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# Evaluation of physical properties, colour quest and sensory of sorghum-based nutribar

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**Abstract**
The aim of the study is to develop a functional snack product using sorghum flour as the primary base, supplemented with mushroom powder, finger millet, soybean flour, foxtail millet, and oats. Five formulations ($T_{90}$ to $T_{70}$) were prepared by varying the proportion of sorghum from 90% to 70% and stored under refrigerated conditions for 90 days. The Nutri bars were evaluated for physical properties, sensory quality, and colour quest. Sensory analysis showed that $T_{70}$ received the highest acceptability scores, while physical attributes remained consistent throughout storage. Overall, the study concluded that sorghum-based Nutri bars, when fortified with complementary functional flours, can be developed as nutritionally superior, sensorially acceptable, and shelf-stable snack products with strong commercial potential.

**Keywords:** Sorghum, nutribar, development, standardization, quality

## Introduction

Nutribars are energy-dense supplemental bars made from cereals and other high-energy foods, especially for individuals who require a quick source of energy but lack the time for a full meal [1]. These bars, often referred to as granola bars, are highly nutritious snacks that are made from a wide range of ingredients [2]. Commonly used ingredients include cereals, rolled or flaked oats, and barley, as well as honey, nuts, raisins, and other nutrient-rich supplements. They are typically baked or cooked, and the wet mixture is continuously stirred during preparation to maintain the desired consistency. The mixture is then shaped into pressed bars for consumption. For the preparation of Nutri bar, the ingredients like millets (puffed and crushed), dried fruits, and nuts (roasted) were added one by one to the binder syrup (glucose syrup and jaggery) and mixed well. Dry ingredients- roasted sorghum flakes, rice flakes, sesame seed, and peanut splits were added to binder syrup and mixed properly; the obtained mixture was transferred to a greased tray, hand pressed, and cut into a rectangular shape. As there is malnutrition in India, Nutri bar can be used to offer a fast energy source as it's a convenient food source that requires no preparation, has a long shelf life, and no refrigeration, which can be easily used in rural areas along with their normal diets [4].

Sorghum is usually a safe food for celiac patients, who cannot tolerate the protein sequences found in wheat gluten, gliadins, and glutenin. Sorghum is considered a safe food for celiac patients because it is more closely related to maize than to wheat, rye, and barley [5]. Sorghum might, therefore, provide a good basis for gluten-free breads and other baked products such as pasta, cookies, and snacks, although no direct testing has been conducted on its safety for celiac patients.

Nowadays snack food market is continually changing and adapting to the new consumer needs. Commercial food manufacturers produce an array of ready-to-eat (RTE) as well as convenient foods, which are high in oil and flavored with salt or salty flavorings. Many nutritious foods are already available in the market, but they contain very high amounts of calories[6]. Most of the Nutri bars are made from whole grain flour, wheat protein powder, soya protein powder, rice flour, and palm oil, which is not at all good from a health point of view because it contains more calories and allergens. But in the present time, there is still not much Nutri bar made up from millet available in the market. Nutri bars made from millets like sorghum, Ragi, Banyard, foxtail, etc., are not only healthy but also contain large amounts of micronutrients. Hence, it becomes necessary to develop nutritious bars which are highly rich in macro and micro nutrients, are cost-effective, and fulfill the nutritional gap that arises due to the hectic working schedule and cover the increased demand throughout the life cycle and during various physiological conditions.

This study looks at the effects of various processing methods and ingredient combinations in an effort to increase the variety of healthy snack options, encourage the use of sorghum's natural nutritional benefits, and investigate ways to improve the overall nutritional profile and consumer appeal of these handy food formats. In the end, this study hopes to offer insightful information to the food business, nutritionists, and food scientists about how to use sorghum to develop new and healthy nutri-bar products. Building on sorghum's well-known nutritional qualities and adaptability, this study recognizes the rising desire from consumers for quick and healthful snack options. An appealing basis for the creation of nutri-bars is sorghum, a gluten-free grain high in dietary fiber, antioxidants, and vital minerals.

## Materials and Methods

Experiments were carried out to develop a *Sorghum-based Nutri bar* with some selected gluten-free grains, in the laboratories established under the RKVY funded project "Establishment of Agro Processing centre" at the Department of Processing and Food Engineering, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut. Experiments were also carried out to evaluate the physical properties (length, width, height), and sensory evaluation (overall acceptability) of Nutri bar. The samples were kept in a refrigerator (4°C) for storage for further study after 30, 60, and 90 days. The present study was carried out to prepare Nutri Bar of Sorghum as the base ingredient blended with other major ingredients, including Finger millet, Foxtail millet, Oats, Soyabean, Oyster Mushroom, along with some additional common ingredients, including Butter, Honey, Jaggery, Salt, Nuts, Dates, Gum Acacia, and KMS. A Completely Randomized Design(CRD) with five samples($T_{90}$ to $T_{70}$) and three replications was adopted.

### Formulation and process of Sorghum based Nutribar

Weigh all the dry and wet ingredients in different petri dishes (Table 1) as per the formulation. Initially of butter was initially melted in a pan. Subsequently, a blend of flours (including sorghum, ragi, foxtail millet, oats, soyabean, and mushroom) along with chopped dried fruits and nuts was added. The dry mix was continuously roasted over a low to medium flame until a nutty aroma emerged to ensure uniform flavour distribution.

In a different pan, binder syrup was prepared and poured into the roasted flour and nut mixture and mixed thoroughly for about one minute. The hot mixture was then spread evenly onto a tray lined with butter paper using a spatula. While still warm, it was cut into rectangular bars with a knife. The bars were then placed in a freezer to cool and set for 45 minutes. After setting, each bar was wrapped in rice paper and packed into aluminum pouches (Fig 1) using a heat-sealing machine for storage and further quality analysis.

**Table 1:** Formulation and used ingredients in Sorghum based Nutribar

| Ingredients,% code | Sorghum | Ragi | Mushroom | Foxtail millet | Soybean | Oats |
|---|---|---|---|---|---|---|
| $T_{90}$ | 90 | 2 | 2 | 2 | 2 | 2 |
| $T_{85}$ | 85 | 3 | 3 | 3 | 3 | 3 |
| $T_{80}$ | 80 | 4 | 4 | 4 | 4 | 4 |
| $T_{75}$ | 75 | 5 | 5 | 5 | 5 | 5 |
| $T_{70}$ | 70 | 6 | 6 | 6 | 6 | 6 |

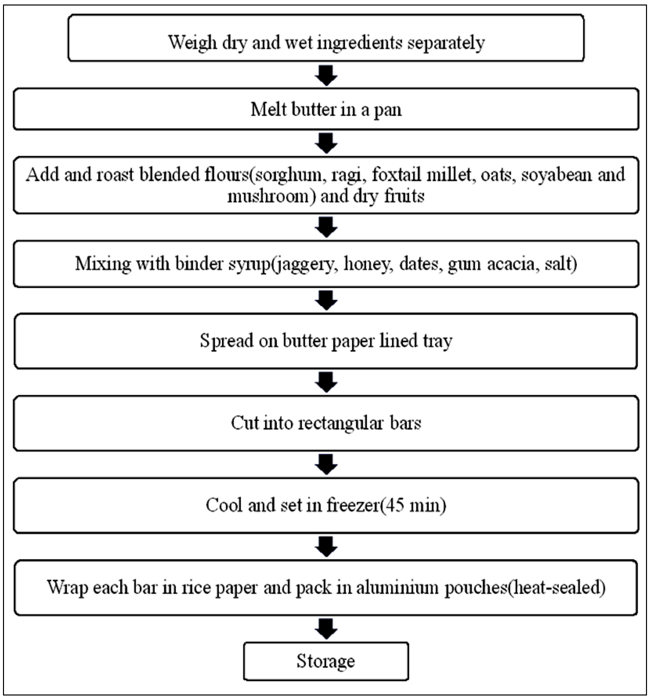


**Fig 1:** Preparation of Nutri Bar

### Physical Properties of Nutri bar

**Mass:** Mass of nutribars(g) was measured as the average of values of five individual bars with the help of an electronic balance.

**Length:** The length(mm) of five individual bars was measured by using vernier caliper.

**Width:** The width(mm) of five individual bars was measured by using vernier caliper.

**Height:** The height(mm) of five individual bars was measured by using vernier caliper.

### Colour determination

Colour measurement of Nutri bar was carried out using a Hunter Colorimeter fitted with an optical sensor(Make: 3nH Colour meter, China)on the basis of CIE L*, a*, b* colour system. The L*, a*, b* colour scale views colour in a similar manner to how the human eye sees colour, with L measuring light to dark colour components, a is a red-green scale, and b* is a yellow-blue scale. The maximum for L* is 100, which would be a perfect reflecting diffuser. The minimum for the L*, which would be black. The a* and b* axis have no specific numerical limits. Positive a* is red while negative a* is green. Similarly, positive b* is yellow and negative b* is blue.

### Sensory Evaluation

Sensory evaluation was done according Ranganna (2001) [7], which is important to assess the consumers' requirements. It is difficult to classify 100% by machine because it is a subjective factor. The sample should have a typical taste, flavor, and texture. To test these organoleptic characteristics, sensory evaluation was done on the basis of a 9-point hedonic scale. The sensory evaluation was carried out for color, texture, and overall acceptability. A sample was served for the evaluation to 10 panelists at a time. The score sheet was provided with the product, and all the panelists were evaluated on a 9-point hedonic scale. This was judged for colour, taste, flavour, and general acceptability on a nine-point hedonic scale, varying from "dislike extremely" (score 1) to "like extremely" (score 9).

**Statistical Analysis**

All statistical analyses were conducted using SPSS software (Version 25.0; SPSS Inc., Chicago, IL, USA). To assess significant differences among sample means, a one-way analysis of variance (ANOVA) was performed, followed by Duncan's multiple range test at a significance level of $P \leq 0.05$. Results are expressed as mean ± standard deviation, based on a minimum of three independent replicates.

**Results and Discussion**

The present research, titled "*Sorghum-based Nutri bar: Development, standardization and quality evaluation*," was performed by using various compositions of sorghum and other ingredients flour. The sorghum flour was combined with mushroom powder, soybean flour, foxtail millet flour, finger millet flour, and oat flour, and five samples ($T_{90}$, $T_{85}$, $T_{80}$, $T_{75}$, and $T_{70}$) were developed, where sorghum content ranged from 90% to 70%. The levels of other ingredients increased proportionally to maintain 100% of the total flour mix, as described in Table 1. The physical properties (including mass, length, height, and width) and sensory quality evaluation (overall acceptability) of Nutri bar were evaluated. Data were statistically analyzed using SPSS software. The results of the present studies are discussed in the following sections:

**Physical properties of Sorghum-based Nutri bar**

The study of physical properties such as shape, length, width, thickness, and mass is necessary for designing baking equipment, packaging materials, handling, and storage systems. These properties are also useful in the calculation of energy and mass balance during processing. The effect of different flours on the physical properties of freshly prepared nutri bars was analyzed and discussed in the following section. Physical properties of fresh SBNB samples were determined.

**Mass**

The experimental data on physical parameter *viz*., mass of Nutri bars made of different composition of flours of sorghum, soyabean, oats, ragi, foxtail millet and mushroom powder is graphically represented in a column chart in Fig. 2. The highest value of mass (26.38 g) was observed in $T_{90}$ sample followed by $T_{85}$(26.22 g), $T_{80}$(25.12 g), $T_{75}$(24.85 g), and $T_{70}$(24.37 g). An average of five replication weights of each sample was calculated, and the mass of each sample was in the range between 24 to 26 g. The mass of nutribar decreased with increasing the amount of other flour and decreasing the level of sorghum flour. The study revealed that the mass of nutribar slightly changed due to the incorporation of different flours. The mass of the nutribar was affected by the mass of blended semi-solid material taken for making the nutribar in a rectangular shape. Similar trends were found for composite flour biscuit [8].

**Length**

The result of physical parameter like length of Nutri bars made of different composition of flours of sorghum, soyabean, oats, ragi, foxtail millet and mushroom powder are graphically represented in a column chart in Fig. 2. The highest value of length (10.21 cm) was observed in $T_{90}$ sample followed by $T_{85}$ (9.78 cm), $T_{80}$ (9.62 cm), $T_{75}$ (9.52 cm) and $T_{70}$ (9.28 cm). The length of the nutribars increased slightly, which may be due to an increase in other flours and a decrease in sorghum flour content, which may have been affected during the shaping of the nutribars. The denaturation of flour proteins and starch due to the thermal process causes the expansion of air bubbles due to the presence of $CO_2$ and water vapor, and leads to an increase in the volume [9]. In the present study, it may be due to the process of roasting of different flours, which may have affected the flour structure, due to which they absorb more syrup during the mixing of dry and wet ingredients with each other. Roasting and ingredient mixing may have affected the length of the nutribar.

**Width**

The experimental data on physical parameter like width of Nutri bars made of different composition of flours of sorghum, soyabean, oats, ragi, foxtail millet and mushroom powder is graphically represented in in Fig. 2. The highest value of width (2.97 cm) is observed in $T_{90}$ sample followed by $T_{85}$ (2.90 cm), $T_{80}$ (2.86 cm), $T_{75}$ (2.64 cm) and $T_{70}$ (2.58 cm). The width of all the samples is almost similar, and a very slight change is observed, which may be due to variation during spreading. The denaturation of flour proteins and starch due to the thermal process causes the expansion of air bubbles due to the presence of $CO_2$ and water vapor, and leads to an increase in the volume[9]. In the present study, it may be due to the process of roasting different flour, which may have affected the flour structure due to which they absorb more syrup during mixing of dry and wet ingredients with each other. Roasting and ingredient mixing may have affected width of nutribar.

**Thickness**

The experimental data on physical parameter like thickness of Nutri bars made of different composition of flours of sorghum, soyabean, oats, ragi, foxtail millet and mushroom powder is graphically represented in a column chart in Fig.2. The highest value of thickness (1.55 cm) is observed in $T_{90}$ sample followed by $T_{85}$ (1.39 cm), $T_{80}$ (1.35 cm), $T_{75}$ (1.11cm), and $T_{70}$ (1.04 cm). The variation in thickness of the samples may be attributed to spreading inconsistency. The denaturation of flour proteins and starch due to the thermal process causes the expansion of air bubbles due to the presence of $CO_2$ and water vapor, and leads to an increase in the volume[9]. In the present study, it may be due to the process of roasting different flours, which may have affected the flour structure, due to which they absorb more syrup during mixing of dry and wet ingredients with each other. Roasting and ingredient mixing may have affected the thickness of the nutribar.

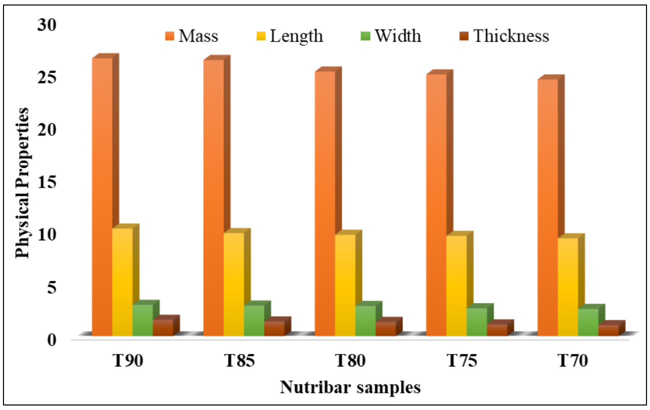


**Fig 2:** Physical Properties of Nutribar

## Colour Quest of Nutri bar

Colour is a necessary attribute for any food product as it influences consumer preference and product acceptability. Consumers observe the surface colour and accordingly form a judgement for its acceptance and rejection. The CIE color space parameters — *L** (lightness), *a** (red-green axis), and *b** (yellow-blue axis), along with total color difference (ΔE) — were evaluated at 0, 30, 60, and 90 days for all the five samples ($T_{90}$, $T_{85}$, $T_{80}$, $T_{75}$, and $T_{70}$) where the proportion of sorghum decreased from 90% to 70%, and the levels of mushroom powder, ragi, soybean flour, oats, and foxtail millet increased.

At 0-day analysis (Fig. 3), *L** values ranged between (36.77- 24.43) from ($T_{90}$) to ($T_{70}$). The experimental data indicate that samples with higher sorghum content ($T_{90}$, $T_{85}$) were significantly lighter in appearance, while those with increased levels of other ingredients like ragi, soybean flour, and mushroom powder ($T_{75}$, $T_{70}$) appeared darker in colour. The naturally dark pigmentation of ragi and mushroom powder and high polyphenol content in foxtail millet and soybean flour are the possible reasons for this, which contribute to a darker product [10]. The a* values were within a narrow range (9.89–11.24), resulting in mild reddish hues. The yellower the millet, the stronger the flavour and the better the Formulation [11]. Highest *b** values (yellowness) were observed in $T_{85}$ and $T_{70}$ samples, which may be because of oats and foxtail millet content, which contributes a yellowish tone [12]. ΔE values were highest in the $T_{85}$ sample (45.64), indicating strong color variation among formulations.

After 30 days of storage (Fig. 4), *L** values in $T_{90}$ and $T_{85}$ remained relatively stable, while they increased substantially (from 24.43 to 34.10) in the $T_{70}$ sample, indicating a lighter product. The gradual increase may be due to moisture migration or a reduction in the intensity of dark pigments due to their partial oxidation. a* values of the $T_{80}$ sample showed a sharp increase (from 9.89 to 13.73), because of Maillard reaction or due to pigment interaction among ingredients like ragi and mushroom powder. *b** values were observed to show a sharp decrease in the $T_{70}$ sample (from 32.35 to 15.07), because of the degradation of yellow pigments or interaction with antioxidant KMS, which may have caused alterations in chromophores. ΔE values decreased significantly in $T_{90}$ and $T_{85}$ (22.86 and 23.12), which indicates that these samples had more stable color during early storage, possibly because of higher sorghum content, which undergoes less pigment degradation.

The analysis after 60 days (Fig. 5) showed that *L** values increased in $T_{90}$ and $T_{75}$ samples (36.85 and 29.89), possibly because of starch retrogradation and moisture changes within the packaging, which resulted in more scattering of light and hence the surface appeared brighter. However, the $T_{80}$ and $T_{70}$(27.54 and 28.32) samples remained darker in appearance due to the balanced presence of darker ingredients like ragi and mushroom powder. It was observed that a* values decreased slightly in most of the samples, likely due to browning reactions[10]. It can also be observed that *b** values showed stability in most of the samples. ΔE values for $T_{90}$ and $T_{85}$ samples were observed to be as low as 12.12 and 11.94, which indicated excellent color retention. ΔE was seen to be higher in the $T_{80}$ and $T_{70}$ samples (27.58–17.83), which reflected visible color changes, likely due to the Maillard reaction.

At the end of the 90-day storage period (Fig. 6), L* value in the $T_{90}$ sample increased to 42.1, indicating further brightening, which may be due to surface drying or breakdown of brown pigments. L* value in $T_{80}$ and $T_{70}$ samples remained visually darker. A decreasing trend was followed in *a** values in all samples, which indicated a reduction in red hues, likely due to degradation of natural red-brown pigments. *b** values also dropped significantly, especially in $T_{75}$ and $T_{70}$ samples, resulting in a loss of yellowness due to oxidative degradation. The ΔE values sharply increased in $T_{75}$ and $T_{70}$ samples, indicating a clear visible change, while $T_{90}$ and $T_{85}$ samples still followed the same pattern and showed lesser changes, showing stability of sorghum-dominant samples during long-term storage.

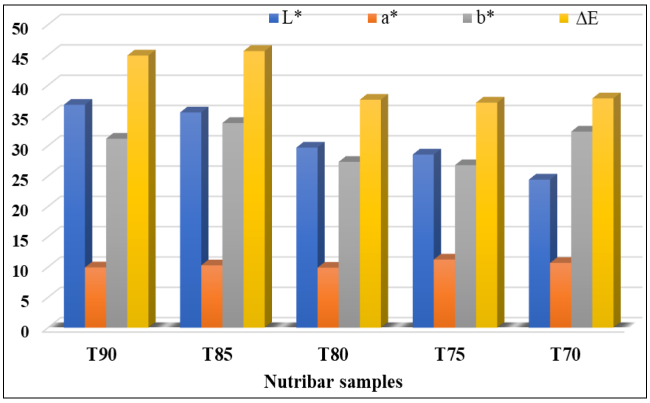


**Fig 3:** Colour Characteristics of SBNB at 0 Day

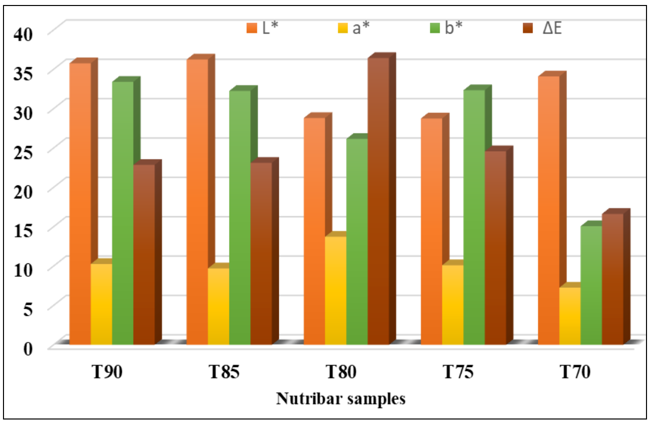


**Fig 4:** Colour Characteristics of SBNB after 30 Days

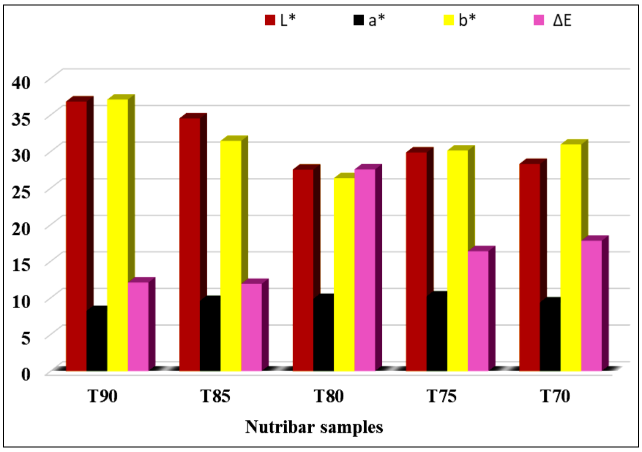


**Fig 5:** Colour Characteristics of SBNB after 60 Days

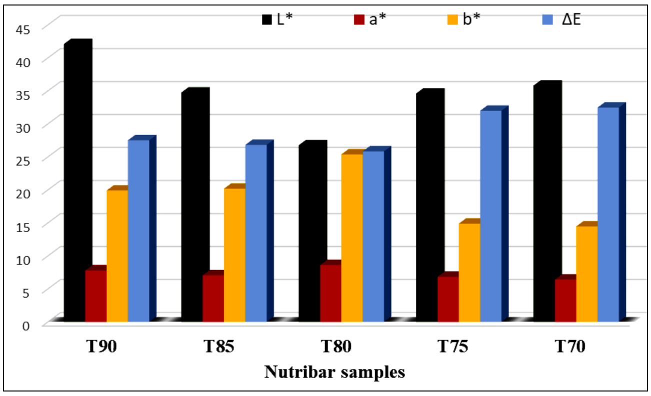


**Fig 6:** Colour Characteristics of SBNB after 30 Days

### Sensorial attributes of Sorghum-based Nutri bar

Sensory evaluation of SBNB was conducted at 0 day as well as for stored samples at 30, 60, and 90 days. The sensory evaluation was carried out to evaluate sensorial attributes like color, texture, taste, flavor, and overall acceptability of the product. All 5 samples were served for the evaluation to 10 panelists at a time. Each panelist received a score sheet on which they were required to fill in their final score using a nine-point hedonic scale. Overall acceptability was calculated by taking the average of all the scores of sensorial attributes. All the samples, along with drinking water, were randomly presented to the panel. The study was conducted under ambient conditions. The effect of inculcation of different compositions of sorghum and other flours and storage on sensorial attributes of sorghum-based nutribars is described in the following section.

### Overall acceptability

The sensory data comprising the final texture scores of SBNB obtained from the panel at 0-day and during the storage period (30,60,90 days). A column chart describing the sensory data for texture scores of SBNB is presented in Fig. 7. The overall acceptability scores ranged from 7.42 to 8.52 before storage, and after storage for three months, they changed to a range of 7.0 to 8.1. $T_{70}$ was found to be highly acceptable in terms of colour, flavour, and texture. The results reveal a clear trend of increasing overall acceptability with decreasing sorghum content. At day 0, $T_{70}$ (70% sorghum) recorded the highest score (8.525), while $T_{90}$ (90% sorghum) had the lowest (7.425). This suggests that formulations with reduced sorghum and higher proportions of complementary ingredients such as oats, finger millet, and mushroom powder were more favourably received by the sensory panel. Throughout the 90-day storage period, a slight decline in overall acceptability was observed across all treatments. This decrease may be attributed to textural changes, flavour degradation, or moisture loss over time. Despite this, $T_{70}$ consistently maintained the highest acceptability scores, remaining above 8.0 even after 90 days, indicating excellent shelf stability and consumer appeal. In contrast, $T_{90}$ and $T_{85}$, with higher sorghum levels, showed comparatively lower scores over the entire storage period. This may be due to the coarser texture, stronger flavour, or denser structure associated with higher sorghum content, which was less appealing to the panellists.

Overall, the findings suggest that lowering the sorghum level to 70–75%, while incorporating other functional and palatable ingredients, enhances the overall acceptability of Nutri Bars and helps maintain consumer appeal during extended storage.

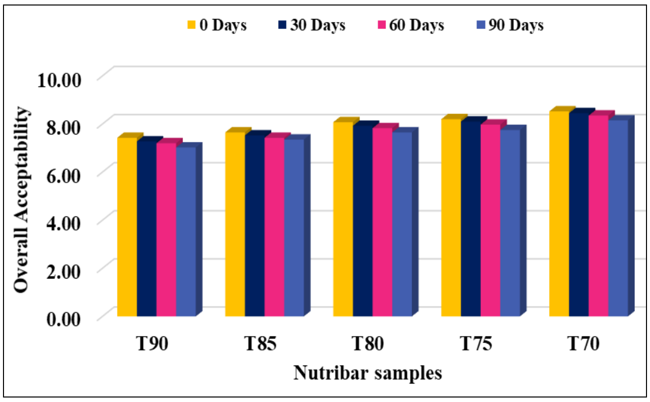


**Fig 7:** Effect of ingredients composition and storage period on overall acceptability of Sorghum-based Nutri Bar

### Conclusion

The analysis of developed sorghum based nutribar was done to evaluate the physical properties (length, width, thickness and mass), colour characteristics ($L^*$, $a^*$, $b^*$) and sensorial quality(overall acceptability) during storage. The data were statistically analyzed using SPSS Software. From the present study, the L*, a*, and b* values of all SBNB samples varied with storage period. The L* value was observed to be lowest, 24.43 in the $T_{70}$ sample and highest 42.1 in the $T_{90}$ sample after 90 days of storage, and at 0 days, respectively, the a* value was observed to be lowest 6.43, in the $T_{70}$ sample and highest 13.73 in the $T_{80}$ sample after 90 and 30 days of storage. b* value was observed to be lowest, 14.47 in $T_{70}$ after 90 days of storage, and was found to be highest, 37.11 in $T_{90}$ sample after 60 days. The colour difference was highest, 45.64 in the $T_{85}$ sample at 0 day, and was lowest, 11.94 for $T_{85}$ after 60 days. In contrast, $T_{90}$ and $T_{85}$, with higher sorghum levels, showed comparatively lower scores over the entire storage period. This may be due to the coarser texture, stronger flavour, or denser structure associated with higher sorghum content, which was less appealing to the panellists. Overall, the findings suggest that lowering the sorghum level to 70–75%, while incorporating other functional and palatable ingredients, enhances the overall acceptability of Nutri Bars and helps maintain consumer appeal during extended storage.

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