Effect of partial substitution of gluten-free flour mixtures with chia (*Salvia hispanica* L.) flour on quality of gluten-free noodles

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Revised: 5 April 2017 / Accepted: 7 April 2017 / Published online: 20 April 2017
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Abstract In this study, chia seed flour (CSF) was used in gluten-free noodle formulation at different levels (0, 10, 20 and 30%, w/w) with and without diacetyl tartaric esters of mono (and di) glycerides (DATEM). Chemical, nutritional, sensory properties and cooking quality of gluten-free noodle samples were investigated. Protein, fat, antioxidant activity and total phenolic content of gluten-free noodles increased by 1.7, 5.5, 2.6 and 2.0 times at 30% usage level of CSF as compared to control sample. Phytic acid and phytate phosphorus content increased from 168.30 mg/100 g and 47.46 mg/100 g to 1057.69 mg/100 g and 298.27 mg/100 g, respectively with CSF usage. Increase of CSF level in gluten-free noodle samples caused an expected increase in the amounts of Ca, P, K, Mg, Fe and Zn. Noodle samples containing CSF showed darker colour than control. Significant increase was observed in volume increase and weight increase values with CSF addition. DATEM reduced cooking loss values of noodle samples. The use of CSF improved the gluten-free noodles taste and odor score. As a result, 20% of CSF with DATEM can be used in gluten-free noodle formulation with acceptable sensory attributes of raw and cooked samples. The present results showed that CSF had a good potential to improve the nutritional quality of noodle.

Keywords Chia · Gluten-free · Noodle · DATEM

Introduction

Celiac disease (CD) is an inflammatory disease of the small intestine caused by the ingestion of gluten proteins from wheat, barley and rye in genetically predisposed individuals (Schuppan et al. 2009). Currently, the only effective treatment of CD is a lifelong adherence to a gluten-free diet. Modern diets are predominantly based on gluten-containing products therefore it is difficult for celiac patients to strictly follow a gluten-free diet over the long term (Caruso et al. 2013).

CD affects approximately 1% of the general population and there has been a significant increase in the number of people diagnosed with celiac disease by improved analytical methods over the past 10 years (Caruso et al. 2013). As a result of diagnosis of people suffering from the CD more quickly than any other time in history, the market for gluten-free products is increasing (Cureton and Fasano 2009; Houben et al. 2012). Most of the gluten-free products are produced with recipes based on flours and starches with the addition of different types of hydrocolloids. For this reason, gluten-free foods are of poor quality, low nutritional value and lack variety with lower palatability (Lerner 2010). Gluten-free noodle can be an alternative to celiac patients due to its ease of transportation, handling, cooking and storage (Yalçın 2005). It can be enriched with supplements from various sources to improve the nutritional quality.

Chia seeds, the seeds of *Salvia hispanica* L., were an important staple food for Mesoamericans cultures in pre-Colombian times (Reyes-Caudillo et al. 2008). Today, chia is cultivated commercially in Mexico, Bolivia, Argentina, Ecuador, Guatemala and consumed traditionally in Mexico, southwestern United States and small amount in South America (Ixtaina et al. 2008). They are important not only

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as food, but also for medicines and paints (Ixtaina et al. 2008). Oil content of chia seeds ranges from 25 to 38% which is rich in polyunsaturated fatty acids: omega-3 linolenic acid (54–67%) and omega-6 linoleic acid (12–21%). Essential polyunsaturated fatty acids can not be synthesized in the human body and must be obtained from the diet. Chia oil contains the highest proportion of omega-3-linolenic acid (more than 60%), compared to other natural source known (Ixtaina et al. 2008; Pizarro et al. 2013; Ullah et al. 2016). The seeds are also a significant source of protein (19–23%) and dietary fiber (18–30%), vitamin and mineral (Coates and Ayerza 1996; Ixtaina et al. 2008; Coelho and de las Mercedes Salas-Mellado 2015). Moreover, it is reported that chia seed extracts contain some compounds, myricetin, quercetin, kaempferol, chlorogenic and caffeic acid with potent antioxidant activity (Ullah et al. 2016). Due to its valuable contents especially polyunsaturated fatty acids, chia is important raw material for obtaining functional foods (Coates and Ayerza 1996; Ixtaina et al. 2008). It was reported that chia helps to increase satiety index, reduce the risk of cardiovascular diseases, inflammatory and nervous system disorders, diabetes, dyslipidemias and also it has an anti-blood clotting, laxative, antidepressant, analgesic, vision and immune improver effects (Muñoz et al. 2013; Coelho and de las Mercedes Salas-Mellado 2015; Ullah et al. 2016).

Emulsifiers are an important group of additives used in cereal based products to improve dough handling characteristics and end product quality. Some commonly used emulsifiers are DATEM, sodium stearyl-2-lactylate, lecithin, monoglycerides and sucrose esters of fatty acids. The use of emulsifiers in noodle-type products has been reported to increase both dough and noodle quality (Kohajdová et al. 2009; Bilgiçli et al. 2011).

The aim of this study was to develop a new gluten-free noodle with high nutritional and functional quality by incorporating CSF and emulsifier (DATEM) into gluten-free noodle formulation. The effects of CSF and emulsifier (DATEM) on the physical, chemical, cooking and sensory properties of gluten-free noodle were evaluated.

Materials and methods

Materials

The chia, *Salvia hispanica* L., seeds (4.38 g/100 g ash, 18.63 g/100 g protein, 32.77 g/100 g fat), rice flour (0.29 g/100 g ash, 7.1 g/100 g protein, 1.29 g/100 g fat), corn starch (0.09 g/100 g ash, 1.96 g/100 g protein, 0.94 g/100 g fat), whole egg and salt were purchased from a local market in Konya. Xanthan gum was obtained from Vatan Gıda (Istanbul, Turkey). CSF was obtained by milling of

chia seeds with coffee grinder (Tefal, Istanbul, Turkey). Diacetyl tartaric acid esters of mono and diglycerides (DATEM, Rikevita, Malaysia) was also used in gluten-free noodle formulation.

Methods

Noodle production

The basic ingredients of control noodle are gluten-free flour (100 g, rice flour:corn starch; 50:50), whole egg (30 g), xanthan gum (3 g), salt (0.5 g) and water (40 ml). Gluten-free flour used in noodle production was replaced with CSF at 0, 10, 20 and 30% levels. Diacetyl tartaric acid esters of mono (and di) glycerides (DATEM) was used as an emulsifier at 0 and 0.8% levels (flour base) as given in experimental design (Table 1). Gluten-free noodles were prepared according to method given by Özkaya et al. (2001). To prepare control noodles, all ingredients were mixed in Hobart mixer (Hobart N50, Canada) for 8 min. The noodle dough was rested at room temperature for 15 min. The dough was divided into two pieces and thickness of the dough was reduced to 2 mm by passing through the reduction rolls of noodle machine (Shule Pasta Machine, China). Then, dough sheets were cut into noodle strip with noodle machine and dried in drying cabinet (Nüve FN-500, Ankara, Turkey) at 50 °C for 18 h. The dried samples were packed in polyethylene plastic bags and stored at room temperature until used for analysis.

Chemical analysis

Due to its technological superiority, only DATEM added samples were used for chemical and sensory analysis. Samples were analyzed for their moisture (AACC method 44-01), ash (AACC method 08-01), protein (AACC method 46-12) and fat (AACC method 30-25) (AACC 1990). Phytic acid (PA) in the sample was extracted using a solution of HCl (0.2 mol/l) and precipitated by solution of ammonium iron (III) sulphate dodecahydrate. Phytate phosphorus value was multiplied by 3.546 factor to determine PA (Haug and Lantzsch 1983).

For mineral content determination, approximately 0.5 g of ground samples were put into a burning cup and mixed with 10 ml $\text{HNO}_3 + \text{H}_2\text{SO}_4$. The samples were incinerated in a microwave oven (MARS-5 Cem, Matthews, NC, USA) at 200 °C and dissolved ash was diluted with a certain volume of water. Contents were determined with an inductively coupled plasma atomic-emission spectrometer (Varian Vista Model, Agilent Technologies, Melbourne, Australia) (Skujins 1998).

Extracts for total phenolic content (TPC) and antioxidant capacity (AC) were prepared according to

Table 1 Experimental design of gluten-free noodles

Gluten-free noodle	Gluten-free flour mix (%)	CSF (%)	DATeM (%; flour basis)
0% CSF	100	–	–
0% CSF + DATeM	100	–	0.8
10% CSF	90	10	–
10% CSF + DATeM	90	10	0.8
20% CSF	80	20	–
20% CSF + DATeM	80	20	0.8
30% CSF	70	30	–
30% CSF + DATeM	70	30	0.8

CSF chia seed flour, DATeM diacetyl tartaric esters of mono (and di) glycerides

Wronkowska et al. (2010) with some modifications. The gluten-free noodle samples (1 g) in powder form were extracted with 80% aqueous methanol (10 ml) by shaking at 37 °C for 2 h. Samples then centrifuged at 2600g for 15 min. The fresh methanolic extracts were used for the determination of TPC and their ability to scavenge DPPH (2,2-diphenyl-1-picrylhydrazyl) radicals.

TPC were determined colorimetrically using Folin–Ciocalteu reagent as described by Wronkowska et al. (2010) with some modifications. For total phenolic assay, 0.1 ml aliquot extract was mixed with 0.9 ml of de-ionized water, 2 ml of Na₂CO₃ (10% w/v) and 1 ml of Folin–Ciocalteu reagent (90% v/v). The mixture was allowed to stand in the dark at room temperature for 1 h. The absorbance was measured at 765 nm by using a spectrophotometer (Mecasys Optizen Pop UV–Vis Single Beams Spectrophotometer, 10F, 640-3, Banseok-dong, Yuseong-gu, Daejeon, Korea). TPC was expressed as µg of gallic acid equivalents (GAE) per gram of dry weight.

AC was measured using a free radical 2,2 diphenyl-1-picrylhydrazyl (DPPH) solution in methanol according to the method given by Wronkowska et al. (2010) with some modifications. The extract (100 µl) was mixed with methanolic DPPH solution (250 µl, 10 mg DPPH/25 ml 80% methanol) and 80% methanol (2 ml). The mixture was incubated in the dark at room temperature for 20 min. The absorbance was measured at 517 nm against the blank. The blank consisted of 80% methanol and the reagent solution without 80% methanolic extract added and the procedure was carried out as described above. AC was calculated as percentage of discoloration: $AC\% = [1 - (\text{Abs}_{\text{sample}} / \text{Abs}_{\text{control}})] \times 100$.

Colour measurement

Colour measurements were performed using Minolta chroma meter CR-400 (Minolta, Osaka, Japan). The numerical values of the colour were expressed as lightness (L*, light–dark), redness (a*, ±red–green) and yellowness

(b*, ±yellow blue). The chroma (C*) ($\sqrt{a^{*2} + b^{*2}}$) describes the brightness or vividness of colour. The hue angle which describes the hue or colour of noodle sample, was calculated as $\arctan [b^*/a^*]$ (if $a > 0$ and $b > 0$) or ($\arctan [b^*/a^*] + 180^\circ$) (if $a < 0$ and $b > 0$) (Francis 1998).

Cooking properties

The changes in volume, weight and cooking losses were determined according to Bilgili et al. (2011). Ten g of noodles were cooked for 18 min in 300 ml of distilled water. To determine the volume increase, uncooked and cooked noodle samples were put into a graduated cylinder with specific amount of distilled water, the increase in water level was measured. The volume increase was calculated as the percentage difference in volume of uncooked and cooked noodles divided by the volume of uncooked noodles. The weight increase was determined as the percentage difference in weight of uncooked and cooked (after draining) noodle divided by the weight of uncooked noodle. Cooking loss, the weight of total solids expressed as a percentage, was determined by drying the cooking water to constant weight at 100 °C.

Sensory analysis

Raw and cooked noodle samples were subjected to sensory analysis. Before analysis of cooked noodle, 100 g noodles were simmered in 1-l unsalted water for 18 min and drained. Noodle samples were served to untrained panelists (n = 26) to evaluate the surface smoothness, speck, crack, and appearance of uncooked noodle and stickiness, taste, odor and chewiness of cooked noodle on a nine-point hedonic scale where 1-dislike extremely, 2-dislike very much, 3-dislike moderately, 4-dislike slightly, 5-neither like nor dislike, 6-like slightly, 7-like moderately, 8-like very much, 9-like extremely.

Statistical analysis

The data were analyzed by using statistical software JMP 8.0 (SAS Institute, Cary, NC, USA). The values are average of triplicate determinations on two replicate noodle preparations. Student's *t* test was used to determine significant differences among the samples. Significance was defined at 5% level.

Results and discussion

Chemical properties of gluten-free noodles

Chemical compositions, nutritional and antinutritional properties of gluten-free noodles are given in Table 2. Increase in the amount of CSF in noodle formulation increased the ash, protein, fat, PA, phytate phosphorus content, AC and TPC of the noodle samples significantly ($p < 0.05$). Pizarro et al. (2013) and Pizarro et al. (2015) found similar results for ash, protein and fat content of pound cake and bread supplemented with chia, respectively. Protein, fat, AC and TPC levels of gluten-free noodles increased 1.7, 5.5, 2.6 and 2.0 fold, respectively, compared to the control sample at 30% CSF substitution level. This is an expected result because CSF has high protein and fat content, TPC and AC (18.63 g/100 g, 32.77 g/100 g, 1610.37 µg/g and 88.45%, respectively data not shown). Costantini et al. (2014) reported that chia flour usage (at 10% ratio) in wheat bread led to a significant increase in TPC and total AC of bread samples. PA and phytate phosphorus contents of gluten-free noodles varied in the range from 168.30 to 1057.69 mg/100 g and 47.46 to 298.27 mg/100 g, respectively. The high PA and phytate phosphorus content of CSF (2147.58 mg/100 g and 605.63 mg/100 g, data not shown) directly affected PA and phytate phosphorus contents of gluten-free noodles. From the nutritional point of view, the increase in PA and phytate phosphorus content is not desirable. PA is an antinutritional agent and is known to bind minerals, proteins and starch. This binding alters the solubility, functionality, digestion and absorption of these food components (Kumar et al. 2010). Different processing techniques or phytase sources can be used for decreasing PA content foods and increasing the availability of the nutrients (Bilgiçli et al. 2006; Kumar et al. 2010).

However, PA has health benefits as well as the adverse effects. It has been shown to be protective against a variety of cancers with antioxidant effects especially colon cancer and coronary diseases also it has therapeutic use against diabetes mellitus, reduces kidney stone formation, HIV-1 and heavy metal toxicity. But, the information about the amount of PA for benefiting the health advantages without

Table 2 Chemical composition, nutritional and antinutritional properties of gluten-free noodles

	Moisture (%)	Ash (%) [*]	Protein (%) [*]	Fat (%) [*]	Phytic acid (mg/100 g) [*]	Phytate phosphorus (mg/100 g) [*]	Antioxidant capacity (%) [*]	Total phenolic content (µg/g) [*]
Control + DATEM	11.33 ± 0.21 ^{ab}	1.10 ± 0.07 ^d	6.23 ± 0.17 ^d	2.18 ± 0.11 ^d	168.30 ± 7.35 ^d	47.46 ± 0.72 ^d	20.37 ± 0.35 ^d	184.44 ± 6.14 ^d
10% CSF + DATEM	10.99 ± 0.30 ^{ab}	1.48 ± 0.08 ^c	7.64 ± 0.13 ^c	5.45 ± 0.14 ^c	463.25 ± 8.34 ^c	130.64 ± 1.78 ^c	33.03 ± 0.18 ^c	244.57 ± 4.34 ^c
20% CSF + DATEM	10.70 ± 0.11 ^b	1.90 ± 0.06 ^b	9.01 ± 0.18 ^b	8.65 ± 0.17 ^b	723.18 ± 6.79 ^b	203.94 ± 0.89 ^b	42.28 ± 0.27 ^b	312.59 ± 3.56 ^b
30% CSF + DATEM	11.55 ± 0.38 ^a	2.15 ± 0.07 ^a	10.41 ± 0.20 ^a	11.98 ± 0.13 ^a	1057.69 ± 9.18 ^a	298.27 ± 1.33 ^a	53.47 ± 0.16 ^a	377.78 ± 4.95 ^a

Values are the average of triplicate measurements on the duplicate sample ± standard deviation

^{*} Results are dry-weight basis; CSF chia seed flour, DATEM diacetyl tartaric esters of mono (and di) glycerides; Data in the same column sharing a lowercase common letter are not significantly ($p < 0.05$) different

causing any adverse effects is limited (Thompson and Zhang 1991; Kumar et al. 2010).

Mineral element concentrations of gluten-free noodles are shown in Table 3. The use of CSF increased all mineral contents of noodle samples significantly ($p < 0.05$). Gluten-free noodles supplemented with CSF (30%) had more Ca, P, K, Mg, Fe and Zn (11.4, 1.7, 2.2, 5.0, 3.0 and 1.5 times, respectively) than control samples.

The recommended dietary allowances (RDA) for adults are 900 mg of calcium, 1.4–1.5 g phosphorus, 2 g of potassium, 350 mg of magnesium, 10 mg of iron and 13 mg of zinc (Demirci 2007). When 100 g gluten-free noodle containing 30% CSF was consumed 22, 24, 19, 32, 25 and 19% of RDA for Ca, P, K, Mg, Fe and Zn can be provided in human body, respectively. These RDA ratios were 2.0% of Ca, 13.6% of P, 8.7% of K, 6.5% of Mg, 8.1% of Fe and 12.5% of Zn in the gluten-free noodle control samples. Da Silva Pereira et al. (2013) stated that chia seeds contain high amounts of minerals, proteins, dietary fiber and polyunsaturated fatty acids and are a good alternative to enrich gluten-free products.

The rich Ca, P, K, Mg, Fe and Zn content of CSF (581.50 mg/100 g, 1078.14 mg/100 g, 760.90 mg/100 g, 327.06 mg/100 g, 6.18 mg/100 g and 4.42 mg/100 g, respectively, data not shown) affected mineral content of end product. In celiac patients, consumption of foods with rich mineral content is important because of the malabsorption of nutrients due to the inflammatory process in the small intestine caused by the disease (Gohara et al. 2013).

Cooking properties of gluten-free noodles

Cooking properties of noodles are given in Table 4. Gluten-free noodles containing CSF had higher volume increase and weight increase values than control samples. The volume increase and weight increase values of control noodles were found as 134.6 and 151.1%, respectively. The volume increase and weight increase values increased to 155.0–221.4 and 152.6–167.3% with CSF supplementation, respectively. The fiber of chia seeds contains mucilage that presents similar properties to several hydrocolloids and

this mucilage has high water absorption and retention capacity (Muñoz et al. 2012; Steffolani et al. 2015). The presence of mucilage in CSF and its high water absorption capacity may have been effective on the increment in volume increase and weight increase values of gluten-free noodles. Kaur et al. (2015) reported that the gums enhanced swelling capacity of mung and corn starch granules by inhibiting leakage of starch components during gelatinization. Pizarro et al. (2015) reported that whole chia flour and vital gluten contributed to the maintenance of the moisture content of breads during the storage period. The use of DATEM significantly ($p < 0.05$) increased both volume and weight increase values of gluten-free noodles at all enrichment ratios compared to samples without DATEM. Cooking loss is one of the most important quality parameters of pasta and noodles and is generally used by both consumers and industry as a predictor of overall spaghetti cooking performance (Tudorica et al. 2002). Cooking loss of gluten-free noodle samples ranged between 5.9 and 6.8%. At the highest enrichment ratio of CSF (30%) with DATEM, the lowest cooking loss value was obtained. Kaur et al. (2016) reported that more proteins found in flours might reduce the swelling of starch granules thus prevent solid loss. In the study by Kaur et al. (2015), the noodles prepared with gums had significantly lower cooking loss than prepared without the gums which may be due to the complex formation between amylose and hydrocolloid. It was also reported that the lowest cooking loss of noodles prepared from mung bean starch might be attributed to the highest amylose content. High protein content and mucilage at the highest CSF level (30%) may have been effective in reducing the cooking loss value of gluten-free noodles.

Cooking loss values of samples with DATEM were found to be lower than samples without DATEM at the same enrichment ratio but this difference was not significantly different ($p < 0.05$). Also, the addition of DATEM may help to strengthen the final product and prevent leakage of solids during cooking. The interaction between emulsifier and the proteins improved dough properties and cooking quality of noodle (Bilgiçli et al. 2011). Ding and Yang (2013) reported that dough rheological

Table 3 Mineral element concentrations of gluten-free noodles

	Ca (mg/100 g)	P (mg/100 g)	K (mg/100 g)	Mg (mg/100 g)	Fe (mg/100 g)	Zn (mg/100 g)
Control + DATEM	17.74 ± 0.71 ^d	196.72 ± 1.24 ^d	173.35 ± 1.65 ^d	22.58 ± 1.90 ^d	0.81 ± 0.04 ^d	1.62 ± 0.03 ^d
10% CSF + DATEM	78.86 ± 1.37 ^c	244.17 ± 1.06 ^c	240.51 ± 1.32 ^c	56.44 ± 2.12 ^c	1.35 ± 0.01 ^c	1.89 ± 0.06 ^c
20% CSF + DATEM	132.57 ± 1.24 ^b	298.53 ± 0.96 ^b	311.79 ± 1.81 ^b	82.77 ± 1.27 ^b	1.88 ± 0.06 ^b	2.27 ± 0.04 ^b
30% CSF + DATEM	201.43 ± 1.92 ^a	342.24 ± 1.37 ^a	381.35 ± 1.68 ^a	113.57 ± 1.97 ^a	2.51 ± 0.03 ^a	2.48 ± 0.01 ^a

Results are dry-weight basis; Values are the average of triplicate measurements on the duplicate sample ± standard deviation; CSF chia seed flour, DATEM diacetyl tartaric esters of mono (and di) glycerides; Data in the same column sharing a lowercase common letter are not significantly ($p < 0.05$) different

Table 4 Effect of incorporation of CSF and DATEM on colour parameters and cooking properties of gluten-free noodles

	L*	a*	b*	C*	hue	Volume increase (%)	Weight increase (%)	Cooking loss (%)
Control	90.36 ± 0.55 ^a	−0.82 ± 0.20 ^f	15.16 ± 0.21 ^a	15.18 ± 0.24 ^a	93.10 ± 0.89 ^a	134.6 ± 1.56 ^f	151.1 ± 0.35 ^h	6.8 ± 0.42 ^a
Control + DATEM	91.38 ± 0.34 ^a	−1.07 ± 0.14 ^f	15.23 ± 0.36 ^a	15.26 ± 0.27 ^a	94.02 ± 0.34 ^a	155.0 ± 1.84 ^e	152.6 ± 0.85 ^g	6.6 ± 0.35 ^{ab}
10% CSF	78.80 ± 0.47 ^b	−0.19 ± 0.23 ^e	10.62 ± 0.27 ^b	10.62 ± 0.21 ^b	91.03 ± 0.45 ^b	164.4 ± 0.85 ^d	162.1 ± 0.14 ^c	6.7 ± 0.40 ^a
10% CSF + DATEM	76.29 ± 0.53 ^c	−0.11 ± 0.28 ^{de}	11.13 ± 0.31 ^b	11.13 ± 0.34 ^b	90.58 ± 0.32 ^b	175.0 ± 1.27 ^c	167.3 ± 0.35 ^a	6.3 ± 0.51 ^{ab}
20% CSF	70.61 ± 0.42 ^e	0.41 ± 0.16 ^{bc}	10.62 ± 0.16 ^b	10.62 ± 0.28 ^b	87.77 ± 0.55 ^c	164.7 ± 1.13 ^d	160.4 ± 0.85 ^d	6.6 ± 0.49 ^{ab}
20% CSF + DATEM	71.74 ± 0.50 ^d	0.31 ± 0.20 ^{cd}	10.66 ± 0.25 ^b	10.66 ± 0.26 ^b	88.35 ± 0.36 ^c	221.4 ± 1.98 ^a	165.8 ± 0.71 ^b	6.1 ± 0.71 ^{ab}
30% CSF	65.34 ± 0.55 ^f	0.87 ± 0.14 ^a	10.89 ± 0.33 ^b	10.92 ± 0.35 ^b	85.43 ± 0.51 ^d	166.6 ± 1.70 ^d	154.4 ± 0.35 ^f	6.5 ± 0.57 ^{ab}
30% CSF + DATEM	65.73 ± 0.46 ^f	0.85 ± 0.16 ^{ab}	10.94 ± 0.28 ^b	10.97 ± 0.22 ^b	85.54 ± 0.49 ^d	187.5 ± 1.41 ^b	156.5 ± 0.45 ^e	5.9 ± 0.42 ^b

Values are the average of triplicate measurements on the duplicate sample ± standard deviation. CSF chia seed flour, DATEM diacetyl tartaric esters of mono (and di) glycerides; Data in the same column sharing a lowercase common letter are not significantly ($p < 0.05$) different

characteristics and quality of noodles improved significantly with the addition of P60 and DATEM emulsifiers.

Colour values of gluten-free noodles

Colour values of gluten-free noodles are given in Table 4. The addition of CSF decreased the brightness and yellowness and increased the redness of gluten-free noodle compared to the control. Coelho and de las Mercedes Salas-Mellado (2015) observed a significant decrease in the brightness of bread crumb by the addition of chia materials. Similarly, Steffolani et al. (2014) reported that the addition of chia (15%, rice flour basis) produced a darker crumb and crust in the gluten-free bread.

Sensory properties of gluten-free noodles

Sensory properties of uncooked and cooked noodle are presented in Table 5. CSF improved the taste score of cooked noodle samples but this increase was not found statistically different. The addition of CSF at 30% decreased especially the surface smoothness, speck and appearance score of raw and chewiness score of cooked noodle samples. Steffolani et al. (2014) reported that 15% chia supplementation chia did not reduce sensory acceptability of gluten-free breads. Pizarro et al. (2013) used different contents of whole chia flour (0–30 g/100 g flour mixture) and hydrogenated vegetable fat (12–20 g/100 g flour mixture) in pound cake production and they reported that cake formulations containing 15 g chia flour and 20 g of hydrogenated vegetable fat exhibited good sensory acceptance.

Conclusion

The effects of CSF substitution on noodle quality were investigated. CSF addition to gluten-free noodle formulation increased ash, protein, fat, TPC, AC as well as PA and phytate phosphorus of gluten-free noodle. In addition, CSF substitution significantly increased Ca, P, K, Mg, Fe and Zn contents of noodle samples. The addition of CSF decreased the brightness of gluten-free noodles and caused a dark colour. When compared to the control, higher volume increase and weight increase values were obtained with CSF addition. DATEM improved the gluten-free noodle quality in terms of volume increase and weight increase. Cooking loss of noodle samples at the highest enrichment ratio (30%) with DATEM was found to be significantly lower than control samples without DATEM. Chewiness score of gluten-free noodle samples decreased by the addition of 30% CSF. The results of this study showed 20% of CSF can be used for the development of a

Table 5 Sensory properties of uncooked and cooked gluten-free noodles

Gluten-free noodle	Uncooked				Cooked			
	Surface smoothness	Speck	Crack	Appearance	Stickiness	Taste	Odor	Chewiness
Control + DATEM	9.0 ± 0.28 ^a	9.0 ± 0.28 ^a	8.8 ± 0.28 ^a	9.0 ± 0.28 ^a	9.0 ± 0.28 ^a	8.6 ± 0.42 ^a	8.0 ± 0.28 ^b	9.0 ± 0.28 ^a
10% CSF + DATEM	8.6 ± 0.14 ^{ab}	8.5 ± 0.57 ^a	8.7 ± 0.28 ^a	8.8 ± 0.42 ^{ab}	8.8 ± 0.42 ^a	8.7 ± 0.28 ^a	8.8 ± 0.14 ^a	8.8 ± 0.42 ^a
20% CSF + DATEM	8.2 ± 0.42 ^{bc}	8.2 ± 0.42 ^{ab}	8.2 ± 0.42 ^a	8.4 ± 0.57 ^{ab}	8.8 ± 0.57 ^a	8.7 ± 0.14 ^a	8.5 ± 0.14 ^{ab}	8.4 ± 0.57 ^a
30% CSF + DATEM	7.6 ± 0.14 ^c	7.4 ± 0.14 ^b	8.0 ± 0.14 ^a	7.8 ± 0.14 ^b	8.2 ± 0.42 ^a	8.8 ± 0.28 ^a	8.0 ± 0.42 ^b	3.8 ± 0.28 ^b

Values are mean ± standard deviation; CSF chia seed flour, DATEM diacetyl tartaric esters of mono (and di) glycerides; Data in the same column sharing a lowercase common letter are not significantly ($p < 0.05$) different

new gluten-free product with minimum adverse effects on sensory properties with DATEM.

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