respectively. The weight of 1000 seeds was 1.4 g for holy basil, and it was 0.1 g lower for chia, at 1.3 g.

Table 4 presents the grinding energy requirements for holy basil and chia seeds. The specific energy consumption for S. hispanica seeds was substantially higher (233.9 ± 9.2 J/g) than for O. tenuiflourum seeds (207.4 ± 8.5 J/g). As compared to basil seeds, it is surmised that the higher energy consumption could be associated with higher fat and carbohydrate content as well as, possibly, the different structure of chia seeds.

Table 2. Basic chemical (%) and mineral composition (mg/kg) of Salvia hispanica and Ocimum tenuiflourum.

| Kind of seeds | Basic chemical parameters |
|---------------|--------------------------|
| Salvia hispanica | Protein content: 19.11 ± 0.94<sup>b</sup> | Fat content: 32.20 ± 1.00<sup>a</sup> | Sugars content: 1.55 ± 0.09<sup>b</sup> | Fiber content: 41.36 ± 2.05<sup>b</sup> |
| Ocimum tenuiflourum | 21.52 ± 1.01<sup>a</sup> | 24.37 ± 0.82<sup>b</sup> | 1.99 ± 0.15<sup>a</sup> | 45.86 ± 2.13<sup>a</sup> |

Table 3. Amino acid composition of Ocimum tenuiflourum and Salvia hispanica.

| Amino acids | Amount of amino acid (mg/g) |
|-------------|----------------------------|
| Salvia hispanica | Ocimum tenuiflourum |
| Asparagine | 17.2 ± 0.89<sup>a</sup> | 14.3 ± 1.10<sup>b</sup> |
| Threonine | 7.58 ± 0.34<sup>a</sup> | 6.00 ± 0.35<sup>b</sup> |
| Serine | 11.6 ± 0.63<sup>a</sup> | 10.0 ± 0.82<sup>b</sup> |
| Glutamic acid | 36.0 ± 1.91<sup>a</sup> | 31.6 ± 1.89<sup>b</sup> |
| Proline | 7.61 ± 0.38<sup>a</sup> | 6.64 ± 0.37<sup>b</sup> |
| Glycine | 9.88 ± 0.54<sup>a</sup> | 8.90 ± 0.51<sup>b</sup> |
| Alanine | 10.2 ± 0.61<sup>a</sup> | 8.03 ± 0.46<sup>b</sup> |
| Cysteic acid | 5.35 ± 0.30<sup>a</sup> | 5.77 ± 0.23<sup>b</sup> |
| Valine | 9.35 ± 0.46<sup>a</sup> | 7.74 ± 0.44<sup>b</sup> |
| Methionine sulfone | 7.95 ± 0.33<sup>a</sup> | 8.99 ± 0.48<sup>b</sup> |
| Isoleucine | 7.29 ± 0.39<sup>a</sup> | 5.40 ± 0.31<sup>b</sup> |
| Leucine | 13.5 ± 0.75<sup>a</sup> | 11.3 ± 0.63<sup>b</sup> |
| Tyrosine | 5.78 ± 0.22<sup>a</sup> | 5.23 ± 0.29<sup>b</sup> |
| Phenylalanine | 11.0 ± 0.58<sup>a</sup> | 9.31 ± 0.41<sup>b</sup> |
| Histidine | 6.78 ± 0.37<sup>a</sup> | 6.53 ± 0.32<sup>b</sup> |
| Lysine | 9.79 ± 0.49<sup>a</sup> | 5.40 ± 0.27<sup>b</sup> |
| Arginine | 20.4 ± 1.01<sup>a</sup> | 20.5 ± 1.15<sup>b</sup> |
| Tryptophan | 7.93 ± 0.46<sup>a</sup> | 9.60 ± 0.52<sup>b</sup> |

*Values in the same column marked with different letters are significantly (α = 0.05) different.
*Los valores en las mismas columnas señalados con letras diferentes son significativamente diferentes (α = 0.05).
terms of energy consumption, the use of holy basil seeds appears to be more cost-efficient. The breads, baked with holy basil and chia in the form of whole and ground seeds, were characterized by a significantly lower specific volume than the control bread (Figure 2). Apart from the control bread, the largest volume was found for bread with ground chia seeds and the lowest volume for bread with whole chia seeds. There were no significant differences between the volume of bread with whole and ground holy basil seeds. In research presented by Steffolani et al. (2014), the addition of 15g/100g chia more than doubled reduced the specific volume of gluten-free bread, and this effect was more evident with the ground seeds than with whole seeds. Furthermore, Huerta et al. (2016) observed that the specific volume of gluten-free bread reduced with the addition of 5% of chia flour. The same results showed that the bread with 2.5% chia flour had specific volume similar to the ***control. Zdybel, Różyło, and Sagan (2019) similarly noticed that addition of 5% of chia flour significantly reduced volume of 100g of gluten-free bread. Moreover, sweet basil seeds in the amount of 1.0 and 1.5% that were used as an ingredient (Rezapour et al., 2016) reduced the volume of baguettes. However, holy basil seeds have not yet been used in bread production.

Bread volume depends on a variety of factors, including the properties of flour and additives (Siasta, Dziki, & Różyło, 2014). In addition, the type of flour dictates the volume of gluten-free bread and this, in turn, contributes to the porous spatial structure of the crumb, which is formed during the enclosing of gas bubbles – primarily from gelatinized starch as well as the additives that are applied (Diowksz, Sucharzewska, & Ambroziak, 2009). Mir, Shah, Naiq, and Zargar (2016) reported that hydrocolloids significantly affect the dough handling and technological properties of gluten-free breads. The quality of gluten-free breads is mainly affected by the nature and properties of hydrocolloids (Lazaridou, Duta, Papageorgiou, Belc, & Biladeris, 2007). Ashgar, Anjum, Tariq, and Hussain (2005) and Collar, Andreu, Martinez, and Armero (1999) indicated that the loaf volume of bread was significantly affected by the addition of hydrocolloids.

Dough productivity that was determined for the control sample was 200%; for dough made with whole seeds, the productivity increased to 220–225%, for both chia and...
basil; however, for dough made with ground seeds of both additives, a significant increase of dough productivity was observed to values approximating to 250%. This likely occurred due to the characteristic properties of these raw materials—that is, *S. hispanica* as well as *O. tenuiflorum* seeds intensively absorb water when exposed to the aquatic environment, as demonstrated during swelling measurements.

The color of gluten-free bread differed significantly between bread with whole and ground seeds (Table 5). In either case, the visually assessed color was acceptable by consumers. Crumb lightness $L^*$ was significantly lower for bread with ground seeds. The lowest value was observed for bread with ground basil seeds.

Another component of color is the $a^*$ index; the value of this parameter increased markedly in samples to which ground seeds were added in comparison with control bread. The share of red color was highest for chia, which can be explained by the color of the seeds used for the dough. The $b^*$ index of bread crumb color was slightly reduced for each type of additive, with the exception of ground chia seeds (SHG) where it increased by an amount proportional to the other additives.

The addition of both whole and ground *O. tenuiflorum* and *S. hispanica* had a favorable effect on the properties of crumb texture (Figure 3). Following the addition of both whole and ground seeds, crumb hardness was reduced significantly. The lowest hardness characterized bread to which ground holy basil seeds (BAG, 26.6 N) and chia seeds (SHG, 26.4 N) were added; the value of this parameter was reduced by >30% compared to the control bread (C, 39.4 N). Three days after baking, a similar tendency for reducing hardness was observed. The hardness of gluten-free breads reduced from 61.1 N (C) to 41.9 N (SHG) and 42.5 N (BAG), respectively. Breads with ground seeds had the most favorable characteristics in this regard.

The addition of whole chia seeds (SH, 8.6 mm) and holy basil seeds (BA, 8.1 mm) resulted in the highest elasticity gluten-free bread. The elasticity of crumb of those breads increased by >30%. The elasticity of C was 6.2 mm and of BAG (6.9 mm) and SHG (7.6 mm) was significantly higher. Compared to C, the crumb cohesiveness was significantly higher for breads to which SH and SHG as well as BA and BAG were added.

Because natural gluten-free breads without additives are characterized by high hardness, low elasticity, and cohesiveness (Różyło et al., 2015), the reduction of hardness and increase in elasticity and cohesiveness of the crumb are highly favorable aspects. The current literature lacks studies that consider the use of *O. tenuiflorum* seeds in gluten-free bread; the effect on physical properties of bread to which only gum extracted from basil seeds was studied, and it caused valuable changes in bread quality (Dorani, Ghavidel, Davoodi, & Ghavidel, 2016; Israr et al., 2017).

In a previous study, hydrocolloids such as agar-agar or gum arabic markedly reduced crumb hardness (Bourekkoua 

Table 5. Color parameters of whole and ground *Ocimum tenuiflorum* and *Salvia hispanica* seeds in comparison with control and gluten-free breads made with these seeds.

| Material                          | $L^*$         | $a^*$         | $b^*$         |
|----------------------------------|---------------|---------------|---------------|
| Whole seeds of *Salvia hispanica*| 51.13 ± 1.59a | 3.21 ± 0.13b  | 3.33 ± 0.09f  |
| Ground seeds of *Salvia hispanica*| 55.79 ± 2.16d | 3.96 ± 0.16e  | 9.73 ± 0.45a  |
| Bread with whole seeds of *Salvia hispanica* | 76.78 ± 1.73* | 0.42 ± 0.02h  | 12.95 ± 0.63c |
| Bread with ground seeds of *Salvia hispanica* | 66.48 ± 3.04a | 2.75 ± 0.11c  | 16.99 ± 0.83e |
| Whole seeds of *Ocimum tenuiflorum* | 39.82 ± 1.03c | 2.26 ± 0.12d  | 2.10 ± 0.04e  |
| Ground seeds of *Ocimum tenuiflorum* | 48.73 ± 2.40d | 2.40 ± 0.12e  | 2.27 ± 0.09f  |
| Bread with whole seeds of *Ocimum tenuiflorum* | 73.15 ± 1.28h | 0.56 ± 0.03d  | 13.24 ± 0.74f |
| Bread with ground seeds of *Ocimum tenuiflorum* | 57.42 ± 2.65e | 2.33 ± 0.13de | 11.80 ± 0.58ef |
| Control bread (without seeds)    | 74.12 ± 3.36f  | 1.19 ± 0.04f  | 15.31 ± 0.52b |

*a*Values in the same columns marked with different letters are significantly ($\alpha = 0.05$) different.

*a*Los valores en las mismas columnas señalados con letras diferentes son significativamente diferentes ($\alpha = 0.05$).

Figure 3. Textural parameters of a gluten-free bread crumb with *Ocimum tenuiflorum* and *Salvia hispanica* seeds: a) hardness, b) elasticity, and c) cohesiveness.

Figura 3. Parámetros de textura de una miga de pan sin gluten con semillas de *Ocimum tenuiflorum* y *Salvia hispanica*: a) dureza, b) elasticidad y c) cohesión.
et al., 2018). Gluten-free breads are the product of a combination of different ingredients and hydrocolloids that are required to build up network structures that are responsible for bread quality. Various gluten-free formulations have applied hydrocolloids to mimic the viscoelastic properties of gluten and, as a consequence, to improve the texture of bread (Mir et al., 2016).

Sensory evaluation (Table 6) showed that bread with ground holy basil (BAG) and ground chia (SHG) was better evaluated than the control bread. These breads were characterized by better taste and texture, which influenced the overall acceptability. Huerta et al. (2016) did not notice significant differences in the taste, appearance and texture of control bread and bread with a 5% share of chia. Steffolani et al. (2014) noticed that there were no significant differences between the breads in the global acceptability, but chia seed breads presented better values in terms of texture than control. Our bread was made without any improving additives, what could have strengthened the effect of additive.

4. Conclusion

The swelling characteristics showed that both holy basil and chia can be classified as rapidly swelling seeds. These seeds at different temperatures in the range between 20 and 100°C swelled with varying intensity.

Holy basil and chia seeds have variable chemical compositions. Holy basil seeds, compared to chia seeds, were characterized by higher calcium, magnesium, copper, and iron content, whereas chia seeds contained higher levels of potassium, sodium, manganese, and zinc. Higher levels of asparagine, threonine, serine, glutamic acid, proline, glycine, alanine, valine, isoleucine, leucine, phenylalanine, and lysine were found in chia seeds compared to holy basil seeds. However, holy basil seeds contained significantly more methionine sulfone and tryptophan. No significant differences were found in the content of cysteic acid, tyrosine, histidine, and arginine. Both species differ in certain geometric characters and physical properties.

The grinding energy requirement for holy basil seeds was lower than for chia seeds; thus, its use may be more recommended in terms of cost-effectiveness. Both holy basil and chia seeds caused significant increase in dough productivity. The specific volume of gluten-free bread with these seeds, both in whole or ground form, was lower than control bread. Highly favorable changes were observed for the crumb texture. Breads with ground basil and chia seeds had the most favorable characteristics and were acceptable by consumers.

Disclosure statement

No potential conflict of interest was reported by the authors.

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References

Anabarasu, K., & Vijayalakshmi, G. (2007). Improved shelf life of protein-rich tofu using Oicium sanctum (tulsi) extracts to benefit Indian rural population. Journal of Food Science, 72, M300–M305. doi:10.1111/j.1750-3841.2007.00487.x

Aighar, A., Anjum, F. M., Tariq, M. W., & Hussain, S. (2005). Effect of carboxy methyl cellulose and gum arabic on the stabilization of frozen dough for bakery products. Turkish Journal of Biology, 29, 237–241.

Asp, N. G., Johansson, C. G., Hallmer, H., & Siljestrom, M. (1983). Rapid enzymatic assay of insoluble and soluble dietary fiber. Journal of Agricultural and Food Chemistry, 31, 476–482. doi:10.1021/jf00117a003

Ayerza, R. (2013). Seed composition of two chía (Salvia hispanica L.) genotypes which differ in seed color. Emirat Journal of Food and Agricultural, 25, 495–500. doi:10.9755/ejfa.v25i7.13569

Boureoukha, R., Różyło, R., Benatalallah, L., Wójtowicz, A., Lysiak, G., Zidoune, M. N., & Sujak, A. (2018). Characteristics of gluten-free bread: Quality improvement by the addition of starches/hydrocolloids and their combinations using a definitive screening design. European Food Research and Technology, 242(4), 345–354. doi:10.1007/s00217-017-1960-9

Bueno, M., Di Sapio, O., Barolo, M., Busilacchi, H., Quiroga, M., & Severin, C. (2010). Quality tests of Salvia hispanica L. (Lamiaceae) fruits marketed in the city of Rosario (Santa Fe province, Argentina). Boletin Latinoamericano Y Del Caribe De Plantas Medicinales Y Aromáticas, 9(3), 221–227.

Collar, C., Andreu, P., Martínez, J. C., & Armero, E. (1999). Optimization of hydrocolloid addition to improve wheat bread dough functionality: A response surface methodology study. Food Hydrocolloid, 13(6), 467–475. doi:10.1016/S0265-6767(99)00030-2

Costantini, L., Lukic, L., Molinari, R., Kreft, I., Bonafaccia, G., Manzi, L., & Merendino, N. (2014). Development of gluten-free bread using tartary buckwheat and chia flour rich in flavonoids and omega-3 fatty acids as ingredients. Food Chemistry, 165, 232–240. doi:10.1016/j.foodchem.2014.03.133

Da Silva, M. R., Aguiar Moraes, E., Alves Lenquiste, S., Teixeira Godoy, A., Nogueira Eberlin, M., & Roberto Maróstica, M., Jr. (2014). Chemical characterization and antioxidant potential of Chilean chia seeds and oil (Salvia hispanica L). LWT - Food Science and Technology, 59(2), 1304–1310. doi:10.1016/j.lwt.2014.04.014

Davis, M. G., & Thomas, A. J. (1973). An investigation of hydrolytic techniques for the amino acid analysis of foodstuffs. Journal of the Science of Food and Agriculture, 24(12), 1525–1540. doi:10.1002/jsfa.2740241208

Devi, P. U. (2001). Radioprotective, anticarcinogenic and antioxidant properties of the Indian holy basil, Oicium sanctum (Tulasi). Indian Journal of Experimental Biology, 39(3), 185–190.

Dziatkosz, A., Sucharzewska, D., & Ambrozik, W. (2009). Function of dietary fibre in forming functional properties of gluten-free dough and bread (in polish). ZYWNOŚĆ. Nauka. Technologia. Jakość, 2(63), 83–93.

Doron, F., Ghavidel, R. A., Davoodi, M. G., & Ghavidel, R. A. (2016). Effect of soybean meal and basil seed gum on physical and sensory quality of wheat bread. Advances in Food Sciences, 38(1), 14–21.

Dziuki, D., Cassak-Pietrzak, G., Mil, A., Jonczyk, K., & Gawlik-Dziuki, U. (2014). Influence of wheat kernel physical properties on the pulverizing process. Journal of Food Science and Technology, 51(10), 2648–2655. doi:10.1007/s13197-012-0807-8

Dziuki, D., & Laskowski, J. (2010). Study to analyze the influence of sprouting of the wheat grain on the grinding process. Journal of Food Engineering, 96(4), 562–567. doi:10.1016/j.jfoodeng.2009.09.002
Verdu, S., Vasquez, F., Ivorra, E., Sanchez, A. J., Barat, J. M., & Grau, R. (2015). Physicochemical effects of chia (Salvia hispanica) seed flour on each wheat bread-making process phase and product storage. *Journal of Cereal Science, 65*, 67–73.

Weber, C. W., Gentry, H. S., Kohlhepp, E. A., & McCrohan, P. R. (1991). The nutritional and chemical evaluation of Chia seeds. *Ecology Food and Nutrition, 26*(2), 119–125.

Zdybel, B., Różyło, R., & Sagan, A. (2019). Use of a waste product from the pressing of chia seed oil in wheat and gluten-free bread processing. *Journal of Food Processing and Preservation, (e)*, 14002. doi:10.1111/jfpp.14002

Zettel, V., Kramer, A., Hecker, F., & Hitzmann, B. (2015). Influence of gel from ground chia (Salvia hispanica L.) for wheat bread production. *European Food of Research and Technology, 240*(3), 655–662.

Ziemichód, A., Wójcik, M., & Różyło, R. (2019). Seeds of Plantago psyllium and Plantago ovata: Mineral composition, grinding, and use for gluten-free bread as substitutes for hydrocolloids. *Journal of Food Process Engineering, 42*, 1. doi:10.1111/jfpe.12931