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POTENTIAL OF QUINOA FOR PRODUCTION OF NEW NON-DAIRY BEVERAGES WITH REDUCED GLYCEMIC INDEX

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ABSTRACT

Recently, there has been a growing effort to include underutilised crops to food products. The potential of pseudocereal quinoa for the production of non-dairy plant-based beverages was investigated. Developed products were analyzed for nutritional composition, sugars, glycemic index, technological parameters, and sensory acceptance in comparison with a commercial quinoa beverage. Quinoa beverages contained 0.60-0.63 g per 100 mL proteins, had a medium glycemic index and their energy values ranged from 113.14 to 120.79 kJ per 100 mL of beverage. For improvement sensory acceptance of beverages, these were sweetened with natural sweeteners with a low glycemic index (inulin or agave syrup). It was found that the final products had similar consistency as commercial quinoa drink, but showed a lower overall acceptance. Moreover, it was determined that the acceptance of beverages sweetened with agave syrup was higher than those sweetened with inulin.
Due to the absence of gluten in quinoa and medium glycemic index of final products, the developed beverages can represent a new alternative for consumers with special nutritional needs. The addition of suitable ingredients may be recommended to improve their acceptance.

Keywords: quinoa, glycemic index, beverages, sensory evaluation, nutritional composition

INTRODUCTION

In the last decades, considerable attention of researchers was oriented to inclusion of underutilised grains and pseudocereals (starch-rich grains, but dicotyledons) to different types of foods and beverages **(Vega-Gálvez *et al*., 2010; Kaur and Tanwar, 2016; Urquizo *et al*., 2017; Lorruso *et al*., 2018)**.
Quinoa (*Chenopodium quinoa*) is an ancient crop originated in the Andean region of South America that is known for its nutritional and health benefits **(Zannini *et al*., 2018)**. Quinoa is a rich source of protein (12-20%), as its protein level is remarkably higher than in common cereals **(Väkeväinen *et al*., 2020)**. The globulins (37%) and albumins (35%) are the major proteins found in quinoa, while prolamins are present in a low percentage (0.5–7.0%) **(Dakhili *et al*., 2019)**. Due to this fact, the consumption of quinoa and quinoa derived products is recommended for celiac disease patients **(Agregán *et al*., 2022)**. Moreover, the proteins of this pseudocereal contain a high amount of essential amino acids, such as lysine (5.1–6.4%) (limiting amino acid in some grains and wheat), methionine, and threonine **(Urquizo *et al*., 2017; Aguilar *et al*., 2019; Sezgin and Sanlier, 2019)**. According to FAO/WHO recommendations, quinoa protein can supply over 180% of the daily recommended intake of essential amino acids for adult nutrition **(Graf *et al*., 2015)**. Quinoa seeds also contain significantly higher amounts of minerals (calcium, magnesium, iron, and zinc) and some vitamins (E, B group, and C) than common cereals **(Aguilar *et al*., 2018; Zannini *et al*., 2018)**. The main carbohydrate present in quinoa is starch (52-60%). Content of total dietary fibre in quinoa varied from 2.6 to 10% with about 78% of its fibre content being insoluble and 22% soluble **(Bastidas *et al*., 2016; Navruz-Varli and Sanlier, 2016; Montemurro *et al*., 2019)**. Moreover, this crop contains about 3% of sugars, represented by high levels of D-xylose and maltose, a low amount of glucose and fructose **(Graf *et al*., 2015; Gordillo-Bastidas *et al*., 2016; Navruz-Varli and Sanlier, 2016; Ahmed *et al*., 2019)**. The lipid content of quinoa ranges from 2 to 9.5%, which is a higher amount, as determined in maize (3-4%). The most abundant fatty acids are polyunsaturated fatty acids such as linoleic and alpha-linolenic acids **(Bastidas *et al*., 2016; Navruz-Varli and Sanlier, 2016; Montemurro *et al*., 2019)**. Quinoa is also an excellent source of phytosterols, lipophilic compounds with hypocholesterolemic effects, among which β-sitosterol is present in the highest amount **(Navruz-Varli and Sanlier, 2016; Montemurro *et al*., 2019)**.
Quinoa is also considered as a food with a low glycemic index (35-53, depending on the processing) **(Vega-Galvez *et al*., 2010; Srujana *et al*., 2017)** with slow glucose release into the bloodstream after intake **(Lopes *et al*., 2019)**. **Erfidan *et al*. (2022)** described, that the consumption of quinoa is supposed to be beneficial in diabetes and associated hypertension. It was shown that intake of this pseudocereal significantly lowers blood sugar and increase the glucose tolerance in diabetic patients **(Gabrial *et al*., 2016)**. **Graf *et al*. (2015)** demonstrated that 20-hydroxyecdysone, the most abundant quinoa phytoecdysteroid, is responsible for the antidiabetic effect of these crops.
In recent years, interest in plant-based beverages derived from different crops has been increasing worldwide **(Jeske *et al*., 2017; Fernandes *et al*., 2018; Fructuoso *et al*., 2021; Pointke *et al*., 2022)**. On the other hand, only limited studies related to quinoa-based drinks are available **(Pineli *et al*., 2015; Kaur and Tanwar, 2016; Urquizo *et al*., 2017; Sruthy *et al*., 2021)**. Due to the nutritional facts mentioned above, quinoa can have a great potential for production beverages with added value.
The aim of this study was to assess the potential of underutilised pseudocereal quinoa for the production of gluten free beverages. The nutritional composition, physicochemical properties, and sensory acceptance of beverages were also determined.

MATERIAL AND METHODS

Raw materials

Quinoa seeds (dmBio, dm-drogerie markt GmbH, Karlsruhe, Germany), sunflower oil (Vénusz, Bunge Zrt., Budapest, Hungary), lecithin (Adelle Davis, s.r.o., Bratislava, Slovakia), xanthan gum (Vega Provita, s.r.o., Frýdek Místek, Czech Republic), inulin (FandN, s.r.o., Tišice, Czech Republic) and agave syrup (dmBio, dm-drogerie markt GmbH, Karlsruhe, Germany) were purchased from local markets in Slovakia. Bacterial alpha amylase (Termamyl SC DC, Novozymes, Denmark) was applied to starch hydrolysis in the samples.

Quinoa pretreatment

Before using quinoa seeds for beverages preparation, they were treated by desaponification, drying (at 60°C for 8 hours) and grinding according to the procedure that was previously reported by **Urquizo *et al*. (2017)**.

Preparation of beverages

The procedure was adopted from **Pineli *et al*. (2015)** with several modifications. Pretreated seeds were mixed with water (12.5% quinoa in the mixture). The mixture was cooked for 30 minutes (gelatinization of starch) and cooled to 80°C. Subsequently, heat-stable bacterial alpha amylase (Termamyl SC DC, Novozymes) was added (calculated to 2 mL/kg of starch) and the mixture was heated at 80-85°C for 60 min, after that the enzyme was inactivated by boiling (15 min). The product was cooled to 40°C and filtered through gauze and then sunflower oil (0.8%, v/v) and lecithin (0.03%, w/v) were added. In the next step, four types of beverages (A-D) were formulated by adding the following ingredients in different combinations: xanthan gum (0.5%, w/v), inulin (3%, w/v), agave syrup (3%, v/v). The ingredients included in the individual beverages are presented in Table 1. Beverages were stored at 5°C.

Table 1 Additional ingredients incorporated to beverages

Beverage A	Beverage B	Beverage C	Beverage D
Lecithin	Lecithin	Lecithin	Lecithin
Sunflower oil	Sunflower Oil	Sunflower Oil	Sunflower Oil
Xanthan gum	Xanthan gum	-	-
Inulin	Agave syrup	Inulin	Agave syrup

Proximate composition and glycemic index

The fat, moisture, ash, and starch were determined according to methods described by **Moreels and Amylum (1987)** and **Sowbhagya *et al*. (2007)**. Nitrogen content was estimated by the Kjeldhal method and converted to protein using a factor of 6.25 **(Ayadi *et al*., 2009)**. A digital pH meter (inoLab pH Level 2; WTW, Weilheim, Germany) was applied to pH determination. Total carbohydrates were calculated by difference (100% minus the contents of water, protein, fat, and ash) **(Raczkowska *et al*., 2019)**. Saponin content was measured by method adopted from **Koziol (1991)**. The energy values of the samples were calculated using conversion factors reported by **Onoja *et al*. (2014)** (% protein × 4 + % carbohydrates × 4 + % fat × 9 kcal). Sugars (glucose, fructose and maltose) were determined by HPLC with RI detector according to methods of **Kohajdová *et al*. (2009)** and **Magala *et al*. (2015)**. Glycemic index (GI) of beverages was calculated according to GI prediction model described by **(Rytz *et al*., 2019)**.

Colour of beverages

The colour measurements were realised by Spectrophotometer Cary 300 (UV–VIS Agilent Technologies, Santa Clara, USA). Colour values were determined using the CIELAB colour system with reference to the illuminant D65 and a visual angle of 10°. The colour of the beverages was characterised as the whiteness index (WI) and was calculated according to the equation reported by **Milovanovic *et al*. (2020)**.

Technological properties of beverages

Water holding capacity (WHC) of beverages was measured according to centrifugation method described by **Zannini *et al*. (2018)**. The viscosity of beverages was determined using a rotation viscometer (Haake VT 550, Haake Mess –Technic, Germany) **(Magala *et al*., 2015)**. Serum separation was measured by procedure of **Koksoy and Kilic (2004)**.

Sensory evaluation of beverages

Sensory attributes of beverages were evaluated by panel assessors (11 –member panel) using a 9 –points hedonic scale (1 –dislike extremely; 9 –like extremely) **(Walsh *et al*., 2014)**. Assessors evaluated taste, odour, colour, and consistency of prepared products. The overall acceptance of beverages was assessed by using 100 mm graphical unstructured line segments with specified end-points **(Karovičová *et al*., 2020)**. The commercially available quinoa drink in the local Slovak market was used as a reference beverage (unflavored drink, Organic La Famiglia organic, Italy) (composed of spring water, organic quinoa, rice, sunflower oil, safflower oil, and sea salt).

Statistical analysis

All experimental analyses were carried out using three independent determinations and expressed as the mean value ± standard deviation. Statistical analyses were performed using Microsoft Excel (Microsoft Corp., Redmond, WA, USA) with XLSTAT for MS Excel Addinsoft SARL, Paris, France). A Pearson correlation analysis was applied to find the relationship between nutritional composition and glycemic properties of beverages. Analysis of variance was used to describe the significance differences ($p<0.05$) between the nutritional composition, technological properties, and sensory attributes of commercially produced and developed quinoa beverages.

RESULTS AND DISCUSSION

Formulation of quinoa-based beverages

Quinoa pericarp can contain bitter compounds saponins at levels up to 5% depending on the variety **(Urquizo *et al*., 2017)**. For removing these substances, processing of seeds by peeling, washing or water maceration is necessary **(Vega-Galvez *et al*., 2010; Pineli *et al*., 2015; Urquizo *et al*., 2017).** The studied quinoa sample contained 0.38 ± 0.05% saponins. These compounds were removed from the seeds to non- detectable level by repeated intensively washing with tap water.
Several authors documented that pseudocereals contain large amounts of starch and when heated above gelatinization temperature (55–65°C), they form a viscous paste **(Tano-Debrah *et al*., 2005; Pineli *et al*., 2015; Silva *et al*., 2020)**. Due to this fact, alpha amylase was added to the mixture to liquefaction of gelatinized starch. Content of starch before the application of this enzyme in the studied mixture represented 5.75 ± 0.23 g per 100 mL, due to starch hydrolysis, the starch content in the final beverages was significantly reduced (11.13-11.82 times lower content than in the original mixture). Previously, it was stated that higher GI of some plant-based beverages may be due to the presence of starch, which leads to the release of glucose during digestion **(Shkembi and Huppertz, 2023)**.
Different ingredients can be added to plant-based beverages to improve their nutritional value, functional or sensory attributes **(Mc Clements *et al*., 2019; Aydar *et al*., 2020; Fructuoso *et al*., 2021)**. According to **Fructuoso *et al*. (2021),** the addition of vegetable oils to plant-based beverages can provide a smooth mouthfeel similar to that of cow's milk. **Aydar *et al*. (2020)** and **Pineli *et al*. (2015)** documented that the addition of sunflower oil to these types of beverages can improve the silky appearance of the final products. Due to these recommendations, sunflower oil was added to prepared beverages. Another ingredient added to the products was lecithin. This substance was applied as an emulsifying agent and also to improve the physical stability of beverages as was previously described by **Aydar *et al*. (2020)**. Beverages A and B were also incorporated with xanthan gum. This ingredient has been reported as successful hydrocolloid for textural stabilisation of beverages **(Kaur and Tanwar, 2016)**. Finally, the beverages were sweetened by inulin (beverages A and C) or agave syrup (beverages B and D). In recent years, these substances have become popular as natural substitutes for common sweeteners (such as sucrose or honey) with low GI (5-14 and 10-27, respectively) **(Ozuna and Franco-Robles, 2022; Mudannayake *et al*., 2022; Saraiva *et al*., 2022)**. Besides that, inulin belongs to the class of dietary fibre known as fructan and is often applied in processed foods for its nutritional and therapeutic benefits **(Ahmed and Rashid, 2019; Rungraeng *et al*., 2022)**. The concentration of added inulin was selected according to nutritional and health claims made on foods defined as a source of fibre **(Kuchtová *et al*., 2018)**.

Composition of beverages and their glycemic index

Nutritional composition of quinoa-based beverages is presented in Table 2. Beverages prepared in this study contained 0.60-0.63 g per 100 mL of proteins. **Tangyu *et al*. (2019)** documented that most commercial plant-based drinks contain little or even no protein (< 0.50 g per 100 mL). Values obtained from this study were higher than was previously determined by **Jeske *et al*. (2017)** in commercially produced quinoa drink (0.22 g per 100 mL) but similar to those measured by **Kaur and Tanwar (2016)** in experimentally prepared quinoa beverages (0.68 g per 100 mL). On the other hand, a significantly higher protein content (1.23 g per 100 mL) was detected in the commercial quinoa drink presented in this study. Previously, **Pineli *et al*. (2015)** described that the application of a saline solution with 0.03 mol/L of NaCl acidified to pH 5 resulted in the highest protein yield in the final quinoa product. The pretreatment of seeds by the malting process can also be a useful method to increase the level of proteins in beverages **(Kaur and Tanwar, 2016)**. Quinoa beverages showed a fat and ash content comparable to quinoa drinks developed by **Bianchi *et al*. (2014)** and **Kaur and Tanwar (2016)**. On the other hand, a significantly higher fat content was determined in the commercial quinoa drink (1.52 g per 100 mL). This could be related to the fact that the commercial product contained additional ingredients such as sunflower and safflower oil. Furthermore, it was observed that the developed beverages contained significantly lower amounts of total carbohydrates than the commercial drink, which was also reflected by lower energy value of the products.
Sugar composition and GI of studied beverages are presented in Table 3. Prepared beverages were sweetened with sweeteners (inulin or agave syrup) that contributed to their sugar content in the products. It was found that beverages B and D sweetened with agave syrup contained a significantly higher amount of fructose compared to other beverages. Fructose represents a sugar that is present in a high content (approximately 80%) in agave syrup **(Saraiva *et al*., 2022)**. Content of maltose in developed beverages varied between 1.35 and 1.45 g per 100 mL. During beverage processing, alpha amylase was applied to the starch liquefaction.

These enzymes catalyse starch hydrolysis to dextrins, oligosaccharides, maltose, and glucose **(Presečki *et al*., 2013)** and thus products of starch hydrolysis can represent another source of sugar in the beverages **(Jeske *et al*., 2017)**. Moreover, it was found that the commercial drink contained significantly higher amounts of glucose and maltose than experimentally prepared samples. The higher content of these components in the commercial product could be originated from the used ingredients (quinoa and rice). Previously, it was documented that plant drinks prepared from the ingredients which are rich source of starch, contains higher amount of maltose and glucose **(Jeske *et al*., 2017)**. This fact was also confirmed in this study.

GI is applied to demonstrate the ability of foods to increase blood glucose. This parameter is considered a very important characteristic of novel foods and beverages **(Di Cairano *et al*., 2022)**. GI of beverages was calculated based on the model for prediction of GI including common glycemic carbohydrates and non-glycemic nutrients **(Rytz *et al*., 2019)**. GI of prepared beverages varied between 62.78 and 68.97. Foods can be classified according to their GI into three categories: foods with low (≤ 55), medium (56-69), or high (≥70) GI **(Di Cairano *et al*., 2022)**. All laboratory prepared beverages can be categorised as medium GI products. Previously, **Pineli *et al*. (2015)** prepared experimental unsweetened quinoa drink with increased content of proteins and low GI (52). These authors documented that a higher amount of proteins may have contributed, in part, to its lower GI. On the contrary, **Shkembi and Huppertz (2023)** described that the higher GI of plant derived drink may be due to the presence of starch, which leads to the release of glucose during digestion.

A Pearson correlation analysis was applied to find the relationship between the nutritional composition and glycemic properties of studied beverages. Strong negative correlations were observed between GI and content of glucose (r= -0.982) and fructose (r=-0.997). On the other hand, high positive correlations were found between GI and the starch and ash content (r=0.867 and r=0.877). **Wills *et al*. (1998)** documented that monosaccharides, glucose and fructose, and total minerals are considered as nutrients with the strongest correlations with GI, this fact was also confirmed in this study. Moreover, strong correlations were found between energy value and protein (r=-0.962) and total carbohydrates (r=0.852) and between starch and glucose content (r=0.922).

Table 2 Nutritional composition of quinoa-based beverages

	Commercial drink	Beverage A	Beverage B	Beverage C	Beverage D
Moisture (g per 100 mL)	86.23 ± 0.19	93.82 ± 0.09*	93.39 ± 0.23*	93.44 ± 0.35*	93.69 ± 0.15*
Protein (g per 100 mL)	1.23 ± 0.02	0.63 ± 0.01*	0.60 ± 0.04*	0.61 ± 0.02*	0.63 ± 0.01*
Fat (g per 100 mL)	1.52 ± 0.02	0.72 ± 0.04*	0.71 ± 0.03*	0.69 ± 0.04*	0.60 ± 0.03*
Ash (g per 100 mL)	0.21 ± 0.04	0.33 ± 0.01*	0.29 ± 0.01*	0.37 ± 0.01*	0.18 ± 0.01
Starch (g per 100 mL)	1,05 ± 0.07	0.68 ± 0.04*	0.64 ± 0.04*	0.69 ± 0.02*	0.66 ± 0.02*
pH	6.25 ± 0.01	6.05 ± 0.01	6.29 ± 0.04	6.32 ± 0.03	6.30 ± 0.01
Total carbohydrates (g per 100 mL)	10.81 ± 0.08	4.51 ± 0.12*	5.02 ± 0.05*	4.9 ± 0.09*	4.91 ± 0.11*
Energy (kJ per 100 mL)	253.04 ± 0.84	113.14 ± 1.04*	120.79 ± 0.57*	118.20 ± 0.79*	115.31 ± 0,92*

* denotes a statistically significant difference (p<0.05)

Table 3 Sugars compositions and glycaemic index of quinoa-based beverages

	Commercial drink	Beverage A	Beverage B	Beverage C	Beverage D
Glucose (g per 100 mL)	2.43 ± 0.05	1.33 ± 0.03*	1.87 ± 0.00*	1.36 ± 0.02*	1.83 ± 0.01*
Maltose (g per 100 mL)	2.45 ± 0.03	1.45 ± 0.02*	1.42 ± 0.02*	1.42 ± 0.01*	1.35 ± 0.00*
Fructose (g per 100 mL)	0.04 ± 0.01	0.05 ± 0.00	2.38 ± 0.01*	0.07 ± 0.00*	2.55 ± 0.03*
predicted GI	75.68 ± 0.49	68.70 ± 0.65*	63.72 ± 0.57*	68.97 ± 0.82*	62.78 ± 0.71*

* denotes a statistically significant difference (p<0.05)

Colour of beverages

Colour is one of the most important quality attributes for plant-based beverages **(Clydesdale, 1991; Jeske *et al*., 2017)**. Colour of samples was characterised as WI (Table 4). This parameter indicates the degree of whiteness and mathematically combines lightness and yellow–blue into a single term **(Milovanovic *et al*., 2020; Al-Hilphy *et al*., 2022)**. WI of developed beverages A and C were similar to commercial drink and quinoa drink that was previously reported by **Jeske *et al*. (2017)**. The results also concluded that samples sweetened with inulin and agave syrup had significantly different WI, whereas beverages contained inulin were characterised by about 11.3-12.4% higher WI values. It could be probably due to the fact, that inulin is white in colour and has high WI and the colour of agave syrup can range from light amber to dark amber depending on the processing steps applied during its manufacture **(Willems and Low, 2012; Ahmed and Rashid, 2019)** (WI of applied sweeteners are shown in the Table 4).

Table 4 Whiteness index of raw materials, quinoa- based beverages and commercial drinks

Ingredients			
Quinoa	**Inulin**	**Xanthan gum**	**Agave syrup**
81.17 ± 0.57*	95.58 ± 0.52*	91.19 ± 0.15*	37.04 ± 0.29*
Beverages			
A	**B**	**C**	**D**
72.96 ± 0.04	63.91 ± 0.01*	72.28 ± 0.25	64.72 ± 0.66*
Commercially produced drinks			
Evaluated in this study	**Quinoa[a]**	**Organic oat[a]**	**Organic rice[a]**
70.12 ± 0.42	71.35 ± 0.20	60.21 ± 4.46*	66.49 ± 3.94*

Legend: a- obtained from Jeske *et al*. (2017), * denotes a statistically significant difference (p<0.05)

Technological properties of beverages

Technological properties of quinoa beverages are shown in the Table 5. Viscosity is an essential quality parameter for obtaining food products with desirable attributes **(Zhao *et al*., 2003)**. It was determined that beverages including xanthan gum were characterised by higher viscosity than other beverages. It was already documented that, xanthan gum increases the viscosity of beverages and also supports textural stability by reducing serum separation **(Kaur and Tanwar, 2016; Hosseini *et al*., 2016)**.

Plant-based beverages represent unstable colloidal systems characterised by the presence of immiscible (or partially miscible) colloidal particles that are dispersed in the aqueous phase **(Codina-Torrella *et al*., 2017)**. Serum separation occurs in beverages due to the aggregation and sedimentation of these particles during storage **(Koksoy and Kilic, 2004)**. No serum separation was observed after storage of beverages for 15 days at 5°C.

WHC of developed beverages ranged from 74.32 to 87.83%. Previously, **Demitrellou *et al*. (2021)** declared higher WHC in emmer beverages fortified with fruit juices (95.50-99.00%). On the opposite, lower WHC was observed by **Lorusso *et al*. (2018)** for quinoa like yoghurt beverages (63.00-70.00%). It was also found that beverages containing xanthan gum (beverages A and B) showed significantly higher WHC than beverages C and D and commercial drink. **Bahrami *et al*. (2013)** and **Aidar *et al*. (2021)** described that the addition of gums and gum mixtures resulted in higher WHC of the final products. Moreover, it is well known that WHC depends on the type of water binding and trapping in particular cells or between other ingredients **(Kurek *et al*., 2018)**.

Table 5 Technological properties of quinoa-based beverages

	Commercial drink	Beverage A	Beverage B	Beverage C	Beverage D
Viscosity (mPa.s)	14.25 ± 0.35	22.05 ± 0.15*	25.72 ± 0.08*	14.36 ± 0.11	16.70 ± 0.27*
WHC (%)	74.43 ± 0.24	87.72 ± 0.04*	87.83 ± 0.04*	73.91 ± 0.04	74.32 ± 0.62

* denotes a statistically significant difference (p<0.05)

Sensory evaluation of beverages

The sensory evaluation results of beverages are summarised in Table 6. From the sensory assessment, concluded that no significant differences were found in the consistency of evaluated commercial beverage and beverages included xanthan gum (beverages A and B). Moreover, it was found that beverages sweetened by agave syrup had about 14.1-16.3% higher taste score compared to beverages sweetened by inulin. This could be due to the fact, that inulin has a slight sweet taste and has only 10% sweetness in comparison with 100% for sucrose **(Mudannayake *et al.*, 2022),** on the other hand, agave syrup is 1.8 times sweeter than sucrose **(Vahedi and Mousazadeh, 2016)**.

Overall acceptance of quinoa beverages is presented in Table 6. The acceptance trend was as follows: beverage A < beverage C < beverage B < beverage D < commercially produced beverage. Previously, it was documented that quinoa-based beverages are characterized with low sensory acceptance **(Pineli *et al.*, 2015; Karimidastjerd and Konuskan, 2018)**. This fact was also confirmed in this study. Several researchers indicated that flavoring the quinoa drinks or roasting of quinoa seeds before the processing could be a useful strategy to improve their acceptance by consumers **(Pineli *et al.*, 2015; Aydar *et al.*, 2020; Dhankhar and Kundu, 2021)**.

Table 6 Sensory parameters of quinoa-based beverages and commercially produced quinoa drink

	Commercial drink	Beverage A	Beverage B	Beverage C	Beverage D
Colour	8.67 ± 0.54	6.23 ± 0.15*	6.10 ± 0.20*	6.33 ± 0.15*	6.00±0.22*
Taste	8.33 ± 0.28	5.33 ± 0.15*	6.20 ± 0.30*	5.67 ± 0.04*	6.47±0.31*
Odour	7.33 ± 0.32	6.13 ± 0.18*	6.43 ± 0.32*	6.23 ± 0.25*	6.33±0.08*
Consistency	8.37 ± 0.24	8.00 ± 0.34	8.21 ± 0.22	7.47 ± 0.14*	7.17±0.27*
Overall acceptance	89.57 ± 0.41	56.71 ± 0.12*	64.00 ± 0.26*	59.14 ± 0.19*	65.18±0.35*

* denotes a statistically significant difference (p<0.05)

CONCLUSION

The potential of underutilised crop quinoa as a raw material for production of non-dairy beverages was presented in this study. It was concluded that pretreatment of seeds by desaponification removed saponins, bitter substances, which could decrease the acceptance of quinoa like products and application of thermostable alpha amylase during the processing effectively reduced starch content in the beverages.

Developed beverages contained 0.60-0.63 g per 100 mL protein and had a medium GI. Moreover, it was found that all the developed beverages showed good stability without the serum separation during storage, and beverages that contained xanthan gum had higher viscosity and WHC than other beverages. Sensory evaluation showed that no significant differences were found in consistency of beverages containing xanthan gum and the control sample (commercial quinoa drink available in the Slovak markets). On the other hand, developed beverages had lower overall acceptance than control sample despite the fact that they were sweetened with low GI natural sweeteners. It was also determined that agave syrup was more acceptable as a sweetener due to its higher sweetness compared to inulin. In conclusion, quinoa is a nutritionally rich raw material with absence of gluten and low GI that could be useful for the production of new or reformulated beverages for a group of consumers with specific nutritional needs. However, more research is needed not only to increase sensory acceptance of these products by consumers, but also to determine their nutritional profile and glycemic properties.

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REFERENCES

Agregán, R., Guzel, N., Guzel, M., Bangar, S. P., Zengin, G., Kumar, M., & Lorenzo, J. M. (2022). The effects of processing technologies on nutritional and anti-nutritional properties of pseudocereals and minor cereal. *Food and Bioprocess Technology*, 1-26. https://doi.org/10.1007/s11947-022-02936-8

Aguilar, J., Miano, A. C., Obregon, J., Soriano-Colchado, J., & Barraza-Jauregui, G. (2019). Malting process as an alternative to obtain high nutritional quality quinoa flour. *Journal of Cereal Science*, 90, 102858. https://doi.org/10.1016/j.jcs.2019.102858

Ahmed, W., & Rashid, S. (2019). Functional and therapeutic potential of inulin: a comprehensive review. *Critical Reviews in Food Science and Nutrition*, 59(1), 1-13. https://doi.org/10.1080/10408398.2017.1355775

Al-Hilphy, A. R., Ali, H. I., Al-IEssa, S. A., Gavahian, M., & Mousavi-Khaneghah, A. (2022). Assessing compositional and quality parameters of unconcentrated and refractive window concentrated milk based on color components. *Dairy*, 3(2), 400-412. https://doi.org/10.3390/dairy3020030

Ayadi, M. A., Abdelmaksoud, W., Ennouri, M., & Attia, H. (2009). Cladodes from *Opuntia ficus-indica* as a source of dietary fiber: effect on dough characteristics and cake making. *Industrial Crops and Products*, 30(1), 40-47. https://doi.org/10.1016/j.indcrop.2009.01.003

Aydar, A. Y., Mataracı, C. E., & Sağlam, T. B. (2021). Development and modeling of a novel plant-based yoghurt produced by Jerusalem artichoke and almond milk using I-optimal mixture design. *Journal of Food Measurement and Characterization*, 15(4), 3079-3087.

Aydar, E. F., Tutuncu, S., & Ozcelik, B. (2020). Plant-based milk substitutes: bioactive compounds, conventional and novel processes, bioavailability studies, and health effects. *Journal of Functional Foods*, 70, 103975. https://doi.org/10.1016/j.jff.2020.103975

Bahrami, M., Ahmadi, D., Alizadeh, M., & Hosseini, F. (2013). Physicochemical and sensorial properties of probiotic yogurt as affected by additions of different types of hydrocolloid. *Food Science of Animal Resources*, 33(3), 363-368. https://doi.org/10.5851/kosfa.2013.33.3.363

Bastidas, E. G., Roura, R., Rizzolo, D. A. D., Massanés, T., & Gomis, R. (2016). Quinoa (*Chenopodium quinoa* Willd), from nutritional value to potential health benefits: an integrative review. *Journal of Nutrition and Food Sciences*, 6(3), 1-10. https://doi.org/10.4172/2155-9600.1000497

Bianchi, F., Rossi, E. A., Gomes, R. G., & Sivieri, K. (2015). Potentially synbiotic fermented beverage with aqueous extracts of quinoa (*Chenopodium quinoa* Willd.) and soy. *Food Science and Technology International*, 21(6), 403-415. https://doi.org/10.1177/1082013214540672

Clydesdale, F. M. (1991). Color perception and food quality. *Journal of Food Quality*, 14(1), 61-74. https://doi.org/10.1111/j.1745-4557.1991.tb00047.x

Codina-Torrella, I., Guamis, B., Ferragut, V., & Trujillo, A. J. (2017). Potential application of ultra-high pressure homogenization in the physico-chemical stabilization of tiger nuts' milk beverage. *Innovative Food Science and Emerging Technologies*, 40, 42-51. https://doi.org/10.1016/j.ifset.2016.06.023

Dakhili, S., Abdolalizadeh, L., Hosseini, S. M., Shojaee-Aliabadi, S., & Mirmoghtadaie, L. (2019). Quinoa protein: composition, structure and functional properties. *Food chemistry*, 299, 125161. https://doi.org/10.1016/j.foodchem.2019.125161

Dhankhar, J., Kundu, P. (2021). Stability aspects of non-dairy milk alternatives. In *Milk Substitutes: Selected Aspects*, (pp. 1-28). London: IntechOpen. http://dx.doi.org/10.5772/intechopen.96376

Di Cairano, M., Tchuenbou-Magaia, F. L., Condelli, N., Cela, N., Ojo, C. C., Radecka, I., & Galgano, F. (2022). Glycaemic Index of Gluten-Free Biscuits with Resistant Starch and Sucrose Replacers: an *in vivo* and *in vitro* comparative study. *Foods*, 11(20), 3253. https://doi.org/10.3390/foods11203253

Dimitrellou, D., Kandylis, P., Kokkinomagoulos, E., Hatzikamari, M., & Bekatorou, A. (2021). Emmer-based beverage fortified with fruit juices. *Applied Sciences*, 11(7), 3116. https://doi.org/10.3390/app11073116

Erfidan, S., Dede, S., Usta, A., Yüksek, V., & Çetin, S. (2022). The effect of quinoa (*Chenopodium quinoa*) on apoptotic, autophagic, antioxidant and inflammation markers in glucocorticoid-induced insulin resistance in rats. *Molecular Biology Reports*, 49(7), 6509-6516. https://doi.org/10.1007/s11033-022-07479-x

Fernandes, C. G., Sonawaneb, S. K., & SS, A. (2018). Cereal based functional beverages: a review. *Journal of Microbiology, Biotechnology and Food Sciences*, 8(3), 914-919. https://doi.org/10.15414/jmbfs.2018-19.8.3.914-919

Fructuoso, I., Romão, B., Han, H., Raposo, A., Ariza-Montes, A., Araya-Castillo, L., & Zandonadi, R. P. (2021). An overview on nutritional aspects of plant-based

beverages used as substitutes for cow's milk. *Nutrients*, 13(8), 2650. https://doi.org/10.3390/nu13082650
Gabrial, S. G., Shakib, M. C. R., & Gabrial, G. N. (2016). Effect of pseudocereal-based breakfast meals on the first and second meal glucose tolerance in healthy and diabetic subjects. *Open Access Macedonian Journal of Medical Sciences*, 4(4), 565. https://doi.org/10.3889/oamjms.2016.115
Graf, B. L., Rojas‐Silva, P., Rojo, L. E., Delatorre‐Herrera, J., Baldeón, M. E., & Raskin, I. (2015). Innovations in health value and functional food development of quinoa (*Chenopodium quinoa* Willd.). Comprehensive Reviews in Food Science and Food Safety, 14(4), 431-445. https://doi.org/10.1111/1541-4337.12135
Hosseini, S. A. R. E. S. (2016). Rheological Properties of Yoghurt Manufactured by using Different Types of Hydrocolloids. *Austin Journal of Nutrition and Food Sciences*, 4(2), 1082. https://austinpublishinggroup.com/nutrition-food-sciences/fulltext/ajnfs-v4-id1082.php
https://doi.org/10.1007/s11694-021-00884-z
Jeske, S., Zannini, E., & Arendt, E. K. (2017). Evaluation of physicochemical and glycaemic properties of commercial plant-based milk substitutes. *Plant Foods for Human Nutrition*, 72, 26-33. https://doi.org/10.1007/s11130-016-0583-0
Karimidastjerd, A., Konuskan, Z. G. (2018). Health benefits of plant-based milks as alternatives to conventional milk. In *Health Science*, (pp. 293-301). Ghana: Efe Academy.
https://www.researchgate.net/publication/352179341_HEALTH_BENEFITS_OF_PLANT-BASED_MILKS_AS_ALTERNATIVES_TO_CONVENTIONAL_MILK
Karovičová, J., Kohajdová, Z., Minarovičová, L., Lauková, M., Greifová, M., Greif, G., & Hojerová, J. (2020). Utilisation of quinoa for development of fermented beverages. *Slovak Journal of Food Sciences*, 14, 465-472. https://doi.org/10.5219/1323
Kaur, I., Tanwar, B. (2016). Quinoa beverages: formulation, processing and potential health benefits. *Romanian Journal of Diabetes Nutritiron and Metabolic Diseases*, 23(2), 215-225. https://doi.org/10.1515/rjdnmd-2016-0026
Kohajdová, Z., Karovičová, J. (2009). Chemical characteristics and pasting properties of commercial Slovak common and spelt wheat flours. *Agriculturae Conspectus Scientificus*, 74(4), 313-317. https://hrcak.srce.hr/48521
Koksoy, A., & Kilic, M. (2004). Use of hydrocolloids in textural stabilization of a yoghurt drink, ayran. *Food Hydrocolloids*, 18(4), 593-600. https://doi.org/10.1016/j.foodhyd.2003.10.002
Koziol, M. J. (1991). Afrosimetric estimation of threshold saponin concentration for bitterness in quinoa (*Chenopodium quinoa* Willd). *Journal of the Science of Food and Agriculture*, 54(2), 211-219. https://doi.org/10.1002/jsfa.2740540206
Kuchtová, V., Kohajdová, Z., Karovicova, J., & Lauková, M. (2018). Physical, textural and sensory properties of cookies incorporated with grape skin and seed preparations. *Polish Journal of Food and Nutrition Sciences*, 68(4), 309-317. https://doi.org/10.2478/pjfns-2018-0004
Kurek, M. A., Karp, S., Wyrwisz, J., & Niu, Y. (2018). Physicochemical properties of dietary fibers extracted from gluten-free sources: quinoa (*Chenopodium quinoa*), amaranth (*Amaranthus caudatus*) and millet (*Panicum miliaceum*). *Food Hydrocolloids*, 85, 321-330. https://doi.org/10.1016/j.foodhyd.2018.07.021
Lopes, C. D. O., Barcelos, M. D. F. P., Vieira, C. N. D. G., de Abreu, W. C., Ferreira, E. B., Pereira, R. C., & de Angelis-Pereira, M. C. (2019). Effects of sprouted and fermented quinoa (*Chenopodium quinoa*) on glycemic index of diet and biochemical parameters of blood of Wistar rats fed high carbohydrate diet. *Journal of Food Science and Technology*, 56, 40-48. https://doi.org/10.1007/s13197-018-3436-z
Lorusso, A., Coda, R., Montemurro, M., & Rizzello, C. G. (2018). Use of selected lactic acid bacteria and quinoa flour for manufacturing novel yogurt-like beverages. *Foods*, 7(4), 51. https://doi.org/10.3390/foods7040051
Magala, M., Kohajdova, Z., Karovičová, J., Greifova, M., & Hojerova, J. (2015). Application of lactic acid bacteria for production of fermented beverages based on rice flour. *Czech Journal of Food Sciences*, 33(5), 458-463. https://doi.org/10.17221/74/2015-CJFS
McClements, D. J., Newman, E., & McClements, I. F. (2019). Plant‐based milks: a review of the science underpinning their design, fabrication, and performance. *Comprehensive Reviews in Food Science and Food Safety*, 18(6), 2047-2067. https://doi.org/10.1111/1541-4337.12505
Milovanovic, B., Djekic, I., Miocinovic, J., Djordjevic, V., Lorenzo, J. M., Barba, F. J., & Tomasevic, I. (2020). What is the color of milk and dairy products and how is it measured?. *Foods*, 9(11), 1629. https://doi.org/10.3390/foods9111629
Montemurro, M., Pontonio, E., & Rizzello, C. G. (2019). Quinoa flour as an ingredient to enhance the nutritional and functional features of cereal-based foods. In *Flour and breads and their fortification in health and disease prevention* (pp. 453-464). London: Academic Press. https://doi.org/10.1016/B978-0-12-814639-2.00036-8
Moreels, E., Amylum, N. V. (1987). Measurement of the starch content of commercial starches. *Starch‐Stärke*, 39(12), 414-416. https://doi.org/10.1002/star.19870391203
Mudannayake, D. C., Jayasena, D. D., Wimalasiri, K. M., Ranadheera, C. S., & Ajlouni, S. (2022). Inulin fructans–food applications and alternative plant sources: a review. *International Journal of Food Science and Technology*, 57(9), 5764-5780. https://doi.org/10.1111/ijfs.15947
Navruz-Varli, S., Sanlier, N. (2016). Nutritional and health benefits of quinoa (*Chenopodium quinoa* Willd.). *Journal of Cereal Science*, 69, 371-376. https://doi.org/10.1016/j.jcs.2016.05.004
Onoja, U. S., Akubor, P. I., Ivoke, N., Atama, C. I., Onyishi, G. C., Ekeh, F. N., & Ejere, V. C. (2014). Nutritional composition, functional properties and sensory evaluation of breads based on blends of orarudi (*Vigna sp*) and wheat flour. *Scientific Research and Essays*, 9(24), 1119-1026. https://doi.org/10.5897/SRE2014.6104
Ozuna, C., Franco-Robles, E. (2022). Agave syrup: An alternative to conventional sweeteners? A review of its current technological applications and health effects. LWT - *Food Science and Technology*, 162, 113434. https://doi.org/10.1016/j.lwt.2022.113434
Pineli, L. L. O. Botelho, R. B., Zandonadi, R. P., Solorzano, J. L., Oliveira, G. T., Reis, C. E. G., Teixeira, D. S. (2015). Low glycemic index and increased protein content in anovel quinoa milk. LWT – *Food Science and Technology*, 63, 1261-1267. https://doi.org/10.1016/jlwt.2015.03.094
Pointke, M., Albrecht, E. H., Geburt, K., Gerken, M., Traulsen, I., & Pawelzik, E. (2022). A comparative analysis of plant-based milk alternatives part 1: composition, sensory, and nutritional value. *Sustainability*, 14(13), 7996. https://doi.org/10.3390/su14137996
Presečki, A. V., Blažević, Z. F., & Vasić-Rački, Đ. (2013). Mathematical modeling of maize starch liquefaction catalyzed by α-amylases from *Bacillus licheniformis*: effect of calcium, pH and temperature. *Bioprocess and Biosystems Engineering*, 36, 117-126. https://doi.org/10.1007/s00449-012-0767-4
Raczkowska, E., Łoźna, K., Bienkiewicz, M., Jurczok, K., & Bronkowska, M. (2019). Relation between the recipe of yeast dough dishes and their glycaemic indices and loads. *Foods*, 8(9), 377. https://doi.org/10.3390/foods8090377
Rungraeng, N., Thammakulkrajang, R., & Kraithong, S. (2022). Development of sugar-free brownies using inulin, sucralose, and stevia. *Asia-Pacific Journal of Science and Technology*, 27(2), 1-8. https://www.tci-thaijo.org/index.php/APST/index
Rytz, A., Adeline, D., Lê, K. A., Tan, D., Lamothe, L., Roger, O., & Macé, K. (2019). Predicting glycemic index and glycemic load from macronutrients to accelerate development of foods and beverages with lower glucose responses. *Nutrients*, 11(5), 1172. https://doi.org/10.3390/nu11051172
Saraiva, A., Carrascosa, C., Ramos, F., Raheem, D., & Raposo, A. (2022). Agave syrup: chemical analysis and nutritional profile, applications in the food industry and health impacts. *International Journal of Environmental Research and Public Health*, 19(12), 7022. https://doi.org/10.3390/ijerph19127022
Sezgin, A. C., Sanlier, N. (2019). A new generation plant for the conventional cuisine: Quinoa (*Chenopodium quinoa* Willd.). *Trends in Food Science and Technology*, 86, 51-58. https://doi.org/10.1016/j.tifs.2019.02.039
Shkembi, B., Huppertz, T. (2023). Glycemic Responses of Milk and Plant-Based Drinks: Food Matrix Effects. *Foods*, 12(3), 453. https://doi.org/10.3390/foods12030453
Silva, A. R., Silva, M. M., & Ribeiro, B. D. (2020). Health issues and technological aspects of plant-based alternative milk. *Food Research International*, 131, 108972. https://doi.org/10.1016/j.foodres.2019.108972
Sowbhagya, H. B., Suma, P. F., Mahadevamma, S., & Tharanathan, R. N. (2007). Spent residue from cumin–a potential source of dietary fiber. *Food Chemistry*, 104(3), 1220-1225. https://doi.org/10.1016/j.foodchem.2007.01.066
Srujana, M. N. S., Kumari, B. A., Maheswari, K. U., Devi, K. S., Lakshmi, V. V., & Suneetha, W. J. (2017). Glycemic index profiling of germinated quinoa (*Chenopodium quinoa* Willd). *Journal of Pharmacognosy and Phytochemistry*, 6(5), 2634-2636. https://www.phytojournal.com/archives?year=2017&vol=6&issue=5&ArticleId=2022
Sruthy, KS., Suvarna, VC., Puranik, S., & Vikram, KV. (2021). A fermented nutraceutical beverage from quinoa: the traditional grain of Andes. *Indian Journal of Traditional Knowledge*, 20(4), 1040-1047. http://nopr.niscpr.res.in/handle/123456789/58485
Tangyu, M., Muller, J., Bolten, C. J., & Wittmann, C. (2019). Fermentation of plant-based milk alternatives for improved flavour and nutritional value. *Applied Microbiology and Biotechnology*, 103, 9263-9275. https://doi.org/10.1007/s00253-019-10175-9
Tano-Debrah, K., Asiamah, K., Sakyi-Dawson, E., & Budu, A. S. (2005). Effect of malt enzyme treatment on the nutritional and physicochemical characteristics of cowpea-peanut milk. *Proceedings of the 1st International Edible Legume Conference in conjuction with the IVth World Cowpea Congress*, University of Pretoria, 1-7. https://www.cabdirect.org/cabdirect/abstract/20053163623
Urquizo, F. E. L., Torrez, S. M. G., Tolonen, T., Jaakkola, M., Pena-Nuhr, M. G., Wright, A., Repo-Caromed-Rhonen, H., Plumed-Ferrer, C. (2017). Development of a fermented quinoa-based beverages. *Food Science and Nutrition*, 5, 602-608. https://doi.org/10.1002/fsn3.436
Vahedi, H., Mousazadeh, M. (2016). The effect of using stevia and agave nectar as a substitute for sucrose on physical, chemical, rheological, and sensory properties of dark chocolate. *Der Pharmacia Lettre*, 8(15), 194-201. https://www.scholarsresearchlibrary.com/abstract/the-effect-of-using-stevia-and-agave-nectar-as-a-substitute-for-sucrose-onrnphysical-chemical-rheological-and-sensory-pr-5939.html

Väkeväinen, K., L., Ludena-Urquizo, F., Korkala, E., Lapveteläinen, A., Peränieni, S., Wright, A., Plumed-Ferrer, C. P. (2020). Potential of quinoa in the development of fermented spoonable vegan products. LWT – *Food Science and Technology*, 120, 1-9. https://doi.org/10.1016/j.lwt.2019.108912

Vega‐Gálvez, A., Miranda, M., Vergara, J., Uribe, E., Puente, L., & Martínez, E. A. (2010). Nutrition facts and functional potential of quinoa (*Chenopodium quinoa* Willd.), an ancient Andean grain: a review. *Journal of the Science of Food and Agriculture*, 90(15), 2541-2547. https://doi.org/10.1002/jsfa.4158

Walsh, H., Cheng, J., & Guo, M. (2014). Effects of carbonation on probiotic survivability, physicochemical, and sensory properties of milk‐based symbiotic beverages. *Journal of Food Science*, 79(4), 604-613. https://doi.org/10.1111/1750-3841.12381

Willems, J. L., & Low, N. H. (2012). Major carbohydrate, polyol, and oligosaccharide profiles of agave syrup. Application of this data to authenticity analysis. *Journal of Agricultural and Food Chemistry*, 60(35), 8745-8754. https://doi.org/10.1021/jf3027342

Wills, R. B. H., Miller, J. B., & Matawie, K. M. (1998). Relationship between glycaemic index and nutrient composition of fruit and vegetables. *International Journal of Food Properties*, 1(2), 89-94. https://doi.org/10.1080/10942919809524569

Zannini, E., Jeske, S., Lynch, K. M., & Arendt, E. K. (2018). Development of novel quinoa-based yoghurt fermented with dextran producer *Weissella cibaria* MG1. *International Journal of Food Microbiology*, 268, 19-26. https://doi.org/10.1016/j.ijfoodmicro.2018.01.001

Zhao, B., Basir, O. A., & Mittal, G. S. (2003). Correlation analysis between beverage apparent viscosity and ultrasound velocity. *International Journal of Food Properties*, 6(3), 443-448. https://doi.org/10.1081/JFP-120020115