Novel nutritionally improved snacks for school-aged children: formulation, characterization, and acceptability

Abstract:

Purpose: This study aimed to formulate multiple nutritionally improved snacks intended for school-aged children according to international nutritional goals: Vanilla cookies (VC), Bay biscuits (BB), Cheese crackers (CC), and Tomato muffins (TM).

Design/methodology/approach: The reformulation targets implied incorporating alternative flours and milk powder, and reducing the sugar and sodium contents, with respect to the usually consumed control products. These products were subjected to proximate composition, colour, and sensory profile analyses. Their overall acceptability was assessed by school-aged children whose nutritional status was also evaluated.

Findings: Significant increments in relevant nutrients were observed in the composition of snacks: fibre ($p=0.01$ for VC, $p<0.01$ for BB and CC), proteins ($p<0.01$ for all snacks), and calcium ($p<0.01$ for all snacks). Average sodium reductions of 1.5 % and 3.7 % were achieved for CC and TM. During formulation, added sugar was reduced by 15.5 % and 23.5 % for VC and BB. All snacks were found to be acceptable in terms of appearance, texture, flavour, and overall acceptability by the participants, and VC, BB, and CC were ready for their effective implementation as part of school meals.

Originality/value: Comprehensive policies have become necessary to combat malnutrition, mainly overweight and obesity. The incorporation of nutritionally improved snacks in school environments is one of several strategies for promoting healthier lifestyles among children, including educational programs, workshops, and food assistance.

Keywords:

nutritionally improved snacks; school-aged children; bakery products; addition of milk powder; added sugar and sodium reduction; overall acceptability.

1. Introduction

Multiple forms of childhood malnutrition are prevalent in several countries, as poor access to healthy food leads to underweight, overweight, and obesity (FAO, *et al.*, 2021). According to the latest data from the Joint Child Malnutrition Estimates by UNICEF *et al.* (2021), 33.6 % of children aged 5-19 years and 7.3 % of children under 5 years were overweight and obese. Similar to global trends, prevalence of overweight in school-aged Latin American and Caribbean children and adolescents has increased by 9 % since 2000 (FAO, *et al.*, 2020). Particularly in Argentina, anthropometric data from the 2nd Nutrition and Health National Survey (Moyano *et al*., 2020) show a transitional epidemiological scene where micronutrient deficiency and excess weight coexist. Overweight and obesity were the most prevalent malnutrition statuses in children aged 5-17 years, accounting for 41.1 % of this age group.

Overconsumption of calorie-dense foods rich in fat, salt, and sugar is a major factor contributing to the development of diet-related diseases (WHO, 2013). Sugar intake increases the overall energy density of the diet and leads to a reduction in food with good nutritional quality, resulting in weight gain and development of non-communicable diseases (WHO, 2015). Additionally, consumption of large quantities of poor-quality fats, along with excessive sodium intake, is associated with high blood pressure and early cardiovascular disease (Leyvraz *et al.*, 2018; Millar *et al.*, 2014; Quader *et al.*, 2017).

Then, reformulation of sweet and savoury products widely consumed by children could be a relevant alternative to increase the intake of foods with optimised nutritional value (Hobbs *et al.*, 2014; San José *et al.*, 2018). While reducing food components that may have adverse health impacts, such as sugar, fat, and salt, the nutritional profile of such foods can also be improved by adding ingredients that provide dietary fibre and micronutrients (Mc Clements, 2020). Increases in fiber and calcium contents become relevant when considering their low average intake in Argentina (Kovalskys *et al.*, 2013). According to local surveys and studies (Cuesta *et al*., 2018; Moyano *et al.*, 2020), the average fibre intake reaches only one-third to half of the reference value, whereas an average diet contributes 55 % of the recommended calcium intake, i.e. around 600 mg/day (Arrieta *et al.*, 2021). Additionally, increasing dietary fibre intake in children may improve their overall diet quality (Finn *et al.*, 2019), whereas dietary calcium intake has been inversely related to the prevalence of overweight and obesity (Orden *et al.*, 2019; Soares *et al.*, 2014; Zhang *et al.*, 2019).

However, it must be emphasised that reformulation of food products should not compromise their acceptability. Usually, modifications in product composition, including fat type and content, quantity of added sugar and/or salt, usage of non-traditional flour sources, and increased fibre content, among others, could influence the appearance, flavour, and texture of such products, which are key factors for their successful acceptance (Santos *et al.*, 2021; Savio *et al.*, 2013).

As many children and adolescents grow and develop in obesogenic environments that promote high caloric intake and physical inactivity (Bejarano *et al*., 2021), educational settings provided by schools may become suitable environments for promoting the adoption of healthier food consumption habits (Al Ali *et al.*, 2020). Interventions targeted towards these goals may be carried out at schools, since consumption patterns and food preferences are developed at an early age and can last well into adulthood (Hawkes *et al.*, 2015; Heelan *et al.*, 2015; Mohajeri *et al.*, 2022; Welker *et al.*, 2016).

Therefore, this study aimed to formulate multiple nutritionally improved snacks intended for school-aged children according to international nutritional goals. The proposed snacks were characterised by analysing their composition, colour profiles, and sensory attributes. Subsequently, acceptability of the proposed snacks was assessed by school-aged children from Pérez city, Argentina, whose nutritional status was also evaluated, to determine if these new products would be at least as accepted as control ones usually consumed as part of school breakfasts.

2. Materials and methods

2.1. Snacks formulation

Following evidence-based recommendations for balanced breakfast for children and adolescents from the International Breakfast Research Initiative (Gibney *et al.*, 2018), the nutritional goals adopted were as follows: breakfast energy: 300-500 kcal (15-25 % of daily caloric value); added sugar: < 10 % of breakfast energy; proteins: > 10 g (> 20 % of Recommended Daily Intake, RDI); dietary fibre: > 5 g (> 20 % of RDI); calcium: > 300 mg (> 30 % of RDI); and sodium: < 400 mg (< 20 % RDI).

To achieve these nutritional goals, a balanced school breakfast was proposed, consisting of a cereal-based bakery product, seasonal fruit, and infusion of tea or yerba mate with half a cup of milk. Therefore, snacks were designed to be the cereal-based products of school breakfasts, so their macro and micronutrients approached such goals when considered in conjunction with a seasonal fruit and infusion.

All ingredients were purchased from local markets. All snacks and controls were prepared under identical conditions using standard preparation and cooking methods. The complete formulation of each snack and composition of the resulting school breakfasts are detailed in the supplementary material.

2.2. Snacks characterization

2.2.1. Proximate composition

Ash (method 923.02), fat (method 920.85), dietary fibre (method 985.29), moisture (method 925.10), protein (method 920.87), sodium (method 966.16), and calcium (method 985.35) contents of the snacks were determined according to AOAC (2012), in duplicate. Carbohydrates were determined by difference, and the caloric value was calculated using Atwater´s factors.

2.2.2. Colour measurements

A digital camera was used to measure the colour parameters of the samples under proper and uniform lighting according to Abdollahi Moghaddam *et al.* (2015). Digital images were processed using Image J software (Color Space Converter plugin) to obtain the L* (lightness), a* (greenness/redness), and b* (blueness/yellowness) parameters.

2.2.3. Sensory profile of snacks

Sensory profiling of the snacks was conducted by eight semi-trained panellists, aged 35-45, recruited among university research staff, using Quantitative Descriptive Analysis (QDA) (Lawless and Heymann, 2010). Through seven weekly training sessions, the panel developed a consensus of sensory attributes to characterise the products' appearance, flavour, and texture, using a 5-point Likert scale. Tasting sessions were performed on different days for each snack and its control, in a quiet room with controlled lighting and ventilation. Each panellist evaluated samples of every product in duplicate, and registered the results in a digital scorecard form.

2.3. Snacks acceptability

A descriptive cross-sectional study was conducted to evaluate the acceptability of proposed snacks. The participating children included 371 boys and girls aged 5-13 years who attended primary levels from five public and private schools in Pérez city (Santa Fe, Argentina). Children with any relevant health condition that required a special diet (celiac disease or food allergies/intolerances) were excluded.

Overall acceptability of the snacks was evaluated using a 5-point Likert scale (1 = extremely disliked; 2 = disliked; 3 = neither liked nor disliked; 4 = liked; 5 = extremely liked), complemented by graphical representations of these scores (da Cunha *et al.*, 2013). Sensory analysis was performed on booths under daylight. Samples of approximately 30 g of one snack and the respective control were served to each participating child in random order on disposable plates, and a glass of water was provided to rinse the mouth between product tastings. Participants' opinions regarding their liking or disliking of several attributes of the snacks were also recorded, including colour, shape, taste, smell, sweetness, saltiness, and texture (crunchiness/softness and chewiness), as well as any other relevant observations. All data was taken through semi-structured interviews with guided open-ended questions conducted by trained nutrition specialists.

2.4. Anthropometric measurements

Children's anthropometric variables (height and weight) were measured by trained examiners according to standard procedures (Casadei and Kiel, 2021). Height was measured to the nearest 0.1 cm using a wall-mounted stadiometer and weight was measured to the nearest 0.1 kg using a weights scale (Roma and CAM, Argentina). The participating children were dressed and had no shoes at the time of testing. For data analysis, the weight of clothes they wore was subtracted from the weight recorded at time of measurement. All data were loaded into AnthroPlus (WHO, 2009) to obtain the respective z-score and diagnosis according to WHO (2007) standards.

2.5. Statistical analysis

Results were analysed using one-way Analysis of Variance (ANOVA) and post-hoc Tukey tests, and were expressed as mean and standard deviation where applicable. Differences were considered statistically significant at $p<0.05$. Statistical analyses were done in R-3.6.0 statistical software.

3. Results and discussion

3.1. Snacks characterization

3.1.1. Snacks formulation

Four snacks were formulated to be part of school breakfasts: Vanilla cookie (VC), with corn and whole wheat flours, and mashed sweet potato; Bay biscuit (BB), with whole wheat flour, and mashed carrot; Cheese cracker (CC), with yellow pea and whole wheat flours, and cheese; Tomato muffin (TM), with oat flour, tomato, and onion. All snacks included half a cup of whole milk powder. A Control was also produced for each product, following the usual recipes for bakery products, i.e. with wheat flour, large proportions of sugar and sodium, and no added milk powder. Images of the formulated snacks and their respective controls are shown in Fig. 1. Recipes for the proposed snacks and their respective controls are detailed in the supplementary material.

Figure 1

3.1.2. Proximate composition

All products were analysed for their macro and micronutrients content, as reported in Table I. As general trends, nutritional profile of the four snacks improved with respect to their controls, including an increase in the fibre, protein, and calcium content, along with a reduction in sugar and sodium.

Table I

Total dietary fibre content of the snacks significantly increased with respect to their controls for VC ($p=0.01$), BB ($p<0.01$), and CC ($p<0.01$), but not for TM ($p=0.09$), because of the addition of whole grains and legume flours, which may indicate that a serving of these snacks could hence provide 3.2-6.5 % of the adequate intake of fibre for children aged 5-13 years (Gibney *et al.*, 2018), which reaches 15-18.5 % when considering breakfast as a whole (i.e., including the consumption of fruit).

Protein content was also significantly enhanced ($p<0.01$ for all snacks) as a result of the average addition of 20.8 % milk powder in the recipe. The proposed snacks reached an average of 7.6 g of protein per serving, which represents around 16 % of the total protein daily intake for this age cohort (children aged 5-13 years). Besides, milk not only supplies high-quality proteins, but also provides larger amounts of calcium. All snacks significantly increased their calcium content ($p<0.01$), between 1.6-2.2 times more than their respective controls, covering between 14.7-16.8 % of the daily intake of this micronutrient. Thus, fortification of snacks with milk represents an additional advantage of the proposed reformulation, as data show that school-aged children often do not consume the recommended serving of dairy products, thus negatively affecting their calcium intake (Orden *et al.*, 2019).

Specific emphasis would hence be required for nutrients with larger gaps between consumer intake and recommendations. Since provision of health information about benefits of consuming some nutrients did not necessarily imply an increase in consumers' preferences for healthy food (Wardle and Huon, 2000), milk-enriched snacks appeared to be an acceptable strategy to increase dairy products consumption among children.

Moreover, in a cross-sectional study carried out in eight European countries, it was observed that a higher consumption of milk and other dairy products at snack meal occasions throughout the paediatric age period was correlated with an improvement in diet quality (Iglesia *et al.*, 2020). Whole milk also contributes to dietary fat consumption, although there was evidence of positive health effects of dairy fats (Lordan *et al.*, 2018).

Additionally, there was a reduction of added sucrose of 15.5 % and 23.5 % in VC and BB, respectively, and a reduction of sodium between 46-112 mg for all snacks. Added sugar of snacks contributed to 12.3 % of RDI value for VC and less than 8 % for BB. Sodium reduction was significant in sweet snacks (p=0.01 for VC, p=0.02 for BB), but removal of this mineral in savoury products did not achieve a significant difference with respect to their controls (p=0.22 for CC, p=0.18 for TM). For VC and BB, the snack contribution to the RDI for sodium was less than 5.5 %; whereas CC and TM provided about 9 % of the daily value. Consumption of such dietary components exceeds the maximum recommended values in several Latin American countries, including Argentina (Carrillo-Larco and Bernabe-Ortiz, 2020; Fisberg *et al.*, 2018). Even though sugar is naturally present in different foods, added sucrose in processed products targeted at children is the main source of empty calories in their diet (Velázquez *et al.*, 2021), whereas sodium chloride is the major contributor to daily sodium intake, and is also related to weight gain during childhood (Grimes *et al.*, 2021). On the other hand, effects of sugar and salt reduction on snacks production techniques should also be considered. In their review, Rysová and Šmídová (2021) found that baked products made with reduced salt content changed the texture of their crust, colour, specific volume, and sensory and aroma profiles, while low sugar levels also played a role in exacerbating these presumably negative effects.

Energy density of the snacks was high in all cases, as expected for this type of bakery product. Although reduction of energy density could be achieved with sugar and fat reduction, this procedure is not always as easy as it seems, as it may negatively impact products acceptability and production techniques (Buttriss, 2013; Rysová and Šmídová, 2021). Conversely, when considering breakfast as a whole, including a seasonal fruit, infusion, and nutritionally improved cereal-based snack, the overall energy density fell below one, and the energy value goal for school breakfasts was achieved.

In view of the foregoing, reformulation of snacks including sugar and sodium reduction, and increments in fibre and calcium content, should be addressed stepwise so that children do not perceive abrupt changes in the organoleptic characteristics of the snacks and reject them. Once the targeted population gets adapted to the reformulated products, a new reduction step can be implemented (Deliza *et al.*, 2021). Gradual modification of nutrient content to slowly accustom consumer preferences is a more time consuming method, but with positive results reported for children (Rannou *et al.*, 2018).

3.1.3. Colour measurements

Surface colour parameters are presented in Table I**.** L* mean value for all four snacks was 51.42, without significant differences with the respective control ($p>0.06$). Other researchers have shown similar lightness for this type of product with partial or total refined wheat flour replacement (Marchetti *et al.*, 2018; Portman *et al.*, 2020; Šoronja-Simović *et al.*, 2017). It has been noted that browning, because of Maillard and caramelization reactions, leads to darkening of low moisture baked products, thereby decreasing their lightness (Walker *et al.*, 2012; Kumar *et al.*, 2020).

a* and b* parameters were positive in all samples, showing a slight tendency towards orange/red and a more pronounced one towards yellow. a* was higher in VC than in VC-Control, probably because of the presence of orange carotenoid pigments in sweet potatoes (Saeed *et al.*, 2012; Singh *et al.*, 2008). In CC and TM, b* was significantly lower than in the respective controls (p=0.01 and p<0.01, respectively). Ahmad *et al.* (2017) also found a decrease in b* for cookies supplemented with tomato waste powder, which turned the creamy-yellow colour of the samples to orange-yellow.

3.1.4. Sensory profiling

Through seven weekly training sessions, the panellists agreed a 5-point Likert scale to characterise each snack's appearance, flavour, and texture. For reasons of space, Table II lists only descriptions of extreme scores for each attribute.

Table II

Results from QDA are shown in Fig. 2. With regard to appearance, the snacks' colour did not differ from their respective controls, reaching in all cases high mean scores above 4.4 points. Although sugar or salt reduction can decrease the characteristic colour of baked products, it could be counterbalanced by the addition of lactose from milk powder (Shikha *et al.*, 2018). Only VC´s colour score was significantly higher than that of VC-Control (p=0.03), which the panellists observed as intense and uniform on the whole surface, and was consistent with the corresponding value of a*, as previously discussed. The snack's shape was similar to that of their controls (p>0.15) and well scored, except for BB whose shape was rated as more homogeneous than that of BB-Control (p=0.02).

Figure 2

Regarding flavour, the overall taste and smell mean scores were above 3.5 points for VC, CC, and TM, without significant differences from their controls (p>0.06). For BB, these attributes scored lower than for BB-Control (p=0.01), with similar tendencies for the vanilla taste and smell (p=0.01). For VC, the essence and chocolate taste and smell scores were similar to those for VC-Control (p>0.08). Saltiness of CC and TM was scored above 3.3 points, similarly to their controls ($p>0.23$). Addition of *Alliums* could help mask salt reduction and provide flavour (Balakrishnaraja *et al.*, 2021; Taladrid *et al.*, 2020). Sweetness of VC and BB did not reach as high a score as the respective controls ($p<0.01$). However, the mean scores for VC and BB were 3.3 and 3 points, respectively, indicating adequate acceptability.

Regarding texture attributes, crunchiness of the snacks was lower than that of their controls for all products in which this attribute was evaluated ($p<0.01$ for VC, BB, and CC); while chewiness of the snacks did not significantly differ from that of their controls for BB, CC, and TM ($p>0.17$), but it did for VC ($p=0.03$). Addition of milk powder tends to improve the dough's softness but can decrease crunchiness in low-moisture products because of its hygroscopic capacity (Sharma *et al.*, 2012).

Using principal components and cluster analyses (not presented for reasons of space), it was found that attributes of snacks could be grouped into 6 clusters with a similarity level of 69 and distance level of 0.62. The remaining variables were colour, shape, overall taste, overall smell, sweetness/saltiness, and texture (including crunchiness or softness, and chewiness).

3.2. Children's nutritional status

Demographic and nutritional characteristics of the participating children are presented in Table III, divided into four groups based on the school they attended and their availability for participating in tastings of each snack. All groups included children aged 5-13 years and both genders.

Table III

When analysing BMI-for-age z-scores, a higher value was obtained for men than for women ($p=0.05$). For a large sample of schoolchildren aged 6-14 years from Buenos Aires province, Argentina, Cuesta *et al*. (2018) found that the risk of obesity was higher among boys, which may increase their predisposition to acquiring several health-related conditions. Regarding height-for-age z-scores, no significant differences were observed between genders (p=0.23), as height of the participating children fell almost entirely within the expected range for their respective ages. Cadenas-Sánchez *et al*. (2015) obtained comparable results for height-for-age z-scores of Chilean preschool children, while Cordero and Cesani (2019) reported similar findings for children aged 8-12 years from Tucumán province, Argentina.

Distribution of nutritional status classification of the participating children is presented in Table III. It was observed that 53.4 % of the participating boys and girls had some type of malnutrition condition, primarily overweight and obesity, while only 3.9 % of them fell within the short and tall categories of the height-for-age classification. These results are similar to global trends (FAO, *et al.*, 2020; UNICEF *et al.*, 2021) and local Argentinian indicators reported in the 2nd Nutrition and Health National Survey (Moyano *et al.*, 2020). From reviewing several studies, Corvalán *et al*. (2017) concluded that stunting (height-for-age z-score below -2) is the most common nutritional deficit in Latin American children, although it varies widely between countries. They also found that overweight and obesity (weight-for-height z-score over +2) affected up to 44 % of children over 5 years in some countries.

Several factors have been associated with the occurrence of malnutrition, including availability and access to healthy food and other socio-environmental and economic circumstances (Nicolaidis, 2019; Sanchís *et al.*, 2017). In particular, occurrence of overweight and obesity has been linked to the consumption of ultra-processed foods in several studies reviewed by Martí del Moral *et al.* (2020), as these types of products usually introduce large amounts of free sugars and saturated fats into diets.

In several countries, approximately 60 % of the daily caloric intake of children came from ultra-processed foods, and the primary and secondary school environment were one of the main places of consumption of this type of products because of the accessible acquisition of ready-to-eat meals (Khandpur *et al*. 2020). Moreover, increased consumption of ultra-processed foods was correlated with socioeconomic level, as low-income households had a higher registered consumption of cheaper and less nutritious foods (Matos *et al*., 2021; Walsh *et al*., 2020).

Therefore, adoption of healthier dietary patterns should help reintroduce the ingestion of good-quality components, such as fibre, complex carbohydrates, and unsaturated fats, thus displacing the aforementioned undesirable ones from diets. Gradual incorporation of nutritionally improved bakery products as part of school breakfasts could become a valuable step in this direction. Snacks here proposed were formulated in this respect, while also having no added artificial colours, flavours, or sweeteners, which usage is restricted in products aimed at children as observed by Buttriss (2013). Moreover, snacks needed only low-cost ingredients, which would be accessible in the context of public schools' tight budgets.

3.3. Snacks acceptability

Overall acceptability of the four proposed snacks and their respective controls, expressed as mean scores and standard deviations obtained from the tastings by the participating school-aged children, are presented in Table IV. Children's choices on the Likert scale were categorised as acceptance (extremely liked, and liked), indifference (neither liked, nor disliked), and rejection (extremely disliked, and disliked) (Dourado Gomes Machado *et al.*, 2021), the distribution of which is also shown in Table IV.

Table IV

It was observed that the four formulated snacks were well accepted by the participants, where the overall liking for VC, BB, and TM did not significantly differ from their controls ($p>0.29$), while CC had a lower score than CC-Control ($p<0.01$). Modification of snack recipes to act as a vehicle for whole grains, legumes, and vegetables, without compromising their acceptability as part of school breakfasts, seems to have been successfully achieved in the tested school environments. As part of a school nutrition program, Schindler *et al.* (2013) demonstrated that exposure to a variety of different fruits and vegetables resulted in greater acceptance of such foods, which consumption according to data from UNICEF (2019) often falls well below the recommended values. From a review of food programs and policies, Welker *et al.* (2016) also found that repetition of this type of exposure resulted in an improvement in acceptance and consumption of healthy meals offered in schools after less than one year of implementation.

As children usually prefer products that are high in added sugar and salt (de Cosmi *et al.*, 2017), reformulation of snacks including the reduction of these components represents one of the biggest challenges to be addressed without compromising children´s acceptability (Mc Clements, 2020). Overall acceptability of both sweet products reached high mean scores of 4.3 and 4.2 for VC and BB, respectively, even with a reduction of their added sugar content. More than 87 % of children expressed acceptance of both snacks. When developing cereal bars as a school snack based on oat flakes, popped amaranth seeds, dehydrated chokeberries, and butter

and reduced content of sucrose, Bialek *et al.* (2016) also found high sensory acceptance of these products among children.

Meanwhile, savoury products got acceptable but lower mean scores of 3.7 and 3.3 for CC and TM, respectively. Even though these products were accepted by more than half of the participating children, they showed larger indifference and rejection percentages than sweet ones. For CC, 21.1 % of children chose "neither liked nor disliked", which indicated that more than 87 % of them (adding up the acceptance and indifference percentages) may consume this snack if presented as part of a school breakfast. On the other hand, the rejection percentage for TM almost quadrupled the indifference one, which indicated a markedly lower predisposition towards its consumption. These differences between sweet and savoury products could probably be explained by the innate and learned inclination toward sweet taste during childhood (Ventura and Mennella, 2011).

Participants' opinions regarding their liking or disliking of snacks' attributes are presented in Table V. As a general trend, attributes evaluated for sweet snacks were predominantly rated as positive, whereas both savoury products showed mixed reception in some instances.

Table V

When asked about reasons for their scores, many children expressed that the snacks were not as sweet or salty as those they usually consumed. Nevertheless, most children rated the overall taste of all snacks favourably. It was also observed that sweetness was better regarded than saltiness, which may also be reflected in a more positive rating of the attributes and overall acceptability of VC and BB compared with CC and TM. Bobowski and Mennella (2019) explained that salt is typically added to food because of its functional properties, which may impact the overall acceptability of products with low sodium content, including increased perception of unpleasant tastes and off-flavours. For both savoury snacks, texture and overall taste were the attributes most negatively rated by the children, although their positive assessment was even larger. Many participants also expressed that they would consume snacks accompanied by a cup of tea, milk, chocolate, or yoghurt, which should be an integral part of school meals (Gibney *et al.*, 2018).

4. Conclusions

The entire process of formulation, characterization, and acceptability evaluation of novel nutritionally improved snacks was comprehensively reported. These products were designed to meet the international nutritional goals for school breakfasts, and were intended to be consumed along with a seasonal fruit and infusion. Then, all four snacks would replace usual ultra-processed solid products with cereal-based alternatives which include half a cup of whole milk in their formulation, without needing artificial food additives, preservatives, or sweeteners.

In view of the obtained results, Vanilla cookies (VC), Bay biscuits (BB), and Cheese crackers (CC) would be suitable for incorporation as a snack for such breakfasts. On the other hand, the formulation of Tomato muffins (TM) should be modified to improve their acceptability and attributes prior to their inclusion in school food programs.

Food reformulation in isolation is unlikely to provide a comprehensive solution to malnutrition, but it can constitute a reasonable and accessible starting point, which becomes even more relevant when children are served only unhealthy products as part of daily school breakfasts. In this context, reduction of high contents of sugar, sodium, and fats, and increase of protein, fibre, and calcium contents are substantial steps that were here shown can be achieved without fundamental modification of the products. This strategy also seeks to avoid compromising their acceptability, and to allow their production in available facilities with the same equipment and personnel.

Incorporation of novel nutritionally improved snacks in school breakfasts is one of several strategies being developed to promote healthier lifestyles among local communities, particularly children, including educational programs, workshops, and food assistance, among others. Such comprehensive policies have become necessary to combat malnutrition, including stunning, overweight, and obesity, and have caught the attention of other local governments interested in replicating this experience with their school-aged children. Further work will focus on monitoring the gradual incorporation of the proposed snacks as a daily intake in some schools of Perez city and other nearby districts, and evaluating their long-term acceptability as well as their impact in relevant anthropometric and nutritional indicators.

Declarations

Supplementary material to this work can be accessed at this link.

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