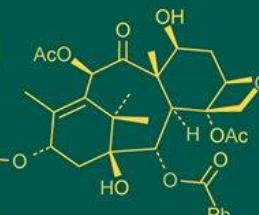
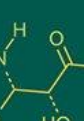
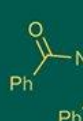


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Optimization and quality evaluation of jaggery based banana nutri bar by incorporation of oats

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Abstract

The demand for bars is rising due to their convenience, taste, and affordability, and processing bananas into powder helps extend shelf life and broaden their use. The study conducted at the Department of Postharvest Management, College of Horticulture, Bagalkot (2024-25) focused on developing and evaluating oats-based banana nutri bar for their physico-chemical, sensory, and storage qualities. Banana nutri bar prepared by varying amount of raw banana powder (0 to 30 g) and rolled oats (35 to 5 g). Treatment T₅ and T₆ showed highest scores for physical parameters (yield, moisture, water activity, dry matter and hardness), colour values (*L**, *a** and *b**) and sensory attribute, then proximate composition-moisture (8.50 and 8.55 g/100 g), protein (11.56 and 11.07 g/100 g), fat (12.49 and 12.01 g/100 g), crude fibre (8.95 and 8.85 g/100 g), ash (4.09 and 4.03 g/100 g), carbohydrate (54.52 and 55.50 g/100 g) and energy (376.30 and 374.03 g/100 g) respective to T₅ and T₆ treatments.

Keywords: Raw banana powder, rolled oats, Nuti bar and nutritional composition

Introduction

Banana (*Musa* sp.) ranks as the second most significant fruit crop in India after mango. Commonly referred to as “Adam’s Fig” or the “Apple of Paradise,” it is favoured for its year-round availability, wide variety of cultivars, appealing taste, nutritional benefits, and medicinal properties, making it popular across all segments of society. Bananas can be processed in different ways to extend their shelf life and enable their use in various products. Recently, new economic approaches, such as producing banana powder, have been explored to increase banana utilization. Green banana powder is an inexpensive ingredient for the food industry and serves as a way to reduce banana waste (Zhang *et al.*, 2005) [24]. Unripe or green banana flour is rich in resistant starch and dietary fibre, which may provide health benefits (Faisant *et al.*, 1995) [8]. Additionally, green bananas have been reported to exhibit hypoglycemic effects by promoting insulin secretion and enhancing glucose utilization. Their high potassium and sodium content is also associated with this glycemic effect. Fibers such as hemicellulose and other neutral detergent fibre from unripe bananas have been shown to reduce the absorption of glucose, cholesterol, and triglycerides (Imam and Akter, 2011) [21]. The popularity of snack bars has grown due to their convenience, appealing taste, affordability, and attractive presentation (Izzo & Niness, 2001) [12]. These bars are especially preferred for their flavour, texture, portability, and cost-effectiveness. They can be consumed as between-meal snacks to reduce the consumption of heavy meals while enhancing feelings of fullness (Ho *et al.*, 2016) [10]. Nutri bars, in particular, are ready-to-eat snacks that provide good nutritional value. Their production is economically viable and aligns well with the current trend of adopting a healthier lifestyle. These bars are formulated with multiple ingredients to meet specific nutritional requirements.

Materials and Methods

Procurement of raw material

The raw banana (var. Grand Naine) was purchased from the APMC market of Bagalkot and organic jaggery from Jamakhandi. Other ingredients (rolled oats, ground nut, green gram, flax seeds, almonds, pumpkin seeds) for preparation of banana nutri bar were purchased from the local market Bagalkot.

Preparation of raw banana powder

Raw banana powder was prepared as per the flow chart given in Fig.1 and that powder was incorporated at different levels as per the treatment details given below for the preparation of banana nutri bar.

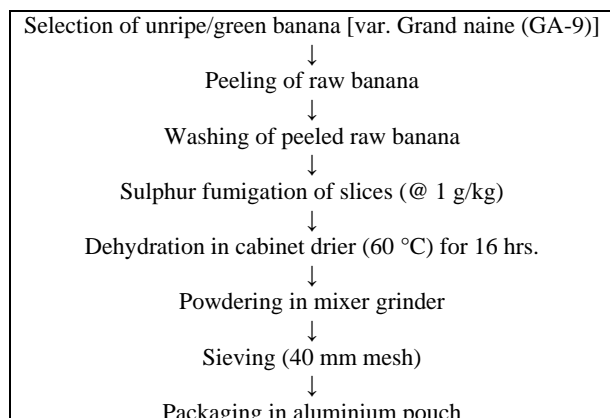


Fig 1: Flow chart of preparation of banana powder

Preparation of oats incorporated banana nutri bar

Banana nutri bar was prepared by using raw banana powder, rolled oats, ground nut, green gram flour, flax seed powder, almonds, pumpkin seeds and organic jaggery (Table 1). Before preparation except jaggery all the ingredients were roasted and grounded in to powder. Jaggery syrup was prepared by using water (25 ml), then all the ingredients were mixed uniformly in the jaggery syrup by constant stirring on hot pan. The product was poured in to ghee greased plate, moulded to desired shape, leave it to cool for 10 min. and then packed in aluminium pouches until further use.

Table 1: Treatments of oats incorporated banana nutri bar

Ingredients (Powders)	T ₁ (Control)	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇
Raw banana powder (g)	0	5.0	10	15	20	25	30
Oats (Rolled) (g)	35	30	25	20	25	10	5.0
Green gram (g)	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Groundnut (g)	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Flaxseeds (g)	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Almonds (g)	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Pumpkin seeds (g)	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Jaggery (g)	32.5	32.5	32.5	32.5	32.5	32.5	32.5

Note: Common ingredients: Water (25mL), ghee (1 g) and gum acacia (1 g)

Physical properties of oats incorporated banana nutri bar

Yield of banana nutri bar of all the treatments were calculated by the formula. Taking the initial and final weight of banana nutri bar.

$$\text{Recovery (\%)} = \frac{\text{Weight of the nutri bar}}{\text{Weight of the ingredients + Added water}} \times 100$$

The moisture content of the nutri bar was determined using a Radwag MAC 50 moisture analyser (Poland). The water activity of the banana nutri bar was measured using a Labswift-aw water activity meter (Novasina). Colour of the banana nutri bar was measured with a Colour Flex EZ (Model CFEZ 1919, Hunter Associates Laboratory, Inc., Reston) with a 45 mm (diameter) measuring tube using a

white tile background. Dry matter content was determined by dividing the dry weight (weight after drying known sample in hot air oven) by fresh weight (weight before drying) and multiplying by 100. The texture of banana nutri bar was assessed by hand penetrometer. The force required to break the banana nutri bar was recorded as per the scale in hand penetrometer. Sensory evaluation, the nine-point hedonic scale was used to assess the attributes such as colour, flavour, texture, taste and overall acceptability. The samples were coded randomly and served to the panellist. In sensory evaluation, the top-scoring (best two treatments + control treatment) treatments were taken for further analysed of nutritional quality.

Proximate composition

The nutritional composition of oats incorporated banana nutri bar, was evaluated following standard procedures. Moisture content was determined using a Radwag MAC 50 moisture analyzer (Poland), crude protein by the Micro Kjeldahl method, and crude fat using an automatic Soxhlet apparatus (SOCS PLUS; Pelican Equipments, Chennai) according to Ojure and Quadri (2012) [18]. Crude fiber was measured with the Fibra Plus-FES-6 instrument, ash content using a muffle furnace, and carbohydrates were estimated as per AOAC (1980). The calorific value was calculated using the differential method described by BeMiller (2017) [4].

Statistical analysis

The physico-chemical data of oats incorporated banana nutri bar, analyzed using a Completely Randomized Design (CRD) with one-way ANOVA, employing the Web Agri Stat Package (WASP) version 2. A significance level of $p = 0.01$ was applied, and critical difference values were calculated whenever the F-test showed significant differences.

Results and Discussion

Physical properties of oats incorporated banana nutri bar

Yield (g)

The yield parameter of oats incorporated banana nutri bar is illustrated in Table 2. Weight of banana nutri bar significantly varied among the treatments and it was ranged from 102.6 to 107.91 g with a mean value of 105.46 g. The highest (107.91 g) value was found in T₇ followed by T₆ whereas control treatment T₁ showed the lowest (102.6 g) value. The weight of nutri bars was observed to increase with higher incorporation of raw banana powder. This may be attributed to the higher bulk density of raw banana powder when compared to oats, resulting in greater mass per unit volume. Similar results were found in research findings of Rahman *et al.* (2021) [21] and Bashmil, *et al.* (2025) [3] who reported that the incorporation of banana flour increases the weight of bread.

Moisture (g/100 g)

Table 2 depicts the moisture content of oats incorporated banana nutri bar. Moisture content ranged from 7.69 to 8.70 g/100 g with a mean value of 8.34 g/100 g. The highest (8.70 g/100 g) moisture content was recorded in T₇ it was on par with T₆ and followed by T₅ and lowest moisture content of 7.69 g/100 g was recorded in T₁ control treatment. The moisture content of nutri bar showed an increasing trend with higher levels of raw banana powder. This can be

explained by the hygroscopic nature and starch composition of banana powder, which facilitates greater water absorption and retention. Olagunju *et al.* (2022) ^[19] also reported an increase in moisture content in multigrain snack bars, which is consistent with the observations of Nadeem *et al.* (2012) ^[17].

Water activity (a_w)

Water activity of oats incorporated banana nutri bar were reported in Table 2. It was ranged from 0.320 to 0.365 a_w having mean value of 0.344 a_w . Water activity of banana nutri bar T₇ recorded the highest (0.365 a_w) it was on par with T₆, T₅, T₄ and T₃ treatments, whereas the lowest water activity (0.320 a_w) was recorded in T₁ control treatment. The higher moisture contributed to greater availability of free water, which in turn increased the water activity of the bars. Olagunju *et al.* (2022) ^[19] also reported an increase in water activity in snack bars, which is consistent with the observations of Nadeem *et al.* (2012) ^[17].

Dry matter (%)

Table 2 reported the dry matter of oats incorporated banana nutri bar. Results varied from 91.33 to 92.30 per cent with a mean value of 91.67 per cent. Highest dry matter (92.30 %) value was found in T₁ treatment followed by T₂ and it was on par with the treatments T₃ and T₄ and the least (91.33 %) value was found in T₇. When moisture is reduced, the dry matter content becomes higher. they are inversely proportional and complementary each other. In banana nutri bar, treatments with higher moisture showed lower dry matter content, while those with reduced moisture retained more dry solids. Similar results with moisture and dry matter were observed in Nadeem *et al.* (2012) ^[17].

Hardness (kg/cm²)

Hardness of oats incorporated banana nutri bar is presented in Table 2. Values were varied from 3.60 to 4.06 kg/cm² and mean of 3.78 kg/cm². The highest (4.06 kg/cm²) hardness was recorded in T₇ and it was on par with T₆ and followed by T₅. The least (3.60 kg/cm²) value was recorded in T₁. As the concentration of raw banana powder increased in the treatment, the value was also increased due to the denser powder also leads to reduced porosity and higher compactness of the product. where the product prepared with the addition of banana flour will be little harder compared to other. Hardness of nutri bar was increased due to addition of apricot powder in nutri snack bar as observed by Nadeem *et al.* (2012) ^[17].

Instrumental colour values (L^* , a^* and b^*)

Instrumental colour values were illustrated in Table 3. The L^* values ranged between 18.23 and 21.44 with the mean of 19.27. Treatment T₇ showed highest L^* (21.44) value which was on par with T₆ as well as T₅ and the lowest L^* (18.23) value was administered in T₁ treatment. It was recorded with a mean a^* value of 6.67 and it was ranged from 6.04 to 7.77. Treatment T₁ recorded the highest (7.77) a^* value and it was comparable with T₂ and T₃. The least (6.04) a^* value was depicted in T₇. And instrumental colour b^* Values were ranged from 22.84 to 24.47 with a mean of 22.59. Treatment T₇ having highest b^* (24.47) value and T₆ on par with T₇ and least (22.84) value was found in T₁. In banana nutri bar, an increase in the concentration of raw banana powder resulted increased L^* and b^* values, indicating enhanced

brightness and yellowness of the product. In contrast, the a^* values showed a decreasing trend, signifying a reduction in redness. This variation in colour attributes can be attributed to the inherent pigmentation of banana powder, which contributes more towards lightness and yellow tones while diminishing the red component.

Sensory evaluation

Data concerning about sensory attributes of oats incorporated banana nutri bar is illustrated in Table 4. Using 9-point hedonic scale, including all attributes overall acceptability scores varied between 7.52 and 7.88 with a mean score of 7.66. Here, treatment T₆ got the overall highest (7.88) score, treatments T₅ and T₁ were on par with T₆. Treatment T₃ received the lowest (7.52) scores for overall acceptability of banana nutri bar. Increasing the level of banana powder in the formulation resulted in higher scores for colour and appearance (8.25), taste (8.23), flavour (7.84) and overall acceptability (7.88) except in case of texture (7.51). This was mainly due to increase in the concentration of raw banana powder increased hardness of nutri bar. Similar results were found in Arun *et al.* (2017) ^[2] and Blicharz-Kania *et al.* (2023) ^[6].

In sensory evaluation, the top-scoring best two treatments (T₅ and T₆ + control treatment) were took for further analysed of nutritional quality.

Proximate composition of banana nutri bar

Moisture (g/100 g)

Data pertaining moisture content is presented in Table 5, revealed the significant difference among the treatments. The values ranged between 7.76 and 8.55 g/100 g with a mean value of 8.27 g/100 g. The lowest (7.76 g/100 g) moisture was observed in T₁ control treatment whereas, the highest (8.55 g/100 g) moisture content was observed in T₆ followed by T₅. The moisture content of the nutri bar increased with higher incorporation of raw banana powder. This is attributed to the hygroscopic property and starch composition of banana powder. Similar findings were reported by Olagunju *et al.* (2022) ^[19] in multigrain snack bars and are in agreement with the results of Nadeem *et al.* (2012) ^[17].

Protein (g/100 g)

Protein content of banana nutri bar prepared by the incorporation of oats was ranged from 11.07 to 13.34 g/100 g with mean value of 11.99 g/100 g (Table 5). The results revealed that highest protein (13.34 g/100 g) was recorded in T₁ control treatment, followed by T₅. And lowest was observed by T₆. Oats rich in protein compared to raw banana powder, Similar results were found by Singh *et al.* (2022) ^[23]. The results align with the observations of Habiba *et al.* (2021) ^[9], who noted a reduction in protein content in bars containing banana flour compared to other formulations.

Fat (g/100 g)

Table 5 presents fat values of oats incorporated banana nutri bar. Significant difference was observed and it was ranged between 12.01 and 16.03 g/100 g with mean value of 13.54 g/100 g. And the highest (16.03 g/100 g) value was found in T₁ followed by T₅ 12.49 g/100 g. And in contrast lowest (12.01 g/100 g) was found in T₆. As the concentration of raw banana powder increased in the formulation, the overall fat content of the nutri bar decreased. This reduction can be

attributed to the lower fat composition of banana powder. The findings are consistent with those of Olagunju *et al.* (2022) ^[19], who reported a reduction in fat content in bars formulated with pearl millet, amaranthus and acha.

Ash content (g/100 g)

Ash content of banana nutri bar presented in Table 5. Ash content in banana nutri bar varied from 4.03 to 4.16 g/100 g with value of 4.12 g/100 g and it was varied among the treatments. The significantly highest 100 g value (4.16 g/100 g) was found in T₁ followed by T₅ and lowest (4.03 g/100 g) was observed in T₆. With increasing levels of raw banana powder, the ash content of the nutri bars showed a decreasing trend when compared to formulations with higher oat content. This indicates that oats contribute more to the mineral composition of the bars, as reflected by their higher ash content. Same results were observed in rolled oat snack bar by Singh *et al.* (2022) ^[23].

Crude fibre (g/100 g)

The data pertaining to crude fibre content of oats incorporated banana nutri bar is displayed in Table 5. There was a significant difference observed between the treatments and crude fibre content of banana nutri bar varied from 8.85 to 9.18 g/100 g with mean value of 8.99 g/100 g. Significantly highest (9.18 g/100 g) value was found in T₁ control treatment followed by T₅ 8.95 g/100 g. And the lowest (8.85 g/100 g) was found in T₆. Oats are naturally rich in dietary fibre, particularly β -glucan, although both oats and raw banana powder are good sources of fibre, the concentration is relatively greater in oats. Similar results were found in oats rich bars (Singh *et al.*, 2022) ^[23]. Blicharz-Kania *et al.* (2023) ^[6] reported that the addition of

grape and apple pomace powder reduce the fibre content in cereal bars.

Carbohydrate (g/100 g)

The data about carbohydrate values of oats incorporated banana nutri bar were showed in Table 5. Carbohydrate values showed significant difference among the treatments. And ranged from 50.12 to 55.50 g/100 g with mean value of 53.38 g/100 g. Results showed the highest (55.50 g/100 g) value in T₆ followed by T₅. Control treatment T₁ showed the lowest value 50.12 g/100 g. Raw banana powder is rich in carbohydrates compared to oats, as it contains a higher proportion of starch and simple sugars. Therefore, formulations with greater levels of banana powder showed increased carbohydrate content. Dahri *et al.* (2017) ^[7] reported increased carbohydrate in bars with addition of banana flour. Arinzechukwu and Nkama (2019) ^[1] reported increased carbohydrate content in fruit bar from banana.

Energy (kcal/100 g)

The data about energy values of banana nutri bar were showed in Table 5. The calorific values of oats incorporated banana nutri bar ranged between 374.03 to 396.75 g/100 g with the mean value of 382.36 g/100 g. T₁ showed highest (396.75 g/100 g) energy value followed by T₅. And T₆ showed lowest (374.03 g/100 g) value. Oats rich formulations exhibited higher energy values compared to bars rich in raw banana powder. This is mainly due to the greater fat and protein content of oats, which contribute more calories per gram than the predominantly carbohydrate-rich banana powder. Thus, inclusion of oats increased the overall caloric density of the nutri bar. This is in accordance with the results reported by Singh *et al.* (2022) ^[23] in oats rich energy bars.

Table 2: Effect of treatments on physical parameters of oats incorporated banana nutri bar

Treatment	Yield (g)	Moisture (g/100 g)	Water activity (a _w)	Dry matter (%)	Hardness (kg/cm ²)
T ₁ : 35 g OT	102.60 g	7.69 ^d	0.320 ^b	92.30 ^a	3.60 ^b
T ₂ : 5 g BP + 30 g OT	103.85 ^f	8.14 ^c	0.330 ^b	91.85 ^b	3.62 ^b
T ₃ : 10 g BP + 25 g OT	104.62 ^e	8.27 ^c	0.337 ^{ab}	91.72 ^b	3.66 ^b
T ₄ : 15 g BP + 20 g OT	105.56 ^d	8.39 ^{bc}	0.350 ^{ab}	91.60 ^{bc}	3.73 ^b
T ₅ : 20 g BP + 15 g OT	106.34 ^c	8.48 ^b	0.353 ^{ab}	91.53 ^c	3.82 ^{ab}
T ₆ : 25 g BP + 10 g OT	107.25 ^b	8.57 ^{ab}	0.357 ^{ab}	91.42 ^c	3.94 ^a
T ₇ : 30 g BP + 5 g OT	107.91 ^a	8.70 ^a	0.365 ^a	91.33 ^c	4.06 ^a
Mean	105.46	8.34	0.344	91.67	3.78
S.Em \pm	0.10	0.06	0.01	0.07	0.06
C.D at 1%	0.42	0.26	0.05	0.29	0.26

Note: Values within the same column followed by different superscripts differ significantly ($p < 0.01$).

BP: Banana powder OT: Oats

Common ingredients

GGP-Green gram powder (5 g), FSP-Flax seed powder (5 g), GNP-Groundnut powder (7.5 g), AP-Almond powder (7.5 g), PSP-Pumpkin seed powder (7.5 g), JG-Jaggery (32.5 g), Ghee and gum acacia(1 g)

Table 3: Effect of treatments on colour values of oats incorporated banana nutri bar

Treatment	L*	a*	b*
T ₁ : 35 g OT	18.23 ^d	7.77 ^a	22.84 ^b
T ₂ : 5 g BP + 30 g OT	19.32 ^c	7.42 ^a	23.00 ^b
T ₃ : 10 g BP + 25 g OT	19.82 ^{bc}	7.41 ^{ab}	23.30 ^{ab}
T ₄ : 15 g BP + 20 g OT	19.92 ^b	7.17 ^{bc}	23.80 ^{ab}
T ₅ : 20 g BP + 15 g OT	20.86 ^{ab}	6.97 ^{bcd}	24.06 ^{ab}

T ₆ : 25 g BP + 10 g OT	21.11 ^a	6.61 ^d	24.25 ^a
T ₇ : 30 g BP + 5 g OT	21.44 ^a	6.04 ^f	24.47 ^a
Mean	19.27	6.67	22.59
S.Em \pm	0.32	0.09	0.28
C.D at 1%	1.36	0.38	1.20

Note: Values within the same column followed by different superscripts differ significantly ($p < 0.01$).

BP: Banana powder OT: Oats

Common ingredients

GGP-Green gram powder (5 g), FSP-Flax seed powder (5 g), GNP-Groundnut powder (7.5 g), AP-Almond powder (7.5 g), PSP-Pumpkin seed powder (7.5 g), JG-Jaggery (32.5 g), Ghee and gum acacia(1 g)

Table 4: Effect of treatments on sensory attributes (9-point hedonic scale) of oat incorporated banana nutri bar

Treatment	Colour/appearance	Taste	Flavour	Texture	Overall acceptability
T ₁ : 35 g OT	7.80 ^{bc}	7.78 ^b	7.46 ^d	7.64 ^a	7.81 ^a
T ₂ : 5 g BP + 30 g OT	7.64 ^c	7.64 ^{bc}	7.56 ^{cd}	7.52 ^b	7.41 ^d
T ₃ : 10 g BP + 25 g OT	7.53 ^{cd}	7.56 ^c	7.64 ^{bc}	7.41 ^c	7.52 ^{cd}
T ₄ : 15 g BP + 20 g OT	7.35 ^d	7.83 ^b	7.70 ^b	7.49 ^{bc}	7.65 ^{bc}
T ₅ : 20 g BP + 15 g OT	8.06 ^a	8.17 ^a	7.77 ^{ab}	7.54 ^{ab}	7.78 ^{ab}
T ₆ : 25 g BP + 10 g OT	8.25 ^a	8.23 ^a	7.84 ^a	7.51 ^b	7.88 ^a
T ₇ : 30 g BP + 5 g OT	8.01 ^{ab}	8.11 ^a	7.77 ^{ab}	6.96 ^d	7.60 ^c
Mean	7.81	7.90	7.68	7.74	7.66
S.Em ±	0.04	0.05	0.03	0.02	0.04
C.D at 1%	0.19	0.20	0.13	0.10	0.17

Note: Values within the same column followed by different superscripts differ significantly ($p < 0.01$).

BP: Banana powder OT: Oats

Common ingredients

GGP-Green gram powder (5 g), FSP-Flax seed powder (5 g), GNP-Groundnut powder (7.5 g),

AP-Almond powder (7.5 g), PSP-Pumpkin seed powder (7.5 g), JG-Jaggery (32.5 g), Ghee (1 g), Gum acacia (1 g).

Table 5: Effect of treatments on water activity, proximate composition and energy of oats incorporated banana nutri bar

Treatment	Water activity (a_w)	Moisture (g/100 g)	Protein (g/100 g)	Fat (g/100 g)	Ash (g/100 g)	Crude fibre (g/100 g)	Carbohydrate (g/100 g)	Energy (kcal/100 g)
T ₁ : 35 g OT	0.320 ^b	7.76 ^c	13.34 ^a	16.03 ^a	4.16 ^a	9.18 ^a	50.12 ^c	396.75 ^a
T ₅ : 20 g BP + 15 g OT	0.351 ^a	8.50 ^b	11.56 ^b	12.49 ^b	4.09 ^b	8.95 ^b	54.52 ^b	376.30 ^b
T ₆ : 25 g BP + 10 g OT	0.353 ^a	8.55 ^a	11.07 ^c	12.01 ^c	4.03 ^c	8.85 ^c	55.50 ^a	374.03 ^c
Mean	0.341	8.27	11.99	13.51	4.12	8.99	53.38	382.36
S.Em ±	0.003	0.009	0.082	0.015	0.008	0.008	0.042	0.321
C.D at 1%	0.010	0.039	0.321	0.063	0.031	0.033	0.251	0.423

Note: Values within the same column followed by different superscripts differ significantly ($p < 0.01$).

BP: Banana powder OT: Oats

Common ingredients

GGP-Green gram powder (5 g), FSP-Flax seed powder (5 g), GNP-Groundnut powder (7.5 g), AP-Almond powder (7.5 g), PSP-Pumpkin seed powder (7.5 g), JG-Jaggery (32.5 g), Ghee (1 g), Gum acacia (1 g).

Conclusion

The findings of the study indicate that incorporating oats into jaggery based banana nutri bar enhanced the nutritional profile of the developed nutri bar. Among the treatments, the most suitable formulation was T₆, consisting of 25 g Raw banana powder + 10 g Oats + other constant ingredients.

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