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RESEARCH ARTICLE

Investigation of Physicochemical and Sensory Properties of Finger-millet (*Eleusine coracana*) Incorporated Chicken Egg-based Snack

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ABSTRACT

Consumers prefer to have a snack with healthy and high nutritional value to satisfy the hunger as a convenient, ready-to-eat food item or replacement meal. Thus, this study was aimed to develop a nutritionally balanced, finger-millet (Eleusine coracana) incorporated egg-based snack with high sensory properties. In this study, two preliminary trials were conducted to select the best replacement level of wheat flour with finger-millet on a weight basis as 10%, 15% and 20% (w/w) and to determine the best incorporation level of egg white from four levels; 0%, 15%, 30% and 45% (w/w). The 15% finger-millet incorporated snack from trial 1 and the snack consisting of 15% finger-millet with 30% egg white from trial 2 were selected via sensory evaluations. The selected two snack products were stored at room temperature (28°C) for one month to evaluate the physiochemical, microbiological and sensory parameters. There was a significant difference ($p<0.05$) in colour, appearance and overall acceptability between the two snacks at the first and fourth week of the storage period, as well as the crispiness of the two snacks showed a significant difference ($p<0.05$) at the end of the storage period. The snack made with 30% egg white and 15% finger-millet had significantly lower ($p<0.05$) bulk density (0.33 ± 0.01 g/cm^3) and significantly higher ($p<0.05$) protein content (18.96 ± 0.30%) than the other treatment. Results of the current study revealed that 15% finger-millet, 30% egg white incorporated snack gives the best sensory, nutritional and physiochemical characteristics that can be used as a novel product in the food industry.

***Keywords**: Egg white, Finger millet, Nutritional, Snack, Wheat flour*

INTRODUCTION

Snacks play an important role in the diets of young people and children as a ready-to-eat or light meal or supplementary food, which are produced by extruding, baking, frying or drying as deep-fried chips, frozen egg pizza, egg fingers (crumb-coated scrambled eggs) and egg flakes (Ovaskainen *et al.*, 2006; Pawar *et al.*, 2012; Kolmaga and Garus-Pakowska, 2024). Based on the nutritional value, the snacks can be categorised in two ways: snacks with high nutritive value and low energy (vegetables, fruits or some dairy food), and snacks with low nutritive value and high energy (candy, chips, cookies, crackers) (Pansawat *et al.*, 2008). However, snacks with high sugar and salt content, such as cookies and potato chips, are more popular among people (Hess *et al.*, 2016; Valverde *et al.*, 2016). Snacks which contain low nutrient contents and high energy contents are recognised as one of the major factors of weight gain among the western population in the world (Whybrow *et al.*, 2007; Verma and Patel, 2013). Developing a snack with functional properties is preferable because most of the snacks are cereal-based, which are low in protein as well as low in other nutrients (Shaikh *et al.*, 2017; Escobedo and Mojica, 2021). It should also be a nutritional, health-promoting snack which has different flavours and sensory characteristics to fulfil consumer acceptance (Rathnayake *et al.*, 2012; Tas and Shah, 2021; Okpara and Chidolue, 2023). The snack food industry has been aiming to incorporate blends of meat, beef or chicken into the non-meat ingredients in order to produce expanded or non-expanded snacks (EI-Faham, 2005). Also, by incorporating protein supplement to the snacks, it gives an opportunity to utilise high-quality protein in by-products, and improve the nutrient density of extruded snacks or breakfast that consists of pigments, flavour components, calcium and other minerals (Murphy *et al.*, 2003) without causing health disorders (Khvostenko *et al.*, 2024). Recently, not only beef and chicken, but also various animal sources such as fish flesh, by-products of crustaceans, eggs, lamb and pork are also tested by incorporating with vegetable sources to produce snacks (Serna-Saldivar, 2022). There are only a few investigations on snacks supplemented with nutrients and functional components using both plant and animal sources (Pęksa *et al.*, 2010). Increasing fibre levels, decreasing calories, replacing fat with hydrocolloids and emulsifiers are mainly focused on the development of healthy and quality snacks (Kaur *et al.*, 2020).

Egg is a balanced diet which supplies nutritionally important substances as well as important functional ingredients to the food industry (Marin *et al.*, 2002). Egg is considered the basic ingredient which plays an important role in obtaining desirable volume, texture and colour of baked food products (Patil *et al.*, 2022). Eggs act as a binding, leaving, tenderising and emulsifying agent and help to develop flavour and colour of the product (Rajiv *et al.*, 2011). Egg proteins can be used for the preparation of protein-rich food products because they contain essential amino acids and good-quality protein that is required for human growth and maintenance (Chernoff, 2004). Therefore, egg white can be used as a protein ingredient during the preparation of snacks as it does not negatively influence the organoleptic properties of food (Kocherla *et al.*, 2012).

Finger-millet (*Eleucine coracana*) is one of the most important grains that is rapidly cultivated in Asia and Africa regions of the world (Panghal *et al.*, 2019), but it is an underutilised cereal in Sri Lanka. According to proximate composition of finger-millets, it contains carbohydrates (65–75%), protein (7–12%), fat (2–5%), dietary fiber (15–20%), minerals (2.5%–3.5%) and ether extractives (1–2%) whereas these proteins are considered as unique due to the presence of sulphur rich amino acids as methionine and cysteine (Panghal *et al.*, 2019; Bafna *et al.*, 2020). In addition to that, it contains vitamins such as B6, folic acid and minerals: calcium, iron, potassium, magnesium and zinc (Valverde *et al.*, 2016). Finger-millet is used for the manufacturing of baby food, especially for weaned children, because it improves the digestibility and bioavailability of the nutrients, and it is easy to prepare a low-cost, nutritious sweet for anyone (Malleshi *et al.*, 2025). Therefore, finger-millet is usually used to prepare porridge, puddings, pancakes, biscuits, bread and noodles in the food industry (Gull *et al.*, 2014; Narayanan, 2023).

Even though wheat is the predominant ingredient in the food industry, there is a trend to replace wheat in bakery products with non-wheat cereal flours and other grain by-products to avoid the overuse of wheat flour. The replacement of finger-millet for the preparation of snacks is beneficial to encourage the utilisation of non-wheat cereals or underutilised cereals during the shortage period of wheat and, economically, advantageous to reduce the importation of wheat at high prices. As well as, it helps to support local farmers, strengthen their livelihood, rural economics and maintain sustainable agriculture in the country. Introducing millet-included egg-based snacks is an economically feasible product for consumers who are seeking health-oriented snacks instead of instant snacks. The innovative product can be used not only to satisfy their hunger but also to contribute to the health and wellness of the consumers because of anti-carcinogenic, anti-diabetic, anti-ulcer, anti-diarrheal, anti-inflammatory, anti-microbial and anti-oxidant characteristics of finger-millet (Kaur *et al.*, 2020). Therefore, in the scenario of developing nutritionally improved functional snacks, utilisation of eggs and finger millets could play a major role in enhancing both nutritional and sensory attributes of the snacks. The finger-millet incorporated egg-based snack can be used for school-age children as a solution for malnutrition, as a ready-to-eat breakfast meal or light meal for young children and adults, because it contains animal source proteins. Moreover, this product can be advantageous to people who lead busy lives, women who are engaged in the labour force and people who prefer various food consumption and eating patterns. By consuming this product, people can recover their micronutrient deficiencies: anaemia and calcium deficiencies, improve gut health and support metabolic wellness (Kaur *et al.*, 2020). Hence, the objective of this present study was to develop a novel product of finger-millet incorporated egg-based snack with a new taste for consumers and to evaluate the nutritional, physico-chemical, sensory and keeping quality characteristics of the newly developed snack.

MATERIALS AND METHODS

Location of the study

All preliminary trials, preparation of egg-based snacks and sensory analysis were done at the Meat Technology Laboratory, Department of Animal Science, Faculty of Agriculture, University of Peradeniya, Sri Lanka. Proximate analysis of the egg-based snacks was conducted in the Nutrition Laboratory, and microbiological analysis was done at the Microbiology Laboratory of the Department of Animal Science.

Materials

Finger-millet was obtained from the Field Crop Research and Development Institute, Maha-Illuppalama, Sri Lanka. The eggs, wheat flour, all the spices, salt, sugar, baking powder and sunflower oil were purchased from a local supermarket in Peradeniya, Sri Lanka.

Preparation of snacks

In this study, the snacks were prepared according to the procedure described by Bafna *et al*., (2020) with slight modifications; incorporation of finger-millet powder and egg white in different ratios. A conventional snack formulation used in the hotel industry was used as a base to prepare the dough of the snack. The initial formulation was modified by adding different spices to improve its taste and aroma. The modified formulation of the snack mixture is shown in Table 1. The required amount of finely ground garlic, onion and white sesame and all the other ingredients were weighed (RADWAG, AS 220/C/2, Wagi Electrroonicizne, Poland) and mixed thoroughly. After the incorporation of egg white, it was beaten for about 30 min before mixing with the dough. When mixing the dough, water was added until the desired consistency was obtained. The prepared dough was sheeted on the wooden cutting board between two wooden strips to control the thickness of the dough to not more than 3 mm. The dough was cut into star shapes using aluminium cutters. Then, it was put into trays and baked in an oven (DX-600, Scientific Co. Ltd, Japan) at 105°C for 30 min.

Table 1: The modified formulation of the snack mixture used for the preparation of the finger-millet incorporated egg-based snack

Ingredients	Content (g)
Wheat flour	80-85-90-100
Finger-millet	20-15-10-0
Egg white	0-15-30-45
Baking powder	3
Sunflower oil	6
Sugar	5
Salt	2.5
Garlic	10
Sesame	10
Onion	10
Pepper	2.5
Water (mL)	30

Preliminary trials

In this present study, 2 preliminary trials were conducted. The first trial was conducted in order to find out the best level of wheat flour replacement with finger millet for the new product. Trial 2 was conducted to determine the best level of egg white in the finger-millet incorporated snack.

Trial 1: Determination of the best finger-millet level to be incorporated into the snack

In this preliminary trial, the snacks were prepared by adding 3 different levels of finger-millet flour (T1=10%, T2=15% and T3=20%) to replace the wheat flour in the dough, as shown in Table 2. After that, sensory evaluation was conducted using 30 untrained panellists to find out the best finger-millet level to be incorporated in the snack. Each panellist was given 3 different snack samples for the sensory evaluation and asked to evaluate the colour, appearance, crispness, mouth-feel and overall acceptability by a seven-point hedonic scale (1=dislike extremely to 7=like extremely) as described by Kocherla *et al*., (2012). In this current study, the best accepted finger-millet incorporation level in the snack among three treatments was further developed with the addition of egg white in another trial.

Table 2: The replacement level of wheat flour with finger-millet flour in the formulation of the snack used for Trial 1

Ingredient	**Composition (w/w)**		
	T1	T2	T3
Finger-millet	10	15	20
Wheat	90	85	80

Composition: T1: 10% finger-millet incorporated snack, T2: 15% finger-millet incorporated snack and T3: 20% finger-millet incorporated snack

Trial 2: Determination of the best egg white level to be incorporated in the finger-millet incorporated snack

The selected finger-millet incorporated snack via the first sensory evaluation was modified by adding different levels of egg white (C=0%, T1=15%, T2=30% and T3=45%) as given in Table 3. The sensory evaluation was conducted to select the best incorporated level of egg white in the finger-millet incorporated snack in order to prepare the egg-based snack. The colour, appearance, odour, crispiness, mouthfeel and overall acceptability were evaluated by a seven-point hedonic scale (1=dislike extremely; 7=like extremely). The samples were encoded with randomly selected three-digit numbers and presented to untrained panellists (30) to evaluate those organoleptic properties as described by Valverde *et al*., (2016).

Table 3: Four different levels of egg white in the finger-millet incorporated snack used in Trial 2

Ingredient	Composition (w/w)			
	C	T1	T2	T3
Egg white	0	15	30	45
Other ingredients	100	85	70	55

Composition: C: control (0% egg white), T1: 15% of egg white, T2: 30% of egg white and T3: 45% of egg white incorporated snack

Sensory evaluation of two snacks during the storage period

The snack selected in the sensory evaluation of Trial 2 (snack which had the best level of egg white in finger-millet incorporated product) and the snack selected from the sensory evaluation of Trial 1 (snacks which had the best incorporation level of finger-millet with replacing wheat flour) were packaged in 300-gauge polythene bags and stored in room temperature (28°C) for one month of period. Colour, appearance, odour, crispiness, mouthfeel and overall acceptability of 2 snacks were evaluated in the first and fourth week of the storage period. The sensory attributes were evaluated through a seven-point hedonic scale by 30 untrained panellists. All the samples used for the sensory evaluation were labelled using 3-digit numbers. The panellists were asked to rinse mouth with water after testing each sample as described by Pawar *et al.* (2012).

Proximate analysis of egg-based snacks

The samples of both snacks (snacks made by incorporating both 15% finger-millet, 30% egg white and the snacks prepared by incorporating 15% finger-millet) were ground into powdered form using a motor and pestle. The samples were subjected to analysis for moisture, crude protein and ash in the first week after manufacturing of both snacks according to the procedure of the Association of Analytical Chemistry (AOAC, 1995). The samples were analysed for crude fat by the Soxhlet extraction method according to the procedure described by Islam *et al.* (2024). In this study, the proximate composition of two snacks was analysed with three replicates for each treatment.

Bulk density of egg-based snacks

The initial weight of 50 mL of the beaker was taken. The beaker was filled using snacks up to the mark of 50 mL, and the weight was measured. The bulk density of 2 types of snacks was calculated using the weight of snacks divided by the volume of the beaker (Kocherla *et al.*, 2012).

Microbiological analysis of egg-based snacks

To determine the microbiological quality of the product, total aerobic plate counts (TAPC) were done at the first and fourth week of the storage period of 2 snacks, which were produced by two trials in this study. Petri dishes were sterilised in a drying oven (DX-600, Scientific Co. Ltd, Japan) at 160ºC for 2 h. Plate count agar, peptone water, glassware and pipette tips were sterilised by autoclaving (SA-300VF, Gemmy Industrial Corp, Taiwan) at 121ºC for 20 min. Then, 100 mL of peptone water and 10 g of the sample were put into stomacher bags and mixed by a homogeniser (Bagmixture 400, Interscience International 30 ch. Bois des Arpents, 78860, St Nom, France) thoroughly. From this mixture, 1 mL was introduced into 9 mL of peptone water, and a dilution series was prepared from 10–1 to 10–5. After that, 1 mL from the 10–3, 10–4 and 10–5 mixture was inoculated into the agar in the petri dishes, dispersed and incubated for about 72 h at 30ºC. After the incubation period, white colonies were counted according to the procedure described by AOAC. (1995).

Keeping quality analysis of two snacks during the storage period

The selected snack samples of the Trial 1 and 2 were subjected to analysis of pH and 2-TBARS value during the four weeks of the storage period. Bulk densities of the two snack samples were evaluated in the first week of the storage period.

Determination of pH

Approximately 5 g of the sample was weighed (RADWAG, AS 220/C/2, Wagi Electrroonicizne, Poland) into a previously cleaned beaker. Then, 50 mL of distilled water was added and homogenised (BM-4, Nihoneseiki Kasisha Ltd., Japan) to obtain uniformity of the mixture. The reading of the final slurry was measured into 2 digits by the digital pH meter (MICROPROCESSOR pH METER, pH 211, Hanna Instruments, Mauritius), immersing the electrode and shaking the beaker for 2–3 min (AOAC, 1995).

Determination of 2-Thiobarbituric acid reactive substances (2-TBARS)

In this study, 5 mL of 10% (w/v) solution of Trichloroacetic acid was added to a centrifuge tube, which had 2 g of the sample. The centrifuge tube was vortexed (VM-96B, Jeio Tech, Korea) at high speed for 2 min. Then, 5 mL of 0.02 M aqueous solution of 2-thiobarbituric acid was added to the centrifuge tube and vortexed for 30 s. After that, the samples were centrifuged (CF 1502, Himac, Hitachi, Japan) at 3000 *g* for 10 min. The supernatants were filtered through Whatman No. 3 filter paper, and the filtrate was heated in a boiling water bath (YCW-010E, Gemmy Industrial Corporation, Taiwan) for 45 min. Then, it was cooled to room temperature using ice cubes. The absorption value of the resulting colour was measured at 532 nm using a spectrophotometer (5104, No 453, WPA Linton, Cambridge, UK). The 2-TBRAS value was obtained by using a standard line prepared with 1,1,3,3- tetramethoxy methane as a precursor of malonaldehyde (AOAC, 1995).

Statistical analysis

All the analyses were done with three replicates per treatment. The sensory data were analysed by using the Friedman non-parametric test using the MINITAB 17 software package at 95% confidence interval. A Complete Randomised Design (CRD) was used to analyse the significance of the proximate analysis of 2 snacks. Data was analysed by using one-way ANOVA using the SAS program (SAS Institute Inc., 2004) version 9.0 with a 95% confidence interval. Mean separation was done by the Duncan Multiple Range Test. The data (pH and 2-TBARS value) of 2 snack samples that were collected during storage were analysed using repeatable measures using the SAS program (SAS Institute Incorporated, 2004) version 9.0 with a 95% confidence interval.

RESULTS AND DISCUSSION

Results of preliminary trials

Trial 1: Initially, the snacks were prepared by replacing wheat flour with different levels of finger-millet as 25%, 50%, 75% and 100%. When the finger-millet incorporation level was increased more than 25%, the snacks became harder in texture, drier, and less palatable. As a result of that, cracks were seen on the surface of the snack. When wheat flour was reduced by less than 60% in dough preparation, it did not possess adequate elasticity and was difficult to mould as it tended to break (Margues *et al.*, 2000). The wheat flour was used in an extensive range of the bakery industry because gluten is an important component for giving unique viscoelastic, adhesive and cohesive characteristics of the bakery products (Singh and Singh, 2006). Thus, it is difficult to produce bakery products with pure millet grain, because they are gluten-free. Therefore, the best method is the replacement of wheat with composites of finger-millet flour (Gull *et al.*, 2014). In this study, it was found that the finger-millet incorporation level in the formulation of snack should not be exceeded more than 25%. The results of the sensory evaluation of the snacks that were prepared with the incorporation of 10%, 15% and 20% finger-millet are shown in Figure 1(A).

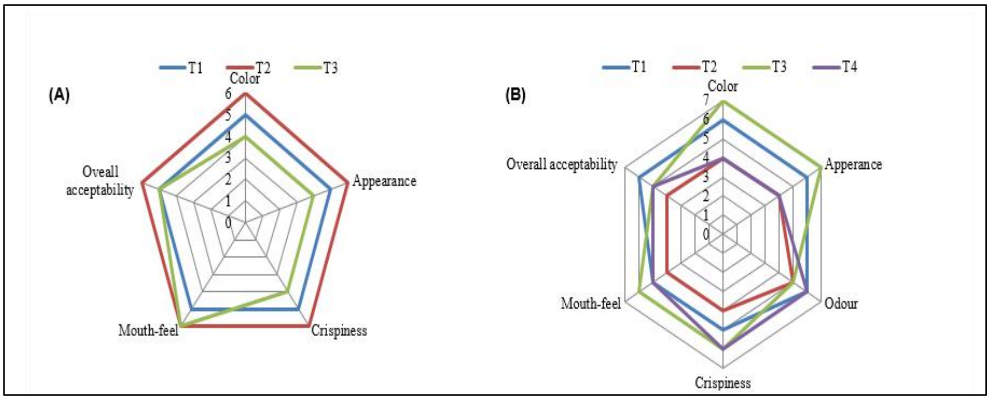

Figure 1: Changes of the sensory attributes in three levels of finger-millet incorporated egg snack in Trial 1 (A) and the snacks that were prepared from four levels of egg white incorporated in 15% finger-millet in Trial 2 (B). Treatments (A)-Tl: 10% finger-millet incorporated snack, T2: 15% finger-millet incorporated snack and T3: 20% finger-millet incorporated snack. Treatments (B)-C: control (0% egg white), T1: 15% of egg white, T2: 30% of egg white, and T3: 45% of egg white used in the finger-millet incorporated snack

There was a significant difference ($p<0.05$) among 3 treatments for the sensory attributes of colour, appearance and crispiness. The highest ($p<0.05$) estimated median value for overall acceptability was observed in 15% Finger-millet incorporated snack. Based on the preferences of the sensory panellists, Treatment 2, which consisted with 15% of finger-millet, was selected as the best level of finger-millet incorporation in the snack. The snack prepared with the highest level (20%) of finger-millet was scored the lowest ($p<0.05$) value for the sensory attributes, such as colour, appearance and crispiness, except for the mouthfeel. When finger-millet level was increased during the snack formulation, it appeared in dark brownish color and it may adversely affected on color and appearance of the product. Naveena *et al*. (2006) revealed that incorporation of finger-millet into chicken patties resulted darker color over to lightness and yellowness. Thomas *et al*. (2024) identified that “L” value (lightness) was decreased with increasing the level of finger-millet up to 40% in the extruded product. Furthermore, a hard texture was developed in the snack when increasing the finger-millet level in the snack, and it may be impacted for the crispiness. Increasing the finger-millet flour level resulted in an increase in the peak force of extrudes, which indicates the hard texture (Sawant *et al*., 2013). Abinayaselvi *et al*. (2018) noted that increasing the finger-millet levels of chicken soups caused a lower score in appearance, flavour, and mouthfeel. However, Thomas *et al*. (2024) stated that the optimal finger-millet replacement level with wheat flour for the production of chicken meat-based biscuit was 30% among 3 different finger-millet incorporation levels as 20%, 30% and 40%. As well as, 19.5% incorporation of pearl millet was selected as the best incorporation level for production of egg nuggets based on flavour, juiciness, texture and overall acceptability among 3 different levels of pearl millet; 17.5%, 19.5% and 21.5% (Gamini *et al*., 2023).

Trial 2: The sensory data of the snacks that were prepared from 4 different levels of egg white (0%, 15%, 30% and 45%) with the incorporation of 15% finger-millet is shown in Figure 1(B). The snack containing 30% egg white had the highest ($p<0.05$) median value for colour, appearance, mouthfeel and overall acceptability. It was selected as the best level of egg white in the 15% finger-millet incorporated snacks. The snacks containing 45% egg white had the lowest ($p<0.05$) score for overall acceptability of the consumers. During egg white incorporation, when it exceeded 45%, the dough became watery and could not get the appropriate shape of the snack. When the incorporation level of liquid egg white was increased, the appearance of the snack became like unbaked or moist. According to the findings of Kreger *et al.* (2012), high protein level had a significant effect on less puffed, porous and uniform attributes and overall acceptability. Increasing moisture adversely affect for macromolecular structure of the snacks by breaking water-water interactions and intermolecular force bonds. This causes the movement of macromolecules and loss of crispiness (Katz and Labuza, 1981). Kocherla *et al.* (2012) stated that ready-to-eat extruded snacks produced from 20% and 30% of egg albumen powder were selected as best formulations compared to other egg albumen levels as 5% and 10%. The incorporation of chicken egg into whole-wheat flour strongly affected the improvement of nutritive value and sensory appeal (Nwadi *et al.*, 2025).

Sensory evaluation of two snacks during the storage period

The findings of the sensory evaluation of 2 types of snacks (only 15% finger-millet incorporated snack and the snack which incorporated with both 15% finger-millet and 30% egg white) during the first and fourth week of the storage period are shown in Figure 2(A) and Figure 2(B), respectively. In the first week of the storage period, there was a difference ($p<0.05$) in colour and appearance between 2 snacks. This may be due to the more preferable golden brown color in egg white incorporated snack rather than the finger-millet incorporated snack. According to the findings of Katekhong and Charoenrein, (2016), egg white protein probably became to desirable brown or golden colour due to the Maillard browning reaction during heating. According to Rhee *et al.* (1997), egg plasma snack obtained the best score for colour because of the development of pigments during storage. Therefore, the results of this study suggest that the addition of egg white improved the colour, appearance and overall acceptability of the snack. The extruded egg-based wheat snack produced from 15% and 20% egg white improved the colour stability of products compared to the control as described by Nwadi *et al.* (2025). A similar study further described that the addition of egg yolk caused an improvement in colour, appearance, texture and taste compared to the addition of egg white. Moreover, the extruded snack produced from corn flour (35%), rice flour (35%) with 30% egg albumin was shown to have higher overall acceptability, followed by corn flour (40%), rice flour (40%) with 20% egg albumin powder showed higher acceptability compared to the control snack (Kocherla *et al.*, 2012).

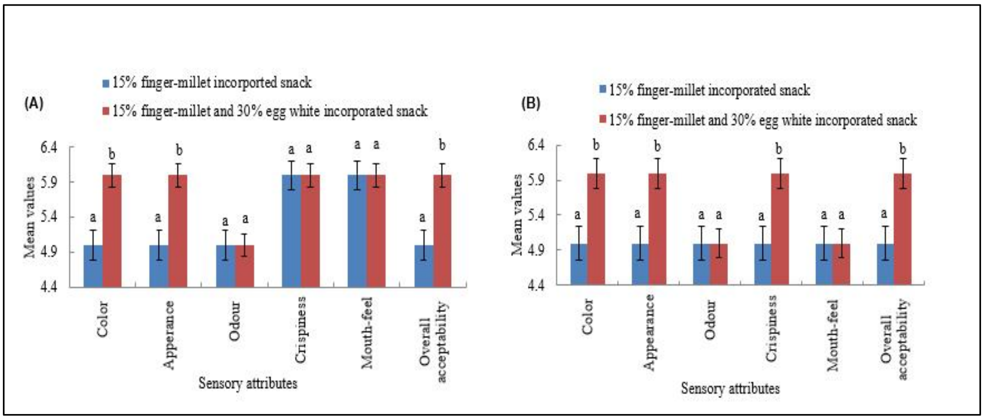

Figure 2: The scores of sensory attributes of two snack products at the first week (A) and fourth week (B) of the storage period. Data represented as Mean±Standard Deviation (n=30). Different alphabetical letters show means are significantly different at p=0.05

In the fourth week of the storage period, there was a difference (p<0.05) in colour, appearance, crispiness and overall acceptability between 2 snacks. However, there wasn't a significant difference in crispiness between 2 snacks in the first week of storage. This scenario may have happened due to the reduction in the hardness of the snack due to absorption of moisture during the storage period. According to Anton *et al*. (2009), heat denaturation of egg whites promotes the protein surface hydrophobicity, and it corresponds to low rigidity, elasticity and water retention capacity. The findings of Rhee *et al*. (1997) showed the lowest score for hardness in egg plasma snacks.

Proximate analysis of egg-based snacks

Table 4 shows the proximate composition of 15% finger-millet incorporated snack and the snack which had 15% finger-millet and 30% egg white. The snack consisting of 15% finger-millet and 30% egg white had a higher (p<0.05) protein level compared to 15% finger-millet incorporated snack. It obviously happened due to the incorporation of egg white in that snack, which had a high amount of good-quality protein. According to Kocherla *et al*. (2012), the highest protein content (24.46±0.55%) was recorded in the ready-to-eat extruded snack that was formulated with corn flour, rice flour and egg albumin powder (35:35:30). This also happened due to the addition of concentrated protein source to the extruded snack mixture. There was no difference in crude fibre, moisture, ash, dry matter and ether extract between 2 snacks except for the crude protein percentage (Table 4). Gamini *et al.*, (2023) showed that the addition of finger-millet flour to the egg nuggets caused no significant difference in moisture content between 19.5% finger-millet added and control snacks due to its lower moisture content. As well as, a similar study further described that the addition of pearl-millet caused a reduction in the fat percentage of egg nuggets due to the lower fat content of pearl-millet. In a similar way, Chatli *et al*. (2015) and Gamit *et al*. (2020) also stated that fat content was reduced in finger-millet flour incorporated with emu meat nuggets and chicken meat cutlets, respectively. In the present study, 15% finger-millet and 30% egg white incorporated snack had 4.87% moisture content, 18.96% protein content, 11.36% fat content and 8.71% crude fibre content. Therefore, the selected egg-based snack can be used as a protein supplement in protein-deficient diets to ensure food security.

Table 4: The proximate composition of the two snack products in the first week of manufacturing

Component (%)	15% finger-millet incorporated egg-based snacks	15% finger-millet + 30% egg white incorporated egg-based snacks
Dry matter	93.04 ±0.16[a]	95.13±1.16[a]
Ether extract	12.22±0.26[a]	11.36±0.73[a]
Crude protein	14.36±1.00[a]	18.96±0.30[b]
Crude fiber	8.60±0.26[a]	8.71±1.00[a]
Ash content	6.80±0.16[a]	6.70±0.38[a]

Different alphabetical letters within the same raw shows treatments are significantly different (p=0.05)

Bulk densities of egg-based snacks

In this study, the snack consisted with 15% finger-millet and 30% egg white incorporated had lower (p<0.05) bulk density (0.33±0.01 g/cm^3) compared to 15% finger-millet incorporated snacks. This may be due to the addition of egg white, which caused an increase in the air incorporation and volume of the product. The extruded product made from 20% egg white protein showed lower bulk density than the product without egg white protein due to the foaming ability of egg white (Kocherla *et al.*, 2012). This study further described that bulk density is inversely related to the expansion ratio, and it is the corresponding result for that. Therefore, the result of this study agrees with Kocherla *et al*. (2012). Moreover, the expansion ratio was decreased when the bulk density of corn-based extruded snack increased (Pracha and Chulaluk, 2000; Pawar *et al.*, 2009).

Microbiological analysis of egg-based snacks

The microbiological results of total viable aerobic counts of 2 snack products during the first and fourth week of the storage period are presented in Figure 3. The TAPC of 2 snack products weren't different during the first and fourth week of the storage period. The standard plate counts of egg crunchy bite with added garlic and its control had 3.96-2.09 and 4.4-3.3 log CFU/g during six months of the storage period (Pawar *et al.*, 2012). According to Shaviklo (2015), the limit of the colony-forming unit of total aerobic plate counts should be less than 10 at 30ºC. Therefore, 2 products were within the acceptable range of total aerobic plate counts according to SLS-1162 (1997), and they were microbiologically sound for consumption during the storage period.

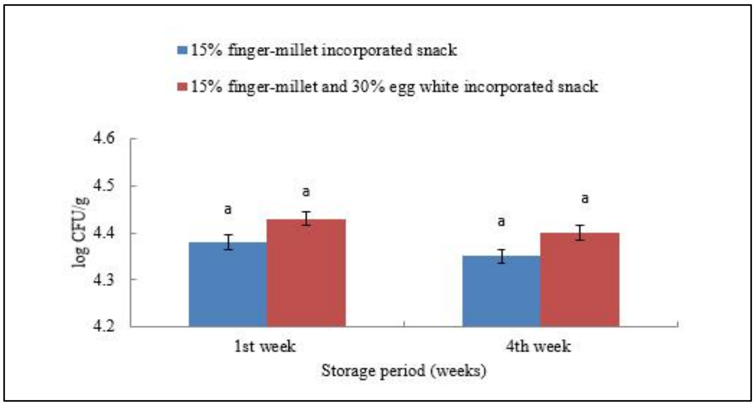

Figure 3: Total aerobic plate count of two snack products during the first and fourth weeks of storage. Data are presented as Mean±Standard Deviation (n=6). Different alphabetical letters show means are significantly different at p=0.05

Analyses of keeping quality of two snacks during the storage period

Changes in pH values of egg-based snacks

As shown in Figure 4, the pH values of 2 snack products were not different (p>0.05) during the storage period. In the first week of the storage period, the pH of 15% finger-millet incorporated egg snack was numerically pH over to other three weeks, and then it showed a decreasing trend. In addition, 15% finger-millet and 30% egg white incorporated egg snack also showed a decline of pH during the storage period. Pavan *et al*. (2019) noted that finger-millet (200 g) incorporated chicken nuggets showed a higher pH on the initial day compared to the control, which could have happened due to the higher pH of finger-millet flour. Therefore, a similar scenario found in the present study is matched with the findings of Pavan *et al*. (2019). The decreasing of pH value with the storage period may be due to the activities of microorganisms or increasing hydrogen ion concentration. It may cause to give sour taste and rejection of the desirable quality characteristics. According to Ocheme *et al*., (2014), a low pH value is preferable because the growth of microorganisms is reduced at low pH. The decrease of pH may occur due to the utilisation of carbohydrates by microorganisms and the formation of lactic acid (Raja *et al*., 2014). As well as Pawar *et al*. (2012), pH values of egg-based snack (egg crunchy bite with added garlic) were decreased from 5.67±0.10 to 5.58±0.30 at the end of six months of the storage period. However, the findings of Pavan *et al*. (2019) and Naveena *et al*. (2006) showed an increasing pattern of pH of chicken nuggets and chicken patties incorporated with finger-millet flour during the storage period, which is totally different from this study. Thomas *et al*. (2024) found a significant difference in pH between control and different levels of finger-millet incorporated chicken meat biscuits, as 20%, 30% and 40%. And also, a similar study further described that the pH of the finger-millet incorporated chicken meat-based snacks had a lower pH when increasing the inclusion level of finger-millet. In contrast to that, the findings of Gamini *et al.* (2023) showed that 19.5% pearl-millet incorporated egg nuggets had lower pH compared to the control samples as well as chicken meat cutlets produced with finger-millet flour, which also reduced the pH value.

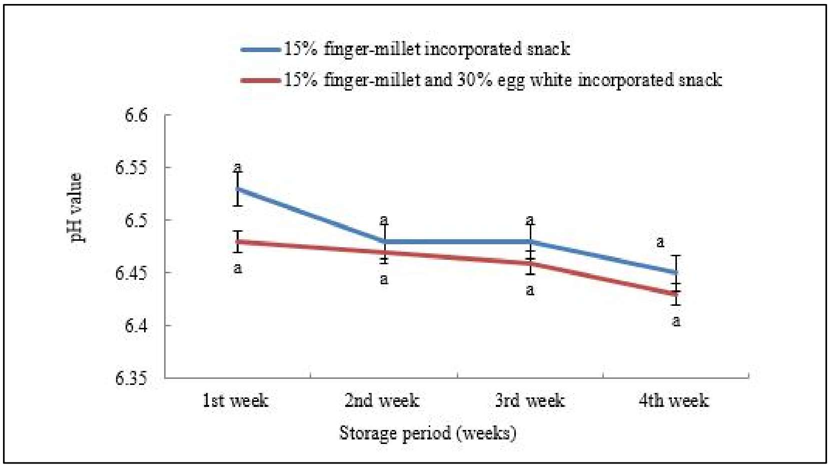

Figure 4: pH value changes of two snacks during the four weeks of the storage period. Data presented as Mean±Standard deviation (n=6). Different alphabetical letters show that the means are significantly different at p=0.05

Changes in 2-TBARS values of egg-based snacks

As illustrated in Figure 5, there was no significant difference in 2-TBARS value between 2 egg-based snacks during one month of the storage period. The 2-TBARS value of both snacks was significantly increased (p<0.05) from the third week of the storage period, which may have happened due to increment of the lipid oxidation of the two products. The amount of TBA indicates the oxidative rancidity of the product, and it directly impacts the quality deterioration. The TBA value of the egg-based snack (egg crunchy bite with added garlic) was increased from 2.26±0.49 to 2.66±0.33 during 6 months of the storage period (Pawar *et al.*, 2012). In this study, the 2-TBARS value of 2 snack products was abnormally high. This may be due to interference of the absorption value by some ingredients included in the snack product, interference of the 2-TBARS assay because of heating samples with strong acids and generating high Malonldehyde (MDA) values. The meat-based snack food generally has 0.85–1.03 mg MDA/kg of 2-TBARS value. The fried food, such as French fries, breaded chicken, and potato chips indicate 0.43–0.90 mg of MDA/kg of 2-TBARS value (Kamel and Sheikh, 2012).

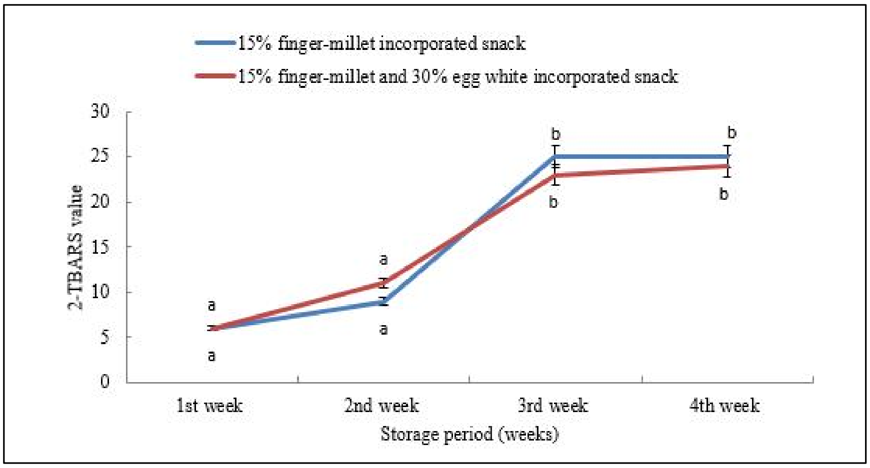

Figure 5: 2-TBARS value changes of two snacks during the one month of the storage period. Data presented as Mean±Standard deviation (n=6). Different alphabetical letters show means are significantly different at p=0.05

CONCLUSION

Finger-millet (15%) and egg white (30%) incorporated snack product had high sensory, nutritional and physico-chemical attributes with favourable consumer acceptance. The novel product can be introduced as a nutritionally rich, ready-to-eat baked snack to the food industry in Sri Lanka. By incorporating 30% egg white into the snacks, the protein level increases up to 18.96±0.30%. The finger-millet incorporated egg-based snack can be stored at room temperature (28ºC) for a one-month storage period. Therefore, this value-added novel product was acceptable and safe for consumption up to 30 days of the storage period with proper packaging materials to avoid quality deterioration. Further study is recommended to evaluate the storability of the product throughout an extended storage period and to evaluate the keeping quality of this novel product.

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