





RESEARCH ARTICLE

Using kiwi (*Actinidia deliciosa*), quinoa (*Chenopodium quinoa*), and watermelon rind (*Citrullus lanatus*) in a plant-based drink

Uso de kiwi (*Actinidia deliciosa*), quinoa (*Chenopodium quinoa*) e casca de melancia (*Citrullus lanatus*) em uma bebida à base de plantas

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Abstract

The growing consumer trend toward healthier foods has challenged the food industry to constantly innovate and offer alternatives that meet the demand for products appealing to the senses and providing attractive health benefits. Quinoa, a gluten-free pseudocereal with high protein content, and kiwi, a fruit with a pleasant taste and high vitamin C content, exemplify this shift. Conversely, watermelon, a widely consumed fruit, yields a fiber-rich by-product in its rind, often discarded and not fully utilized. Following this trend, this research aims to take advantage of the main components of such food matrices in a plant-based drink. Three treatments were developed, varying the content of kiwi, quinoa, and watermelon rind flour while keeping the remaining ingredients constant. Bromatological and microbiological analyses followed the Ecuadorian standard NTE INEN 2337:2008 specifications for fruit and vegetable beverages. The protein and fiber contents ranged from 1.72 to 5.28% and 2.95 to 6.19%, respectively. The evaluated parameters showed significant statistical differences ($p < 0.05$) among all treatments. Vitamin C results ranged from 3.80 to 4.93 mg/100g, with no significant statistical difference. Finally, all microbiological parameters met the requirements of the respective standard. In conclusion, the results support the feasibility of using ingredients such as quinoa and watermelon rind flour to develop beverages with protein and fiber content, respectively.

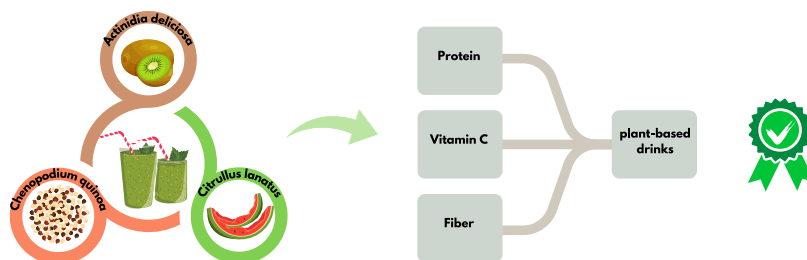
Keywords: By-product, dietary fiber, flour, protein, revalorization, vitamin C.

Resumo

A crescente tendência do consumidor em direção a alimentos mais saudáveis desafiou a indústria alimentícia a inovar constantemente e oferecer alternativas que atendam à demanda por produtos atrativos sensorialmente e que proporcionem benefícios à saúde. A quinoa, um pseudocereal sem glúten com alto teor de proteínas, e o kiwi, uma fruta com sabor agradável e alto teor de vitamina C, exemplificam essa mudança. Por outro lado, a melancia, uma fruta amplamente consumida, gera um subproduto rico em fibras em sua casca, muitas vezes descartado e não totalmente aproveitado. Seguindo essa tendência, esta pesquisa visa aproveitar os principais componentes dessas matrizes alimentares em uma bebida à base de plantas. Foram desenvolvidos três tratamentos, variando o conteúdo de kiwi, quinoa e farinha de casca de melancia, mantendo os demais ingredientes constantes. As análises bromatológicas e microbiológicas seguiram as especificações da norma equatoriana NTE INEN 2337:2008 para bebidas de frutas e vegetais. Os teores de proteínas e fibras variaram de 1,72 a 5,28% e de 2,95 a 6,19%, respectivamente. Os parâmetros avaliados apresentaram diferenças estatísticas significativas ($p < 0,05$) entre todos os tratamentos. Os resultados de vitamina C variaram de 3,80 a 4,93 mg/100g, sem diferença estatística significativa. Finalmente, todos os parâmetros microbiológicos atenderam aos requisitos da respectiva norma. Em conclusão, os resultados indicam a viabilidade do uso de ingredientes como quinoa e farinha de casca de melancia para desenvolver bebidas com teor de proteínas e fibras, respectivamente.

Palavras-chave: Subproduto, fibra alimentar, farinha, proteína, revalorização, vitamina C.

Graphical Abstract



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Received: 28 Dec 2023; Accepted: 19 Jan 2024; Published: 20 Jan 2024.
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1. Introduction

The growing global interest in healthy dietary choices has increased the demand for innovative, nutritious, and sustainable food products (Torres & Guerra, 2022). Watermelon (*Citrullus lanatus*) is a widely consumed fruit known for its delicious and moisturizing flesh. While its pink, succulent interior is highly prized, the rind is often overlooked and discarded (Nkoana et al., 2022). However, the rind of watermelon has valuable nutritional properties and contains a significant amount of dietary fiber (Zia et al., 2021). Kiwifruit (*Actinidia deliciosa*) is famous for its high vitamin C content, and its anti-inflammatory and antioxidant properties, along with other beneficial nutrients such as phenols (Sanz et al., 2021), and quinoa (*Chenopodium quinoa*) is considered a gluten-free cereal rich in high-quality protein and vitamins (Hussain et al., 2021). Combining these ingredients in a beverage not only takes advantage of food waste but also offers a novel approach to conveniently providing essential dietary components; in addition, it affords a unique flavor profile with the sensorial characteristics of watermelon's natural sweetness, the kiwi's tartness, and the quinoa's nutty notes create a distinctive and refreshing taste.

The evaluation of this beverage focuses on key nutritional components, such as dietary fiber, vitamin C, and crude protein content. Dietary fiber, an essential component of a balanced diet (Snauwaert et al., 2022), has been associated with numerous health benefits, such as improved digestive health and reduced risk of chronic diseases (Abreu y Abreu et al., 2021). Meanwhile, vitamin C is a well-known antioxidant vital for immune system function and overall well-being (Velarde, 2019). At a time when consumers are increasingly looking for natural sources of nutrients, a beverage offering a significant dose of vitamin C is a valuable addition to the market. Including quinoa as a protein source further enhances the nutritional profile of the beverage, making it a potential dietary option for those seeking plant-based protein alternatives. In addition to evaluating the nutritional components, we have delved into the microbiological properties of the beverage. Food safety is paramount in developing consumable products (Granato et al., 2020). Therefore, we comprehensively analyzed microbiological properties, including mold and yeast counts, mesophilic aerobic counts, *E. coli* counts, and total coliforms. This comprehensive assessment provides crucial information on the safety and shelf life of the product, ensuring that it meets stringent regulatory and consumer safety standards.

In this context, our research addresses the development of a unique beverage that uses kiwi, quinoa, and watermelon rind flour as the main ingredients to provide a rich source of vitamin C, protein, and dietary fiber (Pereira et al., 2022). This study represents a step towards improving the utilization of food by-products, reducing food waste, and diversifying the range of functional beverages available to consumers. The following sections detail our methods, results, and discussion of the findings, shedding light on this novel beverage's feasibility and potential impact.

2. Materials and Methods

2.1 Materials

The watermelons, kiwis, and quinoa were acquired in the Montebello grocery transfer market in Guayaquil, which is located in the Guayas province (Ecuador). Specimens were selected free of any sign of disease, pests, anthracnose, or deterioration. These were placed in polyethylene bags and kept in

refrigeration (4°C) until use. Potassium sorbate was from Ningbo Wanglong Technology (Guangxi, China). Citric acid and carboxymethylcellulose - CMC were from Vadefood / Vadequímica (Barcelona, Spain). Peracetic acid was from Swipe / Homecare de México (Mexico). The sweetener (*Stevia rebaudiana*) was from América Alimentos (Mexico). All additives were food grade.

2.2 Obtaining watermelon rind flour

The fruits were cut, and the edible part was removed with the help of stainless-steel knives. Drying conditions were 55°C for approximately 14 h, or until a constant weight was reached, using a "Buderus" model 4-5015-3 convection air dehydrator. The dehydrated product was reduced in size using an electric grain mill "MRC" model SM-450C. The pulverized product obtained was consecutively sieved through 250 μm (Mesh #60) particle-size sieves. The sieved pulverized product was packed in food-grade polyethylene bags, vacuum sealed, and refrigerated (4°C) until use.

2.3 Vegetable beverage development

Three beverage formulations were developed based on the work of Huaquipaco-Encinas et al. (2019). The proportions of the key ingredients (watermelon rind flour, kiwi pulp, and quinoa beverage) were selected to highlight in every formulation each of the main components: fiber, vitamin C, and protein content, respectively, while the rest of the ingredients remained unchanged, as shown in **Table 1**. Briefly, the elaboration process consisted of mixing all the components according to the corresponding formula, homogenization using an "AM110W-O" laboratory homogenizer, followed by a pasteurization process at 85°C for 2 min, packaging in transparent glass bottles of 300 mL capacity, which were previously sterilized, sealing using crown caps, followed by a thermal shock to reduce the temperature to approximately 30°C to 35°C, storage under refrigeration at 4°C until its subsequent use. All beverage production operations were carried out in the Pilot Laboratory Plant of the Agroindustry Department of the Universidad Agraria del Ecuador.

Table 1 Composition of the components used in the drink formulations in percent by weight

Ingredient	B1 (%)	B2 (%)	B3 (%)
Watermelon rind flour	31.9	14	23
Kiwi pulp	23	31.9	14
Quinoa drink	14	23	31.9
Water	30	30	30
<i>Stevia rebaudiana</i>	0.33	0.33	0.33
Potassium sorbate	0.30	0.30	0.30
Citric acid	0.30	0.30	0.30
CMC	0.17	0.17	0.17

2.4 Microbiological criteria

The microbiological criteria for the beverage were based on the Ecuadorian standard NTE INEN 2337:2008 (Ecuador, 2008) for fruit and vegetable beverages, which establishes the requirements for *E. coli* count, total coliforms, mesophilic aerobic counts, and mold and yeast counts.

2.5. Laboratory analysis

The procedures described in AOAC (2012) served as a reference for *E. coli* count (AOAC 991.14), total coliforms (AOAC 991.14), mesophilic aerobic count (AOAC 966.23), mold and yeast

enumeration (AOAC 997.02), fiber (AOAC 991.43), protein (AOAC 920.87), and vitamin C content (AOAC 967.21) of the samples. The analyses were performed in triplicate and were carried out in the Food Chemistry Laboratory of the Agroindustry Department of the Universidad Agraria del Ecuador.

2.6 Statistical analysis

Statistical analysis of the data was tabulated using InfoStat statistical software version 2020e (Di Rienzo et al., 2020), using one-way ANOVA analysis of variance, while the determination of statistical differences by Tukey's honest difference test (HSD) ($p < 0.05$).

3. Results and Discussion

3.1 Fiber, protein, and vitamin C content

Table 2 shows the results of the experimental beverage treatments' fiber, protein, and vitamin C content. The protein content showed a significant statistical difference among all the formulations, ranging from 1.72 to 5.28%. The highest value coincided with the beverage with the highest inclusion of quinoa, a recognized component with an appreciable protein content between 12 and 16%, depending on the variety (Piñuel et al., 2019; Repo-Carrasco, Espinoza & Jacobsen, 2003). However, in products such as beverages based on this pseudocereal, the protein content is much lower, with values of 1.5% (Zannini et al., 2018) and 1.93% (Bendezu-Ccanto, Contreras-Lopez & Lozada-Urbano, 2023) have been reported in beverages made from quinoa. These results are significantly lower than those reported in the current research; a possible reason for this lies in the differences in the formulations, in addition to the variability of inclusion of the pseudocereal in the formulations of the products and beverages.

On the other hand, the vitamin C content presented ranges from 3.80 to 4.93 mg/100 g, which did not show a significant statistical difference between them. These values are significantly lower than the 92.7 mg/100 g reported in the kiwi as fresh fruit (Stan, Iliescu & Stănică, 2021; Satpal et al., 2021), which is a significant source of this vitamin. Being also lower than the 21.22 mg/100 g found in a pasteurized carbonated beverage based on kiwifruit, rambutan, and moringa (Armijos-Martinez & Paz-Yépez, 2023); in this case, the total vitamin C content may not only come from kiwifruit but also from rambutan, which presents significant contents of this water-soluble vitamin (Mieszczakowska-Frąc, Celejewska & Plocharski, 2021). Vitamin C is considered one of the most labile and degradable components of food (Fabbri & Crosby, 2016). Therefore, the remarkable difference between these results could be attributed to multiple factors, such as the conditions (time and temperature) of the heat treatment, the heat treatment employed (Tian et al., 2016), interaction with the rest of the beverage components, exposure to oxygen, contact with light, among others (Doseděl et al., 2021).

Finally, the fiber content found ranged from 3.96 to 6.19%. The highest value (B1) coincides with the formulation that incorporated the highest amount of watermelon peel flour, which is an ingredient with significant fiber content (Al-Sayed & Ahmed, 2013), while next was B3 with a content of 3.96%, corresponding to the second formulation with the highest watermelon peel flour content. Part of the present results agree with those previously reported by Zúñiga-Moreno et al. (2022), who found fiber contents of 2.94%, 3.95%, and 4.23% in snacks made from watermelon rind

and seed flour; the possible explanation for this is that the values used for watermelon rind flour are similar in both investigations. The results of this research strongly suggest that this ingredient can be revalorized by including it in the development of new food products with functional properties.

Table 2 Results for protein, vitamin C, and fiber in the developed drinks based on kiwi, quinoa, and watermelon rind

Component	B1	B2	B3
Protein (%)	3.22±0.21 ^a	1.72±0.36 ^b	5.28±0.21 ^c
Vitamin C (mg/100g)	4.12±0.33 ^a	4.93±0.25 ^a	3.80±0.27 ^a
Fiber (%)	6.19±0.16 ^a	2.95±0.25 ^a	3.96±0.43 ^a

Average of three replicates ± standard deviation. Different letters in the same row indicate significant statistical differences, according to Tukey ($p < 0.05$).

3.2 Microbiological analysis

Table 3 shows the results of the microbiological analyses of the treatments of the developed product. It is observed that all the microbial parameters under study met the requirements demanded by the NTE INEN 2337:2008 standard that was taken as a reference; this is because of the application of basic hygiene and food handling standards as part of Good Manufacturing Practices (GMP) (Bastías, Cuadra, Muñoz and Quevedo, 2013). Compliance with microbiological requirements is a fundamental factor in ensuring the safety and quality of agro-industrial products (De Bruin, Otto & Korsten, 2016).

Table 3 Results of microbiological criteria for the developed drinks based on kiwi, quinoa, and watermelon rind

Parameter	B1	B2	B3	Requisite*
Total coliforms (MPN/mL)	<3	<3	<3	<3
Fecal coliforms (MPN/mL)	<3	<3	<3	<3
Mesophilic aerobes (CFU/g)	<10	<10	<10	<10
Molds and yeasts (CFU/mL)	<10	<10	<10	<10

*Taken from standard NTE INEN 2337:2008 (Ecuador, 2008).

4. Conclusion

The variations of the main ingredients (watermelon rind flour, kiwifruit, and quinoa) showed significant statistical differences in protein and fiber contents among all the treatments under study. At the same time, this did not occur concerning vitamin C content. Watermelon rind is a promising by-product with the potential to be revalorized in developing new food products mainly because of its high fiber content. Further analysis should include the evaluation of additional parameters of nutritional content and the determination of sensory acceptability. In conclusion, the results support the feasibility of using ingredients such as quinoa and watermelon rind flour to develop beverages with protein and fiber content, respectively. In addition, applying good manufacturing practices has ensured the microbiological quality of the final product.

Acknowledgments

Not applicable

Authors' Contributions

L.Z-M.: Conceptualization, Data Curation, Software, Writing – Original Draft preparation, Writing – Review and Editing, Supervision; M.B.: Conceptualization, Formal Analysis, Investigation, Methodology; D.G.: Formal Analysis, Project Administration, Supervision; F.L.: Writing – Original Draft preparation, Resources, Validation. All authors read and approved the final manuscript.

Availability of data and materials

Available upon request from the Corresponding Author.

Competing Interests**References**

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