

Development of a Bose corn and local Timorese legume food bar fortified with *Lactiplantibacillus plantarum*: nutritional composition, color characteristics, and probiotic viability.

[Pengembangan food bar jagung Bose dan kacang-kacangan lokal Timor yang difortifikasi dengan *Lactiplantibacillus plantarum*: komposisi nutrisi, karakteristik warna dan viabilitas bakteri]

Joanivita Paulo Gulo Soru^{1*}, Eufasia Reinelda Arianti Lengur¹, Paulus Risan Funan Lalong¹, Ignatia Stefania Nino¹, Eleonora Ana Margareth Bokilia²

¹Department of Food Technology, Faculty of Science and Technology, Widya Mandira Catholic University, Kupang, Indonesia

²Science and Technology Laboratory, Widya Mandira Catholic University, Kupang, Indonesia

*Corresponding author email: joanivitasoru@unwira.ac.id

Submitted: 16 December 2025, Revised: 16 May 2026, Accepted: 02 August 2026, DOI: 10.23960/jthp.v31i2.73-83

ABSTRACT

Food insecurity and nutritional challenges in East Nusa Tenggara Province highlight the need for strategies that promote local food diversification. Diversification of functional foods may help address changing dietary patterns, particularly the increasing demand for nutritious snack products associated with the growing trend of snackification. Probiotic-based functional snacks offer an opportunity to combine potential health benefits with the utilization of local food resources. This study aimed to develop a probiotic food bar based on Bose corn and local Timorese legumes and to evaluate its nutritional composition, color characteristics, and probiotic viability. An experimental study was conducted using a completely randomized design (CRD) with five formulations and three replications. The formulations were prepared by modifying Bose corn with local legumes, including peanuts (*Arachis hypogaea* L.), mung beans (*Vigna radiata*), cowpeas (*Vigna unguiculata* subsp. *unguiculata*), and rice beans (*Vigna umbellata*). *Lactiplantibacillus plantarum* was incorporated into the food bars as a probiotic culture. Among the formulations, F1 exhibited the most favorable overall characteristics, with a moisture content of 51.49%, ash content of 1.46%, protein content of 4.76%, carbohydrate content of 39.99%, crude fiber content of 4.75%, and the lowest fat content (2.31%). F1 also showed favorable color characteristics, with L^* , a^* , and b^* values of 48.50, 1.55, and 7.70, respectively. Probiotic viability increased slightly during the early storage period before declining during subsequent storage, indicating the need for further optimization to improve probiotic survival and support its potential functional role. Overall, F1 was identified as the most favorable formulation based on its nutritional and color characteristics. The findings highlight the potential of Bose corn and local Timorese legumes as ingredients for developing nutritious snack products with probiotic potential.

Keywords: Bose corn, diversification, functional food, legumes, probiotic food bar

ABSTRAK

Kerawanan pangan dan masalah gizi di Provinsi Nusa Tenggara Timur menyoroti perlunya strategi diversifikasi pangan berbasis sumber daya lokal. Diversifikasi pangan fungsional menjadi penting sebagai respons terhadap perubahan pola konsumsi, khususnya meningkatnya konsumsi camilan bergizi (snackification). Camilan fungsional berbasis probiotik berpotensi memberikan manfaat kesehatan sekaligus memanfaatkan sumber daya pangan lokal. Penelitian ini bertujuan untuk mengembangkan food bar probiotik berbasis jagung dan kacang-kacangan lokal Timor serta mengevaluasi komposisi gizi, karakteristik warna, dan viabilitas probiotik. Penelitian eksperimental dilakukan menggunakan Rancangan Acak Lengkap dengan lima formulasi dan tiga ulangan. Formulasi food bar dibuat melalui modifikasi jagung Bose dengan penambahan kacang-kacangan lokal, yaitu kacang tanah (*Arachis hypogaea* L.), kacang hijau (*Vigna radiata*), kacang tunggak (*Vigna unguiculata* subsp. *unguiculata*), dan kacang beras (*Vigna umbellata*). *Lactiplantibacillus plantarum* ditambahkan ke dalam food bar sebagai kultur probiotik. Hasil penelitian menunjukkan bahwa F1 memiliki karakteristik keseluruhan yang paling baik, dengan kadar air 51,49%, kadar abu 1,46%, protein 4,76%, karbohidrat 39,99%, serat kasar 4,75%, dan kadar lemak terendah (2,31%) dibandingkan dengan formulasi lainnya. F1 juga menunjukkan karakteristik warna yang baik, dengan nilai L^* 48,50, a^* 1,55, dan b^* 7,70. Viabilitas probiotik selama penyimpanan menunjukkan penurunan, sehingga diperlukan optimasi lebih lanjut untuk meningkatkan viabilitas probiotik dan mendukung

potensi fungsionalnya. Secara keseluruhan, F1 ditetapkan sebagai formulasi yang paling baik berdasarkan karakteristik gizi dan warnanya. Hasil penelitian ini menunjukkan potensi jagung Bose dan kacang-kacangan lokal Timor sebagai bahan baku dalam pengembangan produk camilan bergizi dengan potensi probiotik.

Kata kunci: diversifikasi, *food bar* probiotik, jagung Bose, legum, pangan fungsional

Introduction

East Nusa Tenggara (NTT) faces significant challenges in fulfilling nutritional requirements because of its high susceptibility to food insecurity. The province records the highest proportion of residents experiencing moderate to severe food insecurity in Indonesia, necessitating targeted interventions to mitigate its adverse effects on community productivity and overall quality of life (Nainupu, 2023). NTT had the second-highest prevalence of moderate to severe food insecurity nationwide in 2024, at 14.48%, far exceeding the national average of 4.02% (Badan Pusat Statistik, 2025). This condition is also linked to the high prevalence of stunting in NTT, which stood at 17% in 2024 (BPS Provinsi Nusa Tenggara Timur, 2025). To overcome nutritional challenges, particularly stunting, diversification of functional foods is essential. This can be achieved by reducing dependence on rice as the staple food and broadening the variety of food sources and products (Nisak et al., 2025). East Nusa Tenggara has a variety of local foods rooted in local knowledge, which play an important role in food sustainability and biodiversity (Widowati & Nurfitriani, 2023). Nevertheless, the implementation of local food diversification is still limited and faces several constraints. Therefore, the utilization and development of nutritionally valuable local food resources into diverse and convenient food products are important strategies for supporting food diversification in NTT.

Corn is a staple food in East Nusa Tenggara and is considered a potential alternative to rice. In 2023, corn production in NTT reached 648,305 tons, with South Central Timor Regency recording the highest output (Badan Pusat Statistik Provinsi Nusa Tenggara Timur, 2024). However, the diversification of corn-based products remains limited (Wijana et al., 2024). One traditional Timorese corn-based dish is jagung Bose (Bose corn), which is prepared by removing the corn husks, combining it with legumes, and boiling the mixture until tender, then mixing it with coconut milk and adding seasoning (Manek & Rato, 2024). The use of corn and legumes in *Bose corn* provides a combination of carbohydrate and plant-based protein sources, indicating its potential as a nutritious local food base for further product development. This food demonstrates that locally produced corn and legumes have potential to be developed for food diversification by improving their nutritional and functional properties.

Functional food diversification is also consistent with the global trend towards snackification, where consumers increasingly prefer healthier and more nutritious snacks in addition to staple foods (Boukid et al., 2022). Moreover, safe, healthy, and nutritious snack products play an important role in supporting child growth (Soru et al., 2025) and have been identified as an effective intervention strategy for reducing stunting (Viana & Qori'ah, 2024). Transforming *Bose corn* with local Timorese legumes into a food bar represents a strategic approach to developing a convenient and nutritionally valuable snack based on local food resources. Food bars are compact, bar-shaped, nutrient-rich products that are popular and practical. They may function as supplementary nutrition for athletes, protein sources, complementary foods for infants and young children, healthy snacks for school-age children, and emergency food during disasters or crises (Ananthan et al., 2021; Hadi et al., 2018; Rizkaprilisa et al., 2023). Therefore, evaluating the nutritional composition of a food bar formulated from local corn and legumes is important to determine its potential as a nutritious food product.

The functional properties of food bars can be enhanced by incorporating probiotics (Rajagukguk et al., 2022). Probiotics are live microorganisms that confer health benefits when consumed in adequate amounts, including supporting gut microbiota balance, immune function, nutrient absorption, and

metabolic health (Ramadhani et al., 2024; Suciati & Safitri, 2021). Lactic acid bacteria, particularly *Lactobacillus* and *Bifidobacterium* species, are among the most commonly used probiotics (Suciati & Safitri, 2021). Notably, consumption of *Lactiplantibacillus plantarum* Dad-13 combined with fructo-oligosaccharides has been reported to improve gut microbiota composition, nutrient absorption, and growth parameters in stunted children (Gunawan et al., 2022). Several studies have demonstrated the feasibility of incorporating probiotics into cereal- and legume-based snacks. Rajagukguk et al. (2022) reported that pulse-based snack bars fortified with *Lactiplantibacillus plantarum* showed potential for maintaining probiotic survival, while de Paula Antunes et al. (2025) found that cereal bars containing *Bacillus clausii* maintained viability above 6.5 log CFU/g during 60 days of storage. Castillo-Escandón et al. (2023) also developed a corn- and legume-based snack containing *Lactobacillus acidophilus*. However, limited research has explored food bars using Timorese local legumes (Puspita et al., 2021), particularly those formulated with Bose corn and *L. plantarum*. Therefore, this study aimed to develop an *L. plantarum*-fortified food bar based on Bose corn and local Timorese legumes and to evaluate its nutritional composition, colour characteristics, and probiotic viability.

Materials and methods

Materials and equipment

The materials used in this research were Bose corn and local Timorese legumes (peanut, mungbean, cowpeas, rice bean), salt, coconut milk powder, coconut milk, xanthan gum (4%), savu liquid sugar, and probiotics *Lactiplantibacillus plantarum*. The chemical materials used include Potassium Sulfate (K_2SO_4), Copper Sulfate ($CuSO_4$), Sulfuric Acid (H_2SO_4), Sodium Hydroxide (NaOH), Zinc (Zn), Hydrochloric Acid (HCl), Phenolphthalein indicator, n-Hexane, and Acetone, Buffered Peptone Water (Merck) (0.1% BPW), MRS Agar (Merck) with 1% $CaCO_3$. The equipment used included cake pan, chopper (Kris), Blender (Philip HR2116/60), dehydrator (Notaus), oven (Kris), digital scale (Kris), analitcal scales (Ohouse pioneer), oven (Memmert), incubator (memmert), Rotary evaporator (Buchi R-210), Soxlet set (Heating mantle B-One), furnace (Mini Furnace B-One), Reflux (Hotplate stirrer Thermo Scientific Cimarec), vaccum pump (Buchi V-700), UV-Vis Spectrometer (Therno Scientific Genesys 150), micropipet (eppendorf), Autoclave (Hirayama), Laminar Air Flow, Texture Profile Analyzer (AMETEK Brookfield), and colorimeter (CHNSpec CS-10 10, China).

Research methods

The research methods used in this study were a laboratory experiment with a Completely Randomized Design (CRD). There were five formulations (F1-F5) and three replications, with a total of 15 experimental units. The formulations were presented in Table 1. The research was conducted in Kupang, East Nusa Tenggara.

Table 1. Formulation of probiotic food bars made of Bose corn and local Timor legumes

Ingredients	Formulation (g)				
	F1	F2	F3	F4	F5
Bose corn	125	125	125	125	125
Peanut	25	25	25	25	25
Mungbean	90	100	75	50	60
Cowpeas	50	50	75	100	75
Rice bean	50	40	40	40	55
Salt	2.5	2.5	2.5	2.5	2.5
Coconut milk powder	7.5	7.5	7.5	7.5	7.5
Coconut milk	50	50	50	50	50

Ingredients	Formulation (g)				
	F1	F2	F3	F4	F5
Xanthan gum (4%)	50	50	50	50	50
Savu liquid sugar	50	50	50	50	50
Probiotics	1 capsule/100 g	1 capsule/100 g	1 capsule/100 g	1 capsule/100 g	1 capsule/100 g

Note: Probiotics were added twice

The process of making a probiotic food bar

The traditional Bose corn processing method was modified to produce and develop food bars. Corn (*Zea mays*) and local Timorese legumes including peanuts (*Arachis hypogaea* L.), mung beans (*Vigna radiata*), cowpeas (*Vigna unguiculata* subsp. *unguiculata*), and rice beans (*Vigna umbellata*) were sorted, washed, soaked, boiled separately until tender, dried using a dehydrator for 3 hours at 60°C, and ground using a chopper. These main ingredients were mixed with supplementary ingredients to form the food bar following the formulations in Table 1. The binding agents used were xanthan gum (4%) and Savu liquid sugar. Probiotics (*Lactiplantibacillus plantarum*) were added at a concentration of one capsule per 100 g. The first probiotic addition was performed during mixing, followed by fermentation for 6 hours. The dough was then baked at 200°C for 20 minutes. After cooling, a second probiotic addition at the same dose was applied. The food bars were cut (10 x 2 x 1,5 cm), packaged in plastic bags, and stored under refrigeration for four weeks.

Research parameters

Basic nutritional component analysis, including proximate and crude fiber content, was conducted following the method of AOAC (2005). Color parameters were recorded in the CIELAB system, including lightness (L^*), redness/greenness (a^*), and yellowness/blueness (b^*). Measurements were taken at three different points on the surface of each sample, and the mean values were reported.

Probiotic viability was evaluated over four weeks using the Total Plate Count (TPC) method following Antunes et al. (2025); Soru et al. (2025); Maisto et al. (2021), with some modifications. A 25 g sample was homogenized and diluted with 225 mL of 0.1% Buffered Peptone Water (BPW). From this suspension, 1 mL was transferred into 9 mL of 0.1% BPW and serially diluted up to 10^{-4} . An aliquot of 0.1 mL from the appropriate dilution was spread onto MRS agar supplemented with 1% CaCO_3 . The plates were incubated at 37°C for 48 hours. Plates containing 30–300 colonies were counted, and probiotic viability was expressed as log CFU/g. Nutritional content, color, and probiotic viability data were analyzed using ANOVA followed by Tukey's post hoc test. The best formulation was selected based on overall desirable characteristics.

Results and discussion

Basic nutritional components

This research developed soft refrigerated food bars from local ingredients, namely Bose corn with local Timorese legumes, fortified with probiotic *L. plantarum* to improve the functionality of the food bar, as depicted in Figure 1. The basic nutritional composition of probiotic food bars is shown in Table 2. Statistical analysis showed that there is no significant difference ($p > 0.05$) in water content, ash content, and protein content, but there is a significant difference ($p < 0.05$) in crude fibre content, fat content, and carbohydrate content. The differences in nutritional composition among formulations may primarily reflect the different proportions of mungbean, cowpea, and rice bean, as the amounts of the other ingredients were kept constant.

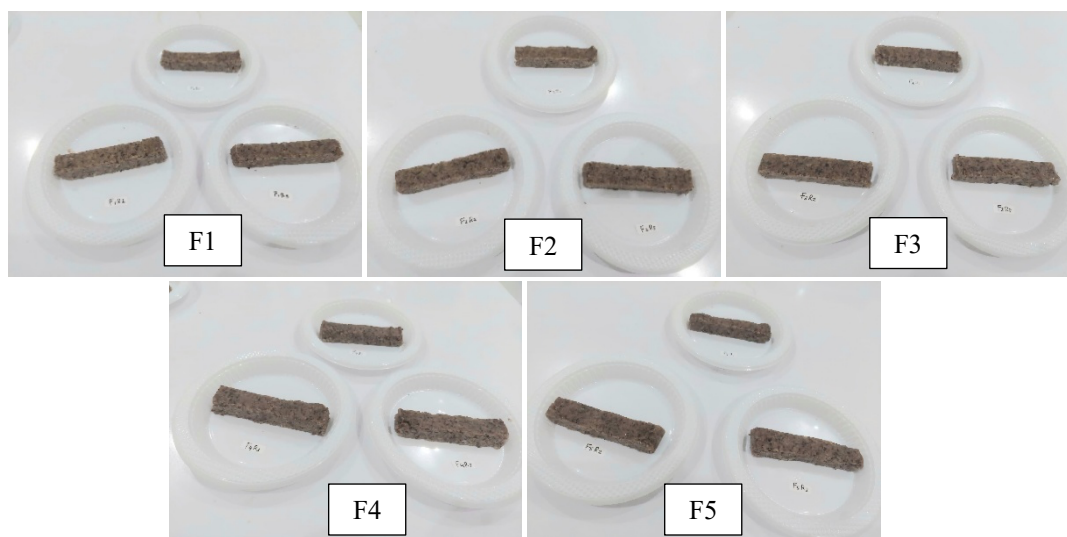


Figure 1. Probiotic food bars formulated from Bose corn and local Timor legumes from 5 different formulations. F1 F5 denote the five formulations described in Table 1.

Table 2. Basic nutritional components of probiotic food bar made of Bose corn and local Timor legumes.

Components (%)	Formulation				
	F1	F2	F3	F4	F5
Moisture	51.49 ^a ± 1.76	52.70 ^a ± 1.05	51.16 ^a ± 1.05	51.23 ^a ± 0.79	49.76 ^a ± 0.92
Ash	1.46 ^a ± 0.04	1.38 ^a ± 0.05	1.49 ^a ± 0.18	1.37 ^a ± 0.03	1.33 ^a ± 0.04
Protein	4.76 ^a ± 0.69	5.11 ^a ± 0.77	5.59 ^a ± 1.13	3.52 ^a ± 1.28	4.52 ^a ± 0.09
Fat	2.31 ^b ± 0.71	6.26 ^a ± 1.19	5.85 ^a ± 2.06	3.23 ^{ab} ± 0.81	4.38 ^{ab} ± 0.51
Crude fibre	4.75 ^a ± 0.35	4.31 ^{ab} ± 1.07	3.94 ^{ab} ± 0.84	2.93 ^{ab} ± 0.82	2.72 ^b ± 0.26
Carbohydrate	39.99 ^a ± 0.89	34.54 ^b ± 1.09	35.90 ^{ab} ± 3.76	40.56 ^a ± 0.70	40.28 ^a ± 0.76

Note: Numbers followed by the same letter within the same row are not significantly different ($p > 0.05$) based on the Tukey Test

Moisture content ranged from 49.76 to 52.70. The moisture content across all formulations exceeded that of commercial food bars, such as SoyJoy (9.2–11.4%) (Rossi & Sumantri, 2025). This was likely attributable to the preparation process, which involved soaking and boiling the Bose corn and legumes, combined with insufficient drying and baking conditions (temperature and duration) to adequately reduce the moisture level. Low moisture content is preferred in energy bars to prevent deterioration and to maintain texture and shelf life (Ekafitri et al., 2020). Although moisture may influence probiotic survival, excessive moisture can increase the risk of microbial deterioration and reduce product stability. A previous study on pumpkin-soybean flour emergency food bar noted that lower moisture content reduces bacterial growth and extends shelf life, while higher moisture content promotes microbial activity and accelerates spoilage (Safira & Yulistiani, 2025). Another study on snack bars made from chickpeas and green lentils enriched with *L. plantarum* reported moisture contents of 4.33% and 6.00%, respectively (Rajagukguk et al., 2022). Therefore, further optimization of processing conditions is necessary to reduce the water content while preserving probiotic viability and maintaining desirable texture.

Statistical analysis showed that there is no significant difference ($p > 0.05$) in ash content among the formulations, and the values range from 1.33% to 1.4%. This result indicates that the formulations had similar total mineral contents. Minerals are essential for maintaining human health, and inadequate intake can result in significant health problems (Jindal et al., 2023). Bose corn was dehulled to become corn kernels, which means the outer layer of the corn seed is removed. A study reported that dehulling of the grains or seeds can improve the palatability and cooking quality, but this process can reduce the nutritional value of the grains because of the loss of their bran and germ, which are rich in vitamins and minerals, especially the loss of B vitamins and essential minerals such as calcium, iron, and magnesium (Ismaila &

Onyeke, 2022). This probiotic food bar study is limited to total ash content. Further study is required to understand the mineral composition and examine the vitamins and mineral enrichment if required, to increase the functionality of the probiotic food bar and meet the dietary requirements.

Statistical analysis showed that the protein content among the formulations is not significantly different ($p > 0.05$). Protein content ranged from 3.52% (F4) to 5.59% (F3) across the formulations. This result shows that the variability in protein levels was likely influenced by the proportion of legumes used as the primary protein sources. Using natural, complementary ingredients allows the development of protein bars with a more balanced nutritional composition while eliminating the need for potentially harmful additives (Duda-Seiman et al., 2025). Cereals and legumes contain various proteins and are diverse in their amino acids, making cereals and legumes valuable and versatile sources of high-quality plant-based nutrition (Jindal et al., 2023).

The fat content differed significantly ($p < 0.05$) among formulations, ranging from 2.31% in F1 to 6.26% in F2. This variation can be attributed to the differing legume proportions used across formulations; specifically, F2 contained the highest amount of mungbean (100 g) relative to cowpea (50 g) and rice bean (40 g). Although mungbean is classified as a low-fat legume, with a reported crude fat content of approximately $1.52 \pm 0.31\%$ (Pokharel et al., 2024), the combined contribution of multiple legumes and ingredients likely accounted for the elevated fat level in F2. However, a limitation of this study is that only total fat content was measured, without profiling specific fatty acids. From a nutritional standpoint, food bar formulation requires balancing ingredient ratios while adhering to low-fat dietary guidelines ($<20\%$ of total energy intake) to optimize lipid profiles, such as reducing LDL and HDL cholesterol (Hadi et al., 2018). Notably, plant-based snack bars, such as those made from glutinous rice and yellow pumpkin powder, have been shown to reduce blood cholesterol levels in animal models (Mustofa et al., 2021).

Carbohydrate content differed significantly among the probiotic food bar formulations ($p < 0.05$), ranging from 34.54% (F2) to 40.56% (F4). Crude fibre content also varied significantly ($p < 0.05$), ranging from 2.72% (F5) to 4.75% (F1). These differences may be attributed to the varying proportions of mung beans, rice beans, and cowpeas incorporated with Bose corn. Dietary fibre is an important component of functional food bars because it supports digestive health by promoting bowel regularity and beneficially modulating the gut microbiota (Ramadhani et al., 2024). The nutritional quality of carbohydrates is also influenced by their food sources and processing conditions. Compared with corn, legumes generally provide more fibre and may result in a slower release of glucose, whereas the glycemic response to corn is strongly influenced by processing conditions (Singh et al., 2025).

Physical property (colour)

The colour property (L^* , a^* , b^*) of probiotic food bars is presented in Table 3. Statistical analysis showed that there is no significant difference ($p > 0.05$) in the lightness (L^*) values and redness/greenness (a^*) values among the formulations. The L^* values ranged from 46.35 to 48.50, and the a^* values ranged from 0.31 to 1.55. These results indicate that the composition of ingredients had less impact on the overall brightness and hue. A significant effect of formulation was observed on the yellowness/blueness (b^*) value ($p < 0.05$), with a gradual decrease in b^* across formulations. The highest b^* values were presented by F1 (7.70) and the lowest was presented by F5 (6.25). This result shows that different compositions of ingredients affected the yellowness intensity of the food bar. This difference may be associated with differences in the natural pigments contributed by the legumes used in the formulations. Some natural pigments in legumes are reported, such as anthocyanins (polyphenols), carotenoids, and chlorophylls (Huang et al., 2022; Krylova et al., 2023). Besides the pigments, the Maillard reaction due to heating may also affect the colour of food bars (Rajagukguk et al., 2022).

Table 3. Colour of probiotic food bars made of Bose corn and local Timor legumes.

Parameters	F1	F2	F3	F4	F5
L*	48.50 ^a ± 0.57	47.74 ^a ± 1.56	47.57 ^a ± 2.30	46.60 ^a ± 0.42	46.35 ^a ± 1.14
a*	1.55 ^a ± 0.72	1.16 ^a ± 0.50	0.84 ^a ± 0.97	0.79 ^a ± 1.11	0.31 ^a ± 0.76
b*	7.70 ^{ab} ± 0.24	8.41 ^a ± 0.84	7.32 ^{abc} ± 0.47	6.84 ^{bc} ± 0.36	6.23 ^c ± 0.45

Note : Numbers followed by the same letter within the same row are not significantly different (p>0.05) based on the Tukey Test

Probiotic viability

Probiotic viability was evaluated over four weeks of refrigerated storage. Probiotic viability data are presented in Table 4. Overall, the number of *Lactiplantibacillus plantarum* was below 10⁶ CFU/g, even at the initial storage period, which does not achieve the commonly claimed range of probiotics (10⁶ - 10⁹ CFU/g). Thus, this may affect the probiotic functionality of this food bar. However, formulations F3 and F4 showed a slight increase in probiotic counts during week 2, reaching approximately 5 log CFU/g, before decreasing in subsequent weeks, like the other formulations. By week 4, probiotic counts in all formulations declined to approximately 2 log CFU/g. The probiotic count in the capsule used was 5.41 log CFU/g, which was lower than the dose stated on the label, consistent with findings reported by Rajagukguk et al. (2022). Based on Table 4, probiotic counts in all formulations started at approximately 4 log CFU/g at week 0. Overall, probiotic viability increased slightly during the early storage period and then declined continuously throughout storage. Formulations F3 and F4 exhibited significantly higher probiotic viability compared to other formulations, reaching approximately 5 log CFU/g at week 2. Statistical analysis indicated that probiotic viability in F3 and F4 was significantly different from the other formulations (p < 0.05). However, after week 1, probiotic counts decreased across all treatments, reaching levels of 2-4 log CFU/g by week 4. Thus, further effort is needed to increase the viability of the probiotic.

A study reported that encapsulation and dispersion of *Lactobacillus acidophilus* in chocolate coating in cereal bars protected the probiotic, maintaining a survival rate of 90% and a high number of probiotics until 120 days of storage time, with 12.54 log CFU, which is sufficient to promote health benefits (Lasta et al., 2021). Another option is enriching the food bar with high-temperature-resistant probiotics or spore-forming probiotics such as *Bacillus clausii* strains O/C, SIN, N/R, T, and *B. coagulans* BC30, or adding the probiotics after heat treatment (de Paula Antunes et al., 2025). Even though spore-forming probiotics are increasingly demanded in the food industry due to their stability during processing, future studies need to evaluate spore-forming probiotics from *Bacillus* sp. for baked functional foods (Payne et al., 2024). It should also be noted that only specific strains have been recognized as probiotics from *B. coagulans* (Fijan et al., 2023) and *B. subtilis* (Vasilean et al., 2022), especially for incorporating in food bars.

Table 4. Probiotic viability of probiotic food bar made of Bose corn and local Timor legumes

Week	Formulation / number of probiotic (log CFU/g)				
	F1	F2	F3	F4	F5
0	4.15 ^b ± 0.05	4.27 ^b ± 0.09	4.40 ^a ± 0.04	4.40 ^a ± 0.04	4.11 ^b ± 0.07
1	4.59 ^b ± 0.03	4.62 ^b ± 0.10	5.19 ^a ± 0.13	5.19 ^a ± 0.13	4.59 ^b ± 0.08
2	4.39 ^a ± 0.34	3.94 ^a ± 0.06	4.30 ^a ± 0.15	4.30 ^b ± 0.15	3.90 ^a ± 0.07
3	3.53 ^a ± 0.06	3.76 ^a ± 0.21	3.67 ^a ± 0.16	3.69 ^a ± 0.16	3.59 ^a ± 0.07
4	2.00 ^a ± 0.89	2.59 ^a ± 0.11	2.36 ^a ± 0.39	2.36 ^a ± 0.39	2.72 ^a ± 0.12

Note: Numbers followed by the same letter within the same row are not significantly different (p>0.05) based on the Tukey Test

The best formulation

The selection of the optimal formulation was based on the integrated evaluation of nutritional composition, colour characteristics, and probiotic viability. In this study, greater emphasis was placed on achieving a balanced nutritional profile while maintaining acceptable probiotic viability and product stability. Although F3 and F4 exhibited the highest probiotic viability during storage, F1 demonstrated the most favourable overall characteristics. In particular, F1 had a significantly lower fat content than the other formulations, which is considered desirable for a healthier snack bar, and the highest crude fibre content, which may provide potential benefits for digestive health. Although the protein content did not differ significantly among formulations, the overall nutritional profile of F1 was considered more favourable. Therefore, based on the combined assessment of nutritional composition, colour characteristics, and probiotic viability, F1 was selected as the optimal formulation.

Conclusion

This study demonstrated the feasibility of developing a novel food bar fortified with *Lactiplantibacillus plantarum* using Bose corn and indigenous Timorese legumes. Among the formulations, F1 was identified as the optimal formulation based on its overall characteristics, particularly its favourable colour properties and nutritional profile. F1 exhibited the lowest fat content and the highest crude fibre content among the formulations, suggesting its potential as a nutritionally valuable snack product. Although F3 and F4 showed the highest probiotic viability during storage, their viable cell counts remained below the commonly recommended level for probiotic food products, which may limit their potential functional benefits. Therefore, further optimization of the formulation and processing conditions is required to improve probiotic survival during storage while maintaining desirable nutritional and colour characteristics. Overall, these findings highlight the potential of indigenous Timorese food resources as ingredients for the development of nutritious food products with probiotic potential.

Acknowledgments

The author acknowledges the Ministry of Higher Education, Science and Technology for providing research finding by the Beginner Lecturer Research Grant Program in 2025. Sincere appreciation is also extended to all parties who contributed to the succesful completion of this study.

References

- Ananthan, P., Sharma, G. K., & Semwal, A. D. (2021). Energy bars: A perfect choice of nutrition to all. In *Advances in Processing Technology* (pp. 309–332). CRC Press.
- Antunes, D. J., de Almeida Costa, N., Martins, M. L., Benevenuto, W. C. A. do N., Talma, S. V., Campos, A. N. da R., & Martins, E. M. F. (2025). Healthy cereal bar enriched with probiotic *Bacillus*: bromatological characterization, probiotic viability, consumer acceptance, and gastrointestinal resistance in vitro. *International Journal of Food Science and Technology*, 60(1), vvae070. <https://doi.org/10.1093/ijfood/vvae070>
- Badan Pusat Statistik. (2025). Relevansi penduduk dengan kerawanan pangan sedang atau berat, berdasarkan pada skala pengalaman kerawanan pangan (Persen), 2023-2024. *Badan Pusat Statistik*. <https://www.bps.go.id/id/statistics-table/2/MTQ3NCMy/prevalensi-penduduk-dengan-kerawanan-pangan-sedang-atau-berat--berdasarkan-pada-skala-pengalaman-kerawanan-pangan--persen-.html>
- Badan Pusat Statistik Provinsi Nusa Tenggara Timur. (2024). *Produksi jagung menurut kabupaten/kota (ton), 2022-2023*. *Badan Pusat Statistik Provinsi Nusa Tenggara Timur*. <https://ntt.bps.go.id/id/statistics-table/2/MTQ3MCMY/produksi-jagung-menurut-kabupaten-kota-ton-.html>
- Badan Pusat Statistik Propinsi Nusa Tenggara Timur. (2025). Jumlah dan persentase balita stunting menurut kabupaten/kota (jiwa) tahun 2023-2024. *Badan Pusat Statistik Provinsi Nusa Tenggara Timur*.

<https://ntt.bps.go.id/id/statistics-table/2/MTQ4OSMy/jumlah-balita-stunting-menurut-kabupaten-kota.html>

- Boukid, F., Klerks, M., Pellegrini, N., Fogliano, V., Sanchez-Siles, L., Roman, S., & Vittadini, E. (2022). Current and emerging trends in cereal snack bars: implications for new product development. *International Journal of Food Sciences and Nutrition*, 73(5), 610–629. <https://doi.org/10.1080/09637486.2022.2042211>
- Castillo-Escandón, V., Ramos-Clamont Montfort, G., Islas Rubio, A. R., Marszalek, J. E., Subiría-Cueto, R., & Fernández Michel, S. (2023). Development of healthy synbiotic corn-based snack: Nutritional composition and effect of agave fructan-alginate coating on survival of *Lactobacillus acidophilus*. *Journal of Cereal Science*, 114, 103777. <https://doi.org/https://doi.org/10.1016/j.jcs.2023.103777>
- Duda-Seiman, C., Mititelu-Tartau, L., Biriescu, S., Almășan, A.-L., Bitu, B.-O., Bucur, A.-I., Luca, A., Hoinoiu, B., & Hoinoiu, T. (2025). A comprehensive study on the nutritional profile and shelf life of a custom-formulated protein bar versus a market-standard product. *Foods*, 14(12), 2141. <https://doi.org/10.3390/foods14122141>
- Ekafitri, R., Kurniawan, Y. R., Desnilasari, D., Surahman, D. N., & Indriati, A. (2020). Shelf-life assessment of energy banana bar using acceleration method with critical moisture content approach. *Food Science and Technology*, 41(suppl 1), 163–168. <https://doi.org/https://doi.org/10.1590/fst.13120>
- Soru, J. P.G., Funan Lalong, P. R., & Nabon, M. N. (2025). Total lactic acid bacteria and pH values in lu'at fermentation with different salt levels and fermentation duration. *Journal of Social Research*, 4(9), 2495. <https://doi.org/10.55324/josr.v4i9.2774>
- Gunawan, D. C. D., Juffrie, M., Helmyati, S., & Rahayu, E. S. (2022). Synbiotic (*L. plantarum* Dad-13 and Fructo-oligosaccharide) powder on gut microbiota (*L. plantarum*, *Bifidobacterium*, and *Enterobacteriaceae*) on stunting children in Yogyakarta, Indonesia. *Current Research in Nutrition and Food Science Journal*, 10(1), 371–383. <http://dx.doi.org/10.12944/CRNFSJ.10.1.31>
- Hadi, V., Norouzy, A., Tehrani, M. M., Nematy, M., & Hadi, S. (2018). Properties of compact food bars: a review study. *Journal of Nutrition, Fasting & Health*, 6(3). <https://doi.org/10.22038/JNFH.2018.34018.1130>
- Huang, P.-H., Cheng, Y.-T., Chan, Y.-J., Lu, W.-C., & Li, P.-H. (2022). Effect of heat treatment on nutritional and chromatic properties of mungbean (*Vigna radiata* L.). *Agronomy*, 12(6), 1365. <https://doi.org/10.3390/agronomy12061365>
- Ismail, F., & Onyeke, L. O. (2022). Effects of dehulling on the mineral elements content of some cereals (maize, millet, and Guinea corn). *Global Journal of Agricultural Research*, 10(3), 1–12. <https://doi.org/10.37745/GJAR.2013/VO10.N3PP112>
- Jindal, A., Patil, N., Bains, A., Sridhar, K., Stephen Inbaraj, B., Tripathi, M., Chawla, P., & Sharma, M. (2023). Recent trends in cereal-and legume-based protein-mineral complexes: Formulation methods, toxicity, and food applications. *Foods*, 12(21), 3898. <https://doi.org/10.3390/foods12213898>
- Krylova, E. A., Mikhailova, A. S., Zinchenko, Y. N., Perchuk, I. N., Razgonova, M. P., Khlestkina, E. K., & Burlyaeva, M. O. (2023). The content of anthocyanins in cowpea (*Vigna unguiculata* (L.) Walp.) seeds and contribution of the MYB gene cluster to their coloration pattern. *Plants*, 12(20), 3624. <https://doi.org/10.3390/plants12203624>
- Lasta, E. L., da Silva Pereira Ronning, E., Dekker, R. F. H., & da Cunha, M. A. A. (2021). Encapsulation and dispersion of *Lactobacillus acidophilus* in a chocolate coating as a strategy for maintaining cell viability in cereal bars. *Scientific Reports*, 11(1), 20550. <https://doi.org/10.1038/s41598-021-00077-0>
- Manek, S., & Rato, Y. I. (2024). Preservation of traditional food jagung Bose as a gastronomic tourism attraction in Timor Island, East Nusa Tenggara. *The Journal Gastronomy Tourism*, 11(1), 116–123. <https://doi.org/10.17509/gastur.v11i1.71554>
- Mustofa, A., Suhartatik, N., & Nugraheni, R. D. (2021). Efek antihiperkolesterol snack bars beras ketan hitam (*Oryza sativa* var. *glutinosa*) labu kuning (*Cucurbita moschata*) pada tikus Sprague dawley. *Jurnal Teknologi & Industri Hasil Pertanian*, 26(1), 37–44. <https://doi.org/10.23960/jtihp.v26i1.37-44>

- Nainupu, A. E. (2023). Determinan Status Kerawanan Pangan Rumah Tangga Di Provinsi Nusa Tenggara Timur: Analisis Regresi Logistik. *Jurnal Statistika Terapan (ISSN 2807-6214)*, 3(01), 37–49. <https://jstar.id/ojs/index.php/JSTAR/article/view/38>
- Nisak, S. K., Septiana, E., Handayani, K., LW, M. T., & Meilinda, N. (2025). Pengaruh diversifikasi pangan lokal terhadap strategi pangan global: sistematik literatur review. *Infokes*, 15(1). <https://jurnal.ikbis.ac.id/index.php/infokes/article/view/922>
- Payne, J., Bellmer, D., Jadeja, R., & Muriana, P. (2024). The potential of *Bacillus* species as probiotics in the food industry: A review. *Foods*, 13(15), 2444. <https://doi.org/10.3390/foods13152444>
- Pokharel, U., Adhikari, N., Gautam, N., Poudel, R., Timsina, P., Dangal, A., & Giuffrè, A. M. (2024). Effects of different processing methods on the antinutritional factors present in mungbean (*Vigna radiata* L.). *Analytica*, 5(3), 414–429. <https://doi.org/10.3390/analytica5030026>
- Puspita, D., Rahardjo, M., & Kirana, S. F. (2021). Formulasi food bar dari kacang lokal Pulau Timor sebagai pangan darurat. *Science Technology and Management Journal*, 1(2), 47–55. <https://doi.org/10.53416/stmj.v1i2.18>
- Rajagukguk, Y. V., Arnold, M., Sidor, A., Kulczyński, B., Brzozowska, A., Schmidt, M., & Gramza-Michałowska, A. (2022). Antioxidant activity, probiotic survivability, and sensory properties of a phenolic-rich pulse snack bar enriched with *Lactiplantibacillus plantarum*. *Foods*, 11(3), 309. <https://doi.org/10.3390/foods11030309>
- Ramadhani, O. S., Chotimah, L., Huda, R. N., Salim, R. N., & Arini, L. D. D. (2024). Literatur review manfaat makanan mengandung probiotik bagi kesehatan. *Quantum Wellness: Jurnal Ilmu Kesehatan*, 1(4), 34–43. <https://doi.org/10.62383/quwell.v1i4.928>
- Rizkaprilisa, W., Alicia, R., Hapsari, M. W., Anggraeni, N., Murti, P. D. B., & Mahardika, A. (2023). Potensi pangan lokal sebagai snack bar mpasi balita: systematic review: Indonesia. *Science Technology and Management Journal*, 3(1), 1–5. <https://doi.org/10.53416/stmj.v3i1.119>
- Rossi, E., & Sumantri, E. (2025). Penggunaan tepung komposit dari pisang kepok, ampas kedelai dan ampas kelapa pada pembuatan snack ba. *Jurnal Teknologi Pertanian*, 26(1), 1–12. <https://doi.org/10.21776/ub.jtp.2025.026.01.1>
- Sadek, N. F., & Pradnya Suari, I. A. L. (2025). The physicochemical and sensory characteristics of a snack bar formulated with porang and corn flours as binding agents. *IOP Conference Series: Earth and Environmental Science*, 1563(1), 012066. <https://doi.org/10.1088/1755-1315/1563/1/012066>
- Safira, F. E. D., & Yulistiani, R. (2025). Formulation and shelf life prediction of a pumpkin-soybean flour emergency food bar using the accelerated shelf-life testing (ASLT) method and Arrhenius model. *Journal of Microbiology, Biotechnology and Food Sciences*, 15(3), e12377–e12377. <https://doi.org/10.55251/jmbfs.12377>
- Singh, M. K., Yun, H. R., Ranbhise, J. S., Han, S., Ju, S., Akter, S., Yeo, S. G., Kim, S. S., & Kang, I. (2025). Grains, cereals, and legumes: implications in glycemic index and perspectives. *Foods*, 14(23), 4038. <https://doi.org/10.3390/foods14234038>
- Soru, J. P. G., Lalong, P. R. F., & Naben, M. N. (2025). Sosialisasi pangan aman, sehat, utuh, halal (asuh) dan keamanan jajanan anak di komunitas belajar gratis rumah sejuta mimpi. *Prima Abdika: Jurnal Pengabdian Masyarakat*, 5(1), 110–120. <https://doi.org/10.37478/abdika.v5i1.4610>
- Suciati, F., & Safitri, L. S. (2021). Pangan fungsional berbasis susu dan produk turunannya. *Journal of Sustainable Research In Management of Agroindustry (SURIMI)*, 1(1), 13–19. <https://doi.org/10.35970/surimi.v1i1.535>
- Vasilean, I., Banuc, M., Patrascu, L., & Constantin, O. E. (2022). Studies on the use of carob powder and *Bacillus subtilis* for improving functionality of the cereal bars. *The Annals of the University Dunarea de Jos of Galati. Fascicle VI-Food Technology*, 46(2), 125–140. <https://doi.org/10.35219/foodtechnology.2022.2.09>

- Viana, R. O., & Qori'ah, M. (2024). Strategi guru dalam penerapan program snack sehat untuk pencegahan stunting pada anak usia dini. *Abata: Jurnal Pendidikan Islam Anak Usia Dini*, 4(2), 144–153. <https://doi.org/https://doi.org/10.32665/abata.v4i2.3390>
- Widowati, S., & Nurfitriani, R. A. (2023). *Diversifikasi pangan lokal untuk ketahanan pangan: perspektif ekonomi, sosial, dan budaya*. Penerbit BRIN.
- Wijana, S., Padang, R., Atikah, H., & Subekti, I. F. (2024). Diversifikasi dan peningkatan kualitas pangan melalui inovasi pascapanen jagung di Kabupaten Timor Tengah Selatan, Nusa Tenggara Timur. *ABDI UNISAP: Jurnal Pengabdian Kepada Masyarakat*, 2(2), 129–136. <https://doi.org/https://doi.org/10.59632/abdiunisap.v2i2.283>