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# Evaluation of Granola Bars Quality Fortified with Sweet Sorghum Jaggery

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***Original Article***

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## ABSTRACT

Granola bars are known for their high nutritional value, antioxidants, calories, and have a light structure. In this study**,** intends to develop the composition of granola bars fortified with sweet sorghum as a natural food ingredient using sweet sorghum stalk juice with high nutritional value as a natural sweetener and binding agent. Six sweet sorghum cultivars (Sugar drip, Rona, Rex, Cukorcirok, Atlas and Brandes) were evaluated to select the best variety to prepare jaggery. The results showed significant differences in nutritional properties and bioactive compounds among the juice of the six cultivars and, The Rona cultivar gave a higher yield of juice rich in total phenols, flavonoid compounds, and antioxidant activity than other cultivars. Such results indicated the sweet sorghum jaggery can be used as an economic sweetener and functional ingredient in preparing functional food. This modification not only provides a source of natural sweetness but also enhances the sensory experience of consuming the bars of granola with jaggery. Our study recommends using concentrated sorghum juice, specifically jaggery of sweet sorghum variety Rona, at 75 Brix 25°C as a replacer for glucose syrup in the production of granola bars.

## 1. Introduction

The universal concept of Jaggery is known as a type of syrup that is prepared by concentrating the extracted juice of sugar cane, sweet sorghum, coconut-palm, or wild date-palm. All of these are used for the preparation of jaggery without any use of chemicals and it is available in the form of solid blocks or to semi-liquid form (Nath et al*.,* 2015). The technology of producing jaggery is an ancient rural industry and before knowing the sugar crystallization process. Therefore, it is considered one of the traditional sweeteners (non-centrifugal sugars) and one of the major alternatives presently available for refined sugar (Venkatesh et al*.,* 2023). It has many common global names e.g., gaggery, Jagger, jiggery, jagra, candy, Gur, Gazak, doublet of sugar and jallab sugar (Sardeshpande et al*.,* 2010). Jaggery is a very nutritious and healthy food and is used as a main sweetener for rural and urban people. One of its most common properties is that it can purify the blood, boost immunity, stimulate the secretion of digestive enzymes and therefore speed up the procedure of digestion (Eggleston et al*.,* 2022). Moreover, jiggery syrup contains properties that help regulate the body, which is highly beneficial for patients with asthma. It is also worth noting that jaggery contains anti-allergy properties as well (Asokan, 2007).

Because the stalk juice of sweet sorghum is rich in sugar, phenolic compounds with antioxidant and antiradical activities and *some* minerals like, Fe, K and Ca, which are considered encouraging factors for use in the food industry (Awad et al*.,* 2010). The sweet sorghum has juicy and sweet stalks; thus, it's mainly been cultivated for making syrup and jiggery (Almodares and Hadi, 2009). Also, (Elkhedir and Osman, 2014) compared the sensory characteristics of different juices made from sweet sorghum varieties (Honey, Brands, Tracy, Williams, and Umbrella) and noticed a significant difference among them.



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The syrup produced from the sweet sorghum variety with honey had a higher degree of taste and consistency than other sweet sorghum syrup varieties. The chemical composition of sweet sorghum syrup is influenced by the type of variety, growing season, agroclimatic conditions and stage of maturity (Reddy et al., 2012). In the field of food processing, (Khalil et al., 2019) stated that sweet sorghum is a good source of syrup production and can be an attractive marketable product with different herbal flavors for all people who need to raise beneficial health while consuming it, as well as for the long shelf-life stability of syrup. On the other hand, (Makori, 2013) showed that higher glucose and fructose levels in sweet sorghum juice are better for producing good quality syrup. So that these characteristics make sweet sorghum an ideal crop for syrup and sweets made of syrup, such as (jiggery and jallab).

Rajvanshi and Nimbkar (2001) showed that sorghum syrup produced from 'Madhura' sweet sorghum hybrid cultivar was preferable in colour to cane syrup. The glazed tamarind candy (jiggery), which is prepared from sweet sorghum syrup, was nutritionally balanced, acceptable to the consumers and rated at a bar with control samples of glucose syrup (Kulkarni et al., 2018). One of the successful applications of sweet sorghum syrup was peanut Chikki (jiggery bar) prepared, which was observed to be nutritionally balanced, acceptable to the consumers and rated at the bar with control samples (Sugarcane jiggery) (Byrappa et al., 2011). Experts are of the view that taking jaggery in the form of a natural sweetener in perfect combination with sesame seeds can be highly beneficial for the respiratory system in humans (Venkatesh et al., 2023).

Granola is often eaten as food for breakfast and between meals because of its lightweight nature and high calories. Granola's common ingredients, such as ground oats, nuts, dried fruits, and honey, are associated with many health benefits and boost immunity as a source of antioxidants (Maurer et al., 2005). Also, granola is rich in protein and fiber, which give a feeling of fullness and thus help reduce food intake and weight loss. In addition, high-fiber foods such as oats and nuts slow stomach emptying and increase digestion time, which may help you feel fuller for longer and may help with appetite control and weight loss (Ahmad et al., 2018). Therefore, the present study was to determine the nutritional properties and bioactive compounds of six sweet sorghum cultivars juice and their utilization as natural sweet food ingredients for producing functional granola. Moreover, the work aimed to investigate the effect of the jiggery on the sensory, chemical, and functional properties of oat granola products containing dried fruits, coconut, and peanuts.

## Materials and methods

### Materials

Six sweet sorghum varieties (Sugar drip, Rona, Rex, Cukorcirok, Atlas and Brandes) were sown in May 2021. Plants were harvested at the dough stage (115–120 days), which is considered the ideal stage to obtain high-quality juice that can be used as a source of syrup and jiggery. Millable stalks of sweet sorghum stems were obtained from Wadi El-Natrun in the Alexandria desert. Raw materials for the bar, including oats, dried fruits (raisins, dried dates, dried apricots, and dried plums), coconut, and peanuts, were purchased from the local market in Cairo and Giza, Egypt.

### Methods

### Technological Methods:

Preparation of sweet sorghum jiggery was carried out according to the method described by (Rajvanshi et al., 1993), as shown in Figure 1.

### Manufacturing process of granola bar

The technology process of sweet sorghum juice and granola bars is shown in Figure 1.

The granola bars were made by combining 400 gm of pre-roasted grains with 100 gm of each type of dried fruit (raisins, dates, apricots, and plums), along with 100 gm of each type of nut and seed (coconut and peanuts). Jaggery was then added to the mixture in a 1:1 quantity which was kneaded to form a loose dough for each with two concentrations of jiggery. The mixture was shaped into moulds for cutting into bars and further cooled. Finally, the finished granola bars were manually packaged as described by (George and Esther 2003)

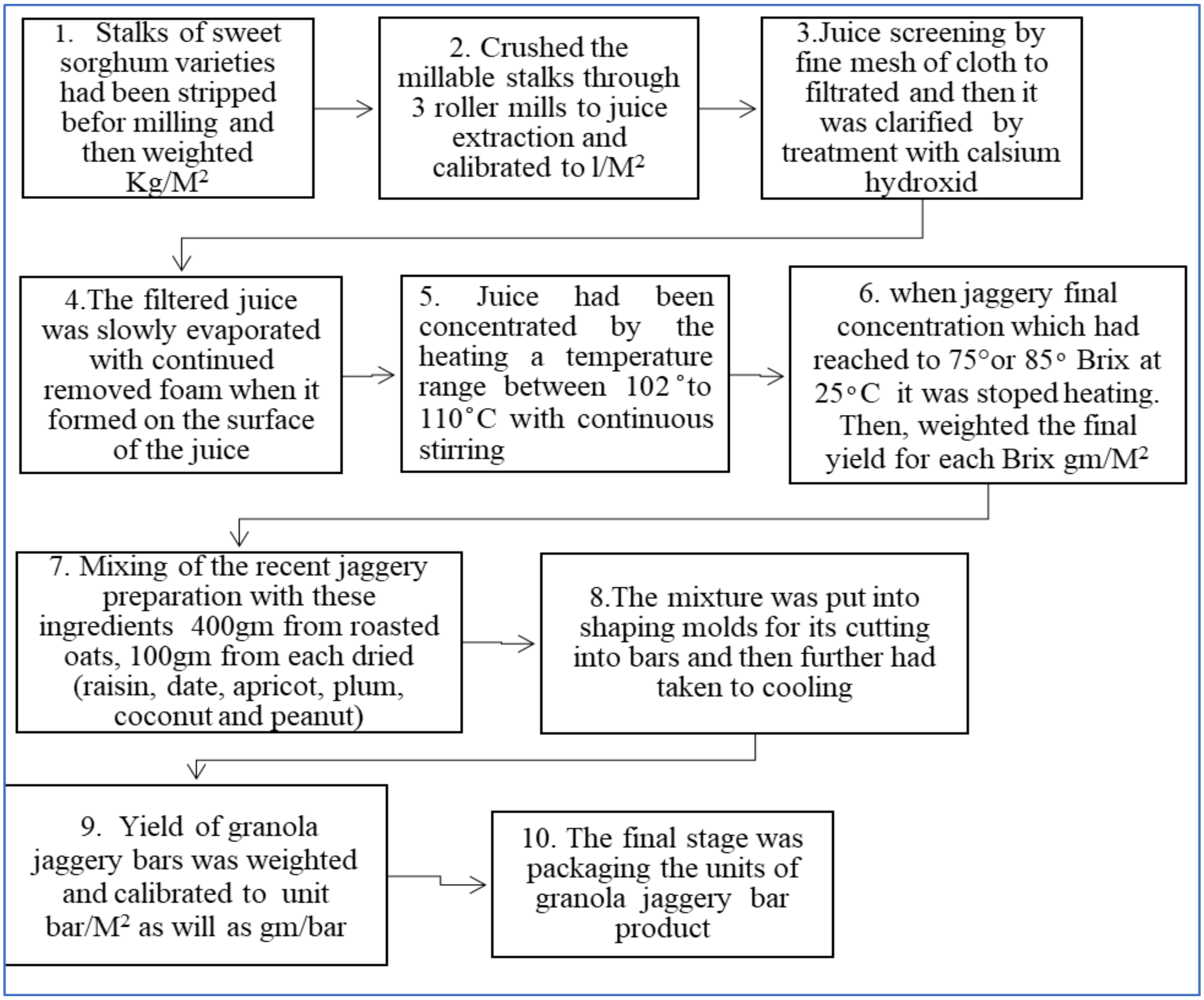


**Figure 1. The technological process of sweet sorghum juice and granola bar**

## Chemical and technological characters of juice, jiggery syrup, and granola bars physiochemical analysis:

Total solids (TS), protein, fat, crude fiber, ash, sucrose, reducing sugars, non-sugar substances (NSS), starch, titratable acidity and purity were determined according to (AOAC, 2005).

Total soluble solids were measured using a Hand refractometer. pH was measured using a digital Metler Toledo Mp 230 pH meter.

Color values like the L* (lightness), a* (red to green color), and b* (yellow to blue color) of the samples were measured using a Hunter Lab Ultra Scan, VIS model, colorimeter (USA).

Carbohydrate content was calculated by difference (100 - (%protein +%fat +%moisture + %Ash)). The energy values of the samples were calculated using the appropriate factor as described by (FAO/WHO/UNU,1985) as following equation (1):

Total calories = 4 (%protein) + 4 (%carbohydrates) + 9 (%fat) (1)

Iron (Fe), magnesium (Mg), potassium (K), zinc (Zn), calcium (Ca), phosphorous (P), selenium (Se) and sodium (Na) were digestion by using microwave digestion system (Multiwave Go Plus) and determined by using microwave plasma Atomic Emission Spectroscopy (MP-AES) (model 4210, Agilent) made in Malaysia according to (A.O.A.C, 2019).

## Functional Properties

Flavonoid fraction and phenolic compounds content in the juice of sorghum varieties were determined using HPLC according to the method described by (Mattila et al., 2000 and Goupy et al., 1999).

A high-performance liquid chromatography system is equipped with a variable wavelength detector (Agilent, Germany) 1100, autosampler, Quaternary pump Degasser and column compartment. Analyses were performed on a C18 reverse phase (BDS 5 µm, Labio, Czech Republic) packed stainless-steel column (4 × 250 mm).

Total phenols were determined calorimetrically using Folin–Ciocalteu reagent (as Gallic acid) according to (Singleton et al*.,* 1999). The total flavonoids were determined (as Quercetin) according to (Marinova et al*.,* 2005). Antioxidant activity (DPPH) was determined according to the method described by (Awika et al*.,* 2003).

## Sensory evaluation:

Color, flavor, taste, texture, appearance and overall acceptability of syrup and granola bars of sweet sorghum samples were evaluated according to the method of (Larmond., 1977), (Yadav and Bhatnagar 2015) by ten panelists of the staff members of Food Technology Res. Inst., Agric. Res. Center, Giza, Egypt.

## Statistical analysis:

All data were expressed as mean values. Statistical analysis was performed using one way analysis of variance (ANOVA) followed by Duncans Multiple Range Test with P >0.05 being considered statistically significant (Snedecor and Cochran, 1980)

# 3. Results and Discussion

## Fractionation of flavonoids and phenols:

The data illustrated in Figure 2. showed that the flavonoids fraction contents in the juice of six sweet sorghum varieties had high amounts of Narengin, Rutin, Hisperdin, Rosmarinic and Quercertrin, moderate amounts of Quercetin, Kampfero, Hispertin and Apergnin, and small amounts of Narenginin and 7-OH-Flavone. The high content of flavonoids in juice encourages using it in the present study as a natural source of antioxidants for protecting human bodies from diseases. These compounds increase the nutritional value of juice and raise its antioxidant capacity. In this regard, (Krueger et al., 2003) reported that sweet sorghum had flavonoid compounds, including tannins and anthocyanins, as the most important constituents isolated from sorghum. Sorghum is a rich source of many phytochemicals, including tannins, phenolic acids, anthocyanins, phytosterols, and policosanols, according to (Awika and Rooney 2004). These phytochemicals could have a substantial effect on human health. Sweet sorghum fractions possess high antioxidant activity (the ability to scavenge free radicals) in vitro relative to other cereals or fruits. (Aherne and O'Brien, 2002) reported that flavonols are phytochemical compounds found in high concentrations in a variety of plant-based foods and beverages Flavonoids, which are defined by their structural similarities, comprise the following substances: quercitin, kaempferol, and myricetin. Numerous elements, such as plant type and development, season, light, degree of ripeness, food preparation, and processing, have an impact on the precise levels of flavonols in foods.

Phenol fractions of sweet sorghum juice (µg /100 g) were introduced in Figure 3. The chart illustrated that sweet sorghum juices had a high content of phenol compounds. The major components of phenols in sorghum juices were Gallic, Pyrogallol, 4-Amino-benzoic, 3-OH- tyrosol, Chlorogenic, Catechol, P-OH -benzoic, E- vanillic, Benzoic, 3,4,5-methoxy-cinnamic, Coumarin, Salycilic and P-Coumaric acids. (Krueger et al*.,* 2003) concluded that the phenolic acids of sweet sorghum are benzoic or cinnamic acid derivatives, whereas the flavonoids include tannins and anthocyanins as the most important constituents isolated from sorghum sp. (Awika and Rooney 2004) investigated that sweet sorghum is a rich source of various phytochemicals including tannins, phenolic acids, anthocyanins, phytosterols and policosanols. These phytochemicals have the potential to significantly impact human health. Sweet sorghum fractions possess high antioxidant activity in vitro relative to other crops or fruits. (Huang et al*.,* 2010) mentioned that Natural phenolic compounds play an important role in cancer prevention and treatment. Phenolic compounds from medicinal herbs and dietary plants include phenolic acids, flavonoids, tannins, stilbenes, curcuminoids, coumarins, lignans, quinones, and others. (Véronique, 2012) demonstrated the diversity of phenolic compounds, a large class of secondary metabolites found in plants. These compounds range in complexity from relatively simple structures like phenolic acids to polyphenols like flavonoids that consist of multiple groups to polymeric compounds based on these various classes. Phenolic compounds are important for the quality of plant-based foods: they are responsible for the color of red fruits, juices, and wines, are substrates for enzymatic browning, and are also involved in flavor properties.

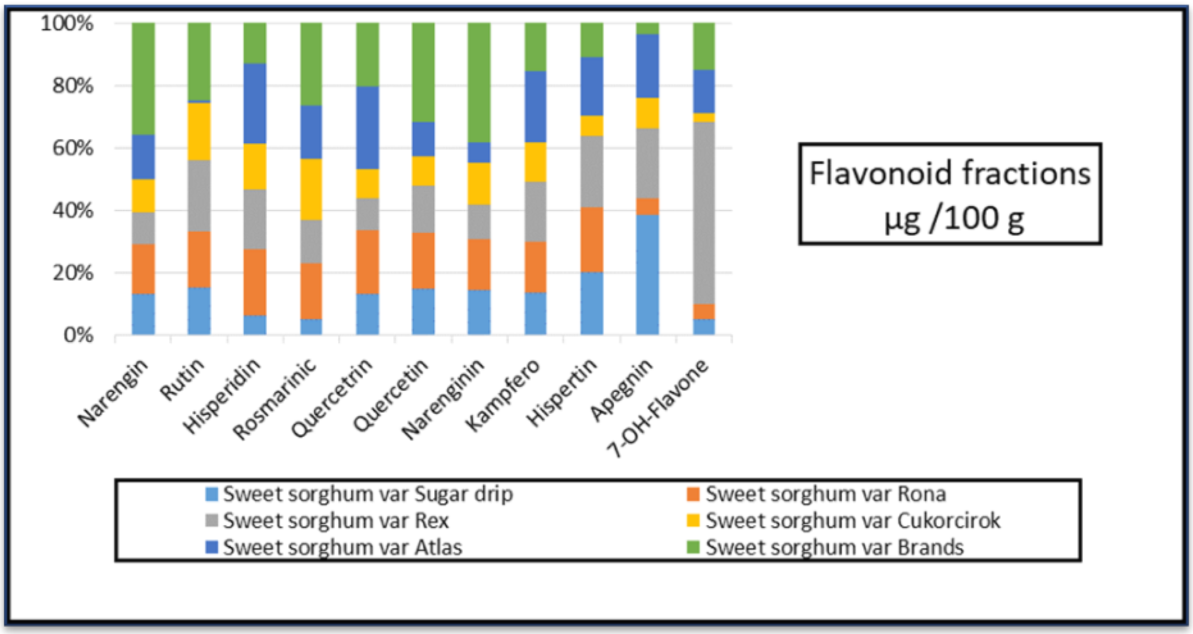


**Figure 2: Flavonoid fractions of six sweet sorghum juice varieties**

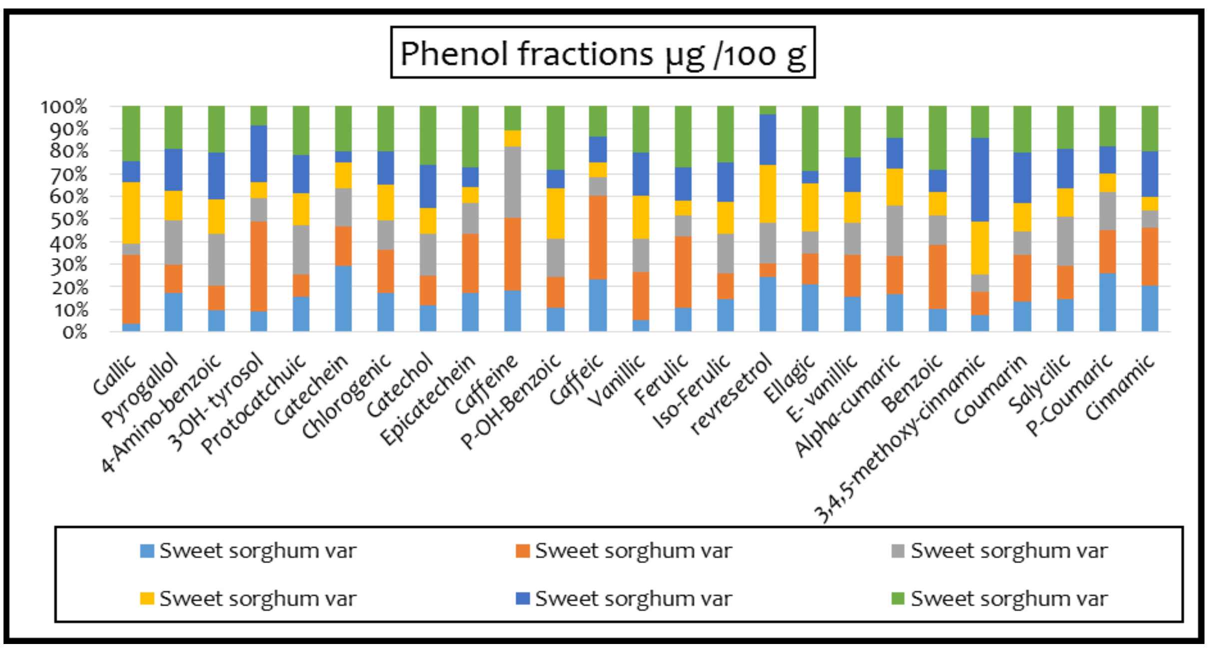


**Figure 3. Phenol fractions of six sweet sorghum juice varieties**

## Productivity and juice quality of sweet sorghum varieties

Data presented in Table 1. indicated that all varieties significantly differed in the yields of stripped stalk, extracted juice and juice quality traits of sorghum varieties under test. The difference in quality among genotypes of sweet sorghum juice is probably due to genetic variation.

Data shows that the "Rona" variety was superior to all the tested varieties in juice characteristics such as

TSS 19.4%, sucrose 16.1%, purity percentages 83.03% and glucose ratio 10.55%, and at the same time, statistically, the yields of sticks and juice were high with no significant differences between it and the "Sugar Drip" variety compared to the varieties under test. Moreover, it was lowest in starch 0.50[c] and non-sugar substances 1.77%. Brands variety statistically showed no significant difference between it and Rona in stripped stalk weight, sucrose, reducing sugar, purity percentages, glucose ratio, and starch content, while it got a second rank in these traits: stripped stalk juice, pH value, moreover the trait of non-sugar substance content was taken a fourth rank.

So, according to these values, it can be judged that varieties Rona and Brands are the most suitable for preparing jiggery, since sugar content is a major factor to ensure the feasibility of the process, as mentioned by (Rajvanshi and Nimbkar 2001) who observed that to produce jiggery of excellent quality, the brix of sweet sorghum juice must be at least 15 degrees and the ratio of sucrose to reducing sugars must be at least 9.

**Table 1. Productivity and juice quality traits of six sweet sorghum varieties**

| Sweet Sorghum Varieties | Stripped Stalk weight | Stripped Stalk Juice | Quality traits of sorghum juice | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | pH | TSS | Sucrose | reducing sugar | Starch | Purity | glucose ratio* | non sugar substance |
| | Kg /M² | L/M² | | | | | % | | | |
| Sugar drip | 10.40[a] ±1.27 | 3.80[a] ±0.17 | 4.79[c] ±0.12 | 14.8[e] ±0.06 | 9.2[d] ±0.05 | 1.13[d] ±0.06 | 0.68[a] ±0.02 | 62.30[d] ±0.69 | 8.20[b] ±0.06 | 4.46[a]±0.12 |
| Rona | 7.98[ab] ±0.87 | 3.40[a] ±0.35 | 5.29[b] ±0.06 | 18.67[b] ±0.01 | 16.1[a] ±0.06 | 1.53[c] ±0.12 | 0.50[c] ±0.01 | 83.03[a] ±1.74 | 10.55[a] ±0.17 | 1.77[d]±0.13 |
| Rex | 4.62[c] ±0.20 | 3.20[ab] ±0.46 | 4.55[cd] ±0.02 | 16.33[c] ±0.02 | 10. 3[c] ±012 | 2.83[a] ±0.06 | 0.59[b] ±0.01 | 62.89[d] ±0.01 | 3.63[d] ±0.635 | 3.23[b]±0.07 |
| Cukorcirok | 3.16[c] ±0.29 | 1.80[c] ±0.35 | 4.37[d] ±.19 | 14.7[e] ±0.12 | 10.9[b] ±0.06 | 2.20[b] ±0.12 | 0.55[bc] ±0.02 | 74.08[b] ±0.58 | 4.94[c] ±0.017 | 1.61[d]±0.12 |
| Atlas | 5.02[c] ±0.60 | 2.20[bc] ±0.20 | 4.57[cd] ±0.18 | 15.56[d] ±0.02 | 10.3[c] ±0.17 | 2.50[ab] ±0.17 | 0.61[ab] ±0.02 | 66.07[c] ±0.01 | 4.11[cd] ±0.058 | 2.78[c]±0.06 |
| Brands | 5.56[bc] ±1.28 | 2.20[bc] ±0.40 | 5. 75[a] ±0.08 | 19.4[a] ±0.17 | 15.8[a] ±0.12 | 1.60[c] ±0.17 | 0.52[bc] ±0.01 | 84.77[a] ±0.64 | 9.89[a] ±0.577 | 1.24[e]±0.02 |

*Glucose ratio= Sucrose/ reducing sugar., TSS=total soluble solids

## Physicochemical of jiggery

Data presented in Table 2. and Figure 4. indicated that all jiggery concentrations with two sweet sorghum varieties significantly differed in all traits under study. The data in the current Table indicated that; sweet sorghum jiggery with brix 85 contained the highest percentages of sugar features such as sucrose, which was very close to that of the total solids compared to other varieties with brix 75. On the other hand, jiggery of the "Rona" variety at brix 85 attained the highest values of TS%, sucrose%, reducing sugar%, glucose ratio and titratable acidity compared to another concentration and sorghum variety (brands) considered. This is the logic result because there was a positive relationship among (sucrose, reducing sugar and titratable acidity) with increasing sugar brix from 75 to 85.

Evaluating the color parameters of sorghum jiggery was introduced in figure (4), which shows that the difference in the color intensity of the jiggery samples may be due to the difference in the sugar level, acidity, while the rise in the dark color was increased with increasing the sugar level and titratable acidity, which leads to the occurrence of (the maillard and caramel reaction that leads to a rise in 5-hydroxy Methylfurfura (HMF) content from non-enzymatic browning in sorghum syrup enhanced the rate of browning reaction. The results are in line with the findings reported by (Khalil et al., 2019). Also, regarding the palatability evaluation of jiggery cultivars (Rona and Brands) in 75 brix, a higher acceptance score was given compared to 85 brix with the same cultivars.

**Table 2: Physicochemical, palatability properties and productivity of jiggery**

| Sweet Sorghum Variety | Quality traits of jiggery | | | | | | | | Palata-bility | Jiggery Produc-tivity |
|---|---|---|---|---|---|---|---|---|---|---|
| | Brix 25°C | Total Solids | Moisture | Sucrose | Reducing Sugar | Glucose ratio* | Non-Sugar sub-stances | TA* | | |
| | | % | | | | | | | Score (10) | Kg /juice $M^2$* |
| Rona | $75.3^{b}$ ±0.11 | $79.38^{d}$ ±0.64 | $20.62^{a}$ ±0.06 | $33.53^{d}$ ±0.01 | $21.16^{d}$ ±0.08 | $1.58^{a}$ ±0.06 | $20.61^{a}$ ±0.06 | $0.346^{d}$ ±0.01 | $10^{a}$ ±0.0 | $0.68^{a}$ ±0.01 |
| | $85.1^{a}$ ±0.23 | $86.72^{b}$ ±0.13 | $13.28^{c}$ ±0.01 | $40.54^{b}$ ±0.13 | $26.47^{b}$ ±0.64 | $1.53^{a}$ ±0.02 | $18.09^{b}$ ±0.58 | $0.506^{b}$ ±0.00 | $8^{bc}$ ±0.58 | $0.57^{b}$ ±0.01 |
| Brands | $75.0^{b}$ ±0.17 | $81.33^{c}$ ±0.11 | $18.67^{b}$ ±0.07 | $35.11^{c}$ ±0.58 | $23.8^{c}$ ±0.06 | $1.48^{a}$ ±0.06 | $16.09^{c}$ ±0.01 | 0.433c ±0.01 | $9^{ab}$ ±0.58 | $0.44^{c}$ ±0.02 |
| | $85.3^{a}$ ±0.12 | $88.95^{a}$ ±0.59 | $11.05^{d}$ ±0.60 | $45.14^{a}$ ±0.64 | $28.42^{a}$ ±0.18 | $1.59^{a}$ ±0.12 | $11.74^{d}$ ±0.12 | $0.557^{a}$ ±0.00 | $7^{cd}$ ±0.58 | $0.37^{d}$ ±0.01 |

*Glucose ratio= Sucrose/ reducing sugar.

*TA: Titratable acidity as ml Na OH 0.1 N/ 100 g sample and calculated by (mg/m Eq as a citric acid).

* Kg /juice$M^2$: kg jiggery weight /stripped stick juice for each meter square in feddan (per $M^2$ in feddan sorghum).

Meanwhile, the data on recovery jiggery in the same table show that at each concentration, the highest yield of jiggery was obtained by the Rona sorghum variety with 75° Brix, so when referring to Table 1, we can find that it obtained the highest percentage of dissolved solids, and therefore the production of jiggery depends largely on the percentage of total solids that was found in the amounts of sorghum juice.

Therefore, based on the evaluation of color and palatability, a brix 75 concentrate of each type of jiggery was selected for use in the granola par application.

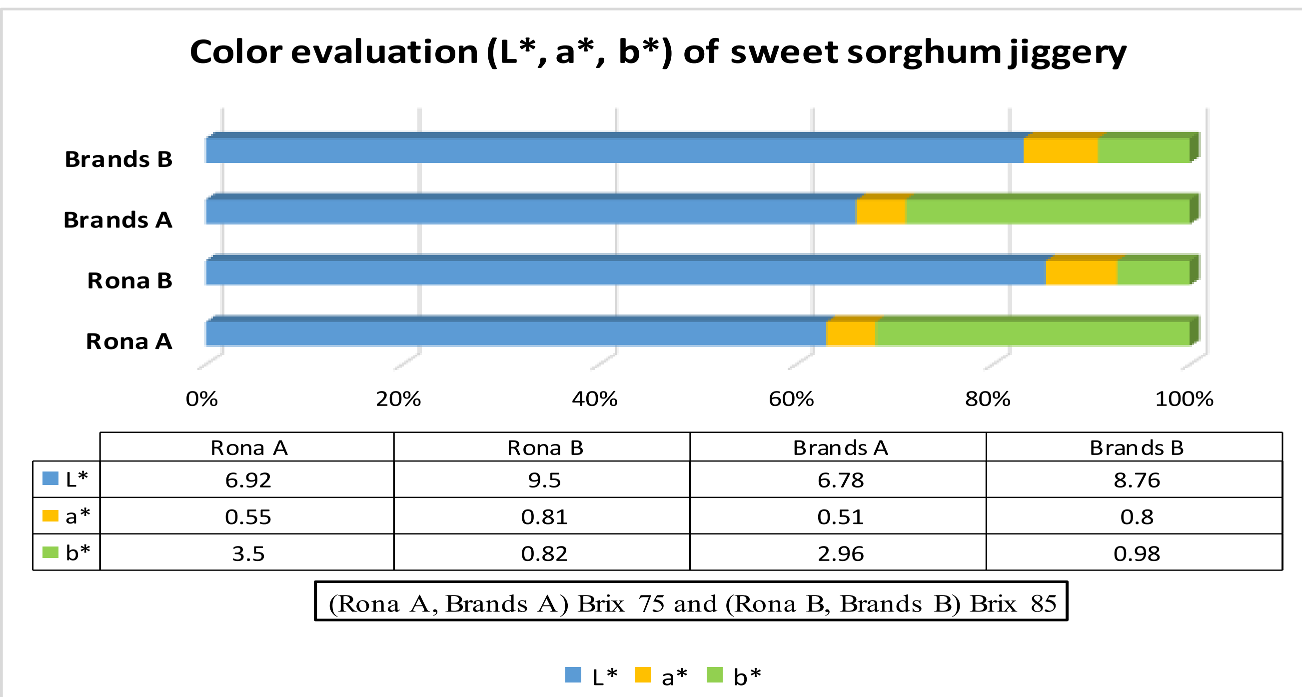


**Figure 4. Color evaluation (L*, a*, b*) of jiggery for two sweet sorghum varieties**

## Sensory Evaluation

Sensory evaluation of sorghum granola includes color, flavour, taste, texture, appearance, and general acceptability as shown in Figure (5). The addition of the combination to sorghum from Rona cultivars and Brands was studied in a ratio of 1:1 (Rona A, Brands A) 2:1 (Rona B, Brands B) compared to the control sample, and the results showed that the addition of sorghum varieties to the combination affected the total degree of acceptance compared to the control sample.

The results indicated that the addition of sorghum of the Rona variety with the mixture at a ratio of (1:1) to prepare granola led to an increase in most of the sensory characteristics under study compared to the rest of the samples. It is also evident from Figure (4) that the greater the circumference of the figure that represents the sample, the greater the general acceptance of that sample. Hence, we find that the best sample was sorghum var, Rona (1:1), as it contained the largest area of the radar shape, as the perimeter was estimated to be 5.8 compared to the control and brands sample (1:1) The samples that were 4.7 and 4.9 respectively, the sample containing brands (2:1) came in the last order, with an area of 3.8 this increases the permissibility of using sorghum instead of glucose. These results confirmed the distinctive characteristics of the granola slice prepared from a mixture of ingredients with sorghum as a source of sweetening and the texture of the granola ingredients with high sensory acceptance compared to using commercial glucose syrup. These results are consistent with (Byrappa et al., 2011) and (Kulkarni et al., 2018).

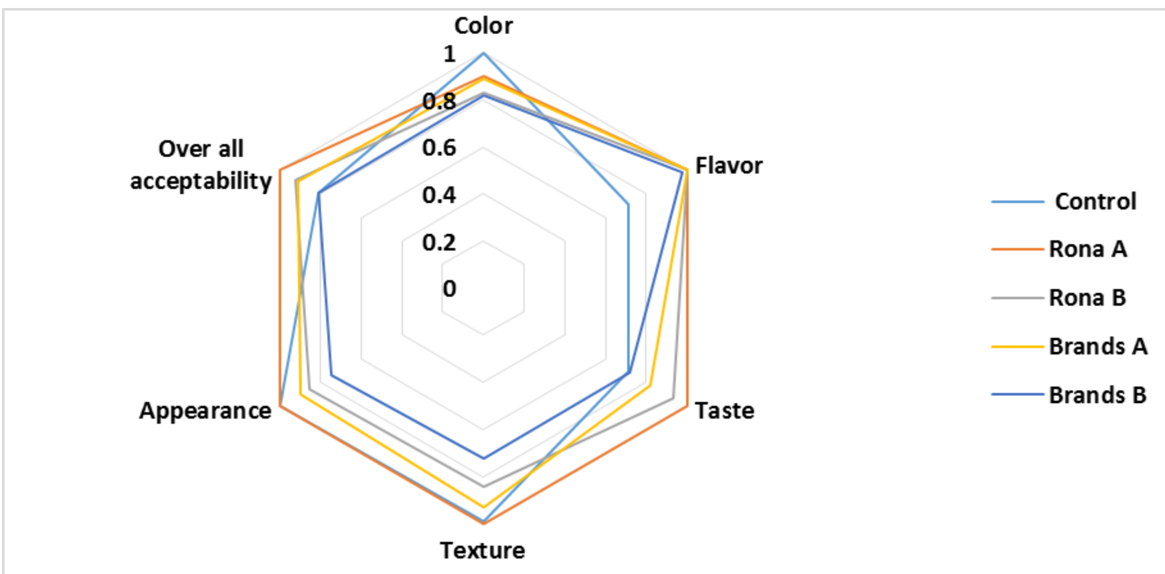


**Figure 5. Sensory evaluation of granola jiggery bars products**

## Nutritional values of granola jiggery bar products

## Chemical Composition, energy, and Phytochemicals of granola jiggery

Data in Table 3 and Figures (6-7) summarize that the effect of two combination ingredients/jiggery ratio who using to preparing granola bars. Statistical data show nutritional quality particularly moisture, protein, fat, Phytochemicals contents and energy contents increased with using sorghum variety Rona whether with combination ingredients/jiggery ratio (1:1) or (2:1) in energy bar compared to control sample. Therefore, our research attempted to develop high calorie energy bar from diverse ingredients rich in nutritional values to maximize the range of phytochemicals through using jiggery of sorghum which rich in high contents of flavonoids compounds and polyphenols as shown in figures 2 and 3 in this respect (Asokan, 2007) investigated that Jaggery has got better nutritional properties compared to sugar hence jaggery is more valued for its nutritional and medicinal value.

Moreover, (Nath et al., 2015) mentioned that according to sorghum varieties, 100 g of jaggery may contain calories 383, sucrose 65-85g, fructose and glucose 10-15g, protein 0.4g, fat 0.1g, and contain traces of vitamins, amino acids, and antioxidants.

**Table 3. Productivity and nutritional values of granola jiggery bar products**

| Sweet Sorghum Var. | Combination ingredients / jiggery | Granola bar | Granola nutritional values | | | | | Energy |
|---|---|---|---|---|---|---|---|---|
| | | | Moisture | Protein | Fat | Ash | Carbohydrate | |
| | | Unit | % | | | | | (Kcal) |
| Control | 1:1 | 20 | 9.20[b] ±0.50 | 5.07[d] ±0.12 | 8.34[c] ±0.20 | 1.65[b] ±0.07 | 75.74[a] ±0.88 | 398.3[bc] ±1.28 |
| Rona A | 1:1 | 34 | 10.54[b] ±0.23 | 6.79[c] ±0.36 | 11.64[b] ±0.25 | 1.97[a] ±0.06 | 69.06[c] ±0.14 | 408.16[b] ±1.38 |
| Rona B | 2:1 | 68 | 12.51[a] ±0.15 | 8.38[a] ±0.05 | 13.95[a] ±0.61 | 2.17[a] ±0.08 | 62.99[e] ±0.59 | 411.36[a] ±3.59 |
| Brands A | 1:1 | 22 | 10.54[b] ±0.23 | 5.39[d]± 0.22 | 10.78[c] ±0.32 | 2.19[a] ±0.22 | 71.10[b] ±0.09 | 402.98[c] ±3.37 |
| Brands B | 2:1 | 44 | 12.55[a] ±0.27 | 7.47[b] ±0.18 | 12.49[b] ±0.26 | 2.30[a] ±0.81 | 65.19[d] ±0.79 | 403.05[b] ±0.11 |

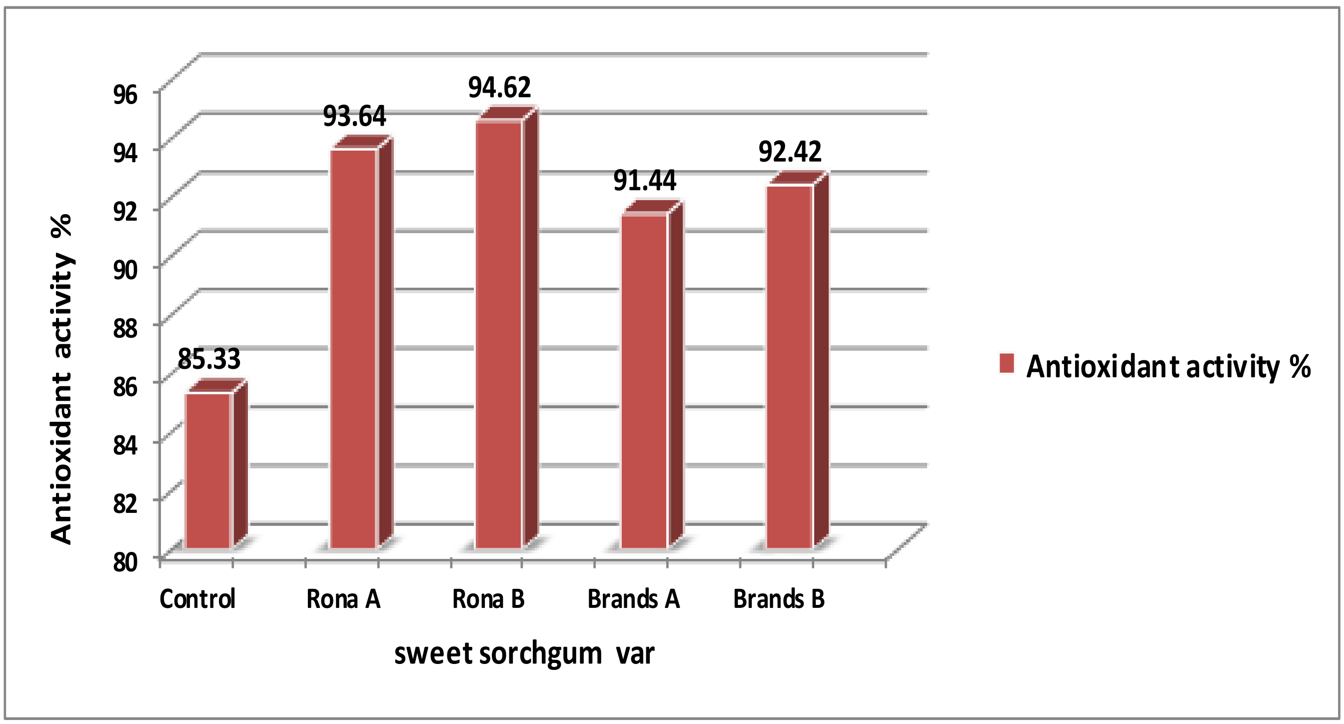


**Figure 6. Antioxidant activity by DPPH (%) of granola jiggery bar products**

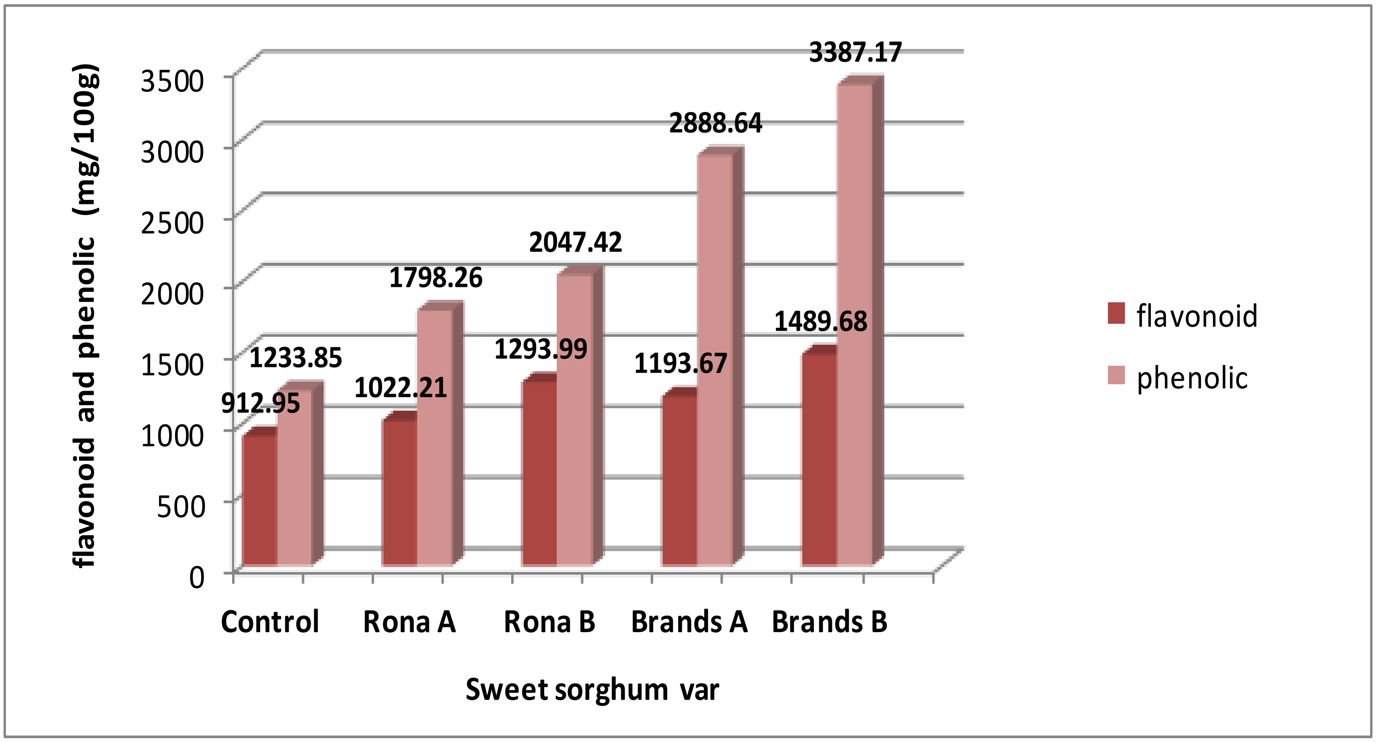


**Figure 7. Total flavonoid and phenolic of granola jiggery bar products**

## Mineral content of granola jiggery

Data in Table (4) was demonstrated that minerals content of (Fe, Ca, Na, Zn, P, Mg, K, Se) for different combinations ingredient/ jiggery of sorghum varieties ratio (mg/100g) on dry weight basis. The minerals amount for granola product were significantly difference among all samples. Statistical data show that all minerals content under study increased with using jiggery of sweet sorghum varieties whether with combination ingredients/jiggery ratio (1:1) or (2:1) in granola bar product compared to control sample. Combination ingredients/ jiggery ratio (2:1) obtained the highest values in all mentioned minerals compared to combination ingredients/ jiggery ratio (1:1) and the check sample. The minerals amount of combination ingredients/ Rona jiggery at ratio (1:1) achieved an increase amounted by 39.13%,28.47%, 27.77%, 33.33%,4.07%, 8.06%, 4.41and 33.33% form Fe, Ca, Na, Zn, P, Mg, K and Se, respectively as a compared with control sample. In these concern (Eggleston et al., 2022) mentioned that sweet sorghum syrups were rich dietary sources of magnesium, potassium, calcium, iron, and contained negligible sodium. These increases of minerals are meaning granola jiggery is the better for supply the human body with the necessary minerals whereas, the child needs about 4.1 iron, while the adult needs about 7 mg/day. Meanwhile, the needs for calcium range from 800 to 1100 mg/day, respectively. As for zinc, the needs for adolescents and adults' range between 4 -9 mg/day, while phosphorus ranges between 405-580 mg/day. On the other hand, we find that the needs for magnesium are 110-350 mg/day, while selenium was 23-45 micrograms / day according to (Joint, 1998). These results are in line with finding of (Nath et al., 2015) mentioned that according to sorghum varieties, 100 gm of jiggery may contain, iron 11mg, or 30% of the RDI, manganese 0.2-0.5mg, or 10-20% of the RDI. Also, it worthily to mention the rise of iron in a granola jiggery par sample, it makes it a great source for treating symptoms of iron deficiency which is consistent with his findings of (Woods, 2003) they noted that the stem of sweet sorghum is used in Nigerian traditional medicine for the treatment of anemia, especially during pregnancy.

**Table 4. Mineral content of granola jiggery 100g/ bar products**

| Sweet Sorghum Var. | Combination ingredients / Jiggery ratio | Mineral content in dry weight | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Fe | Ca | Na | Zn | P | Mg | K | Se |
| | | mg/100g | | | | | | | |
| Control | 1:1 | 1.4[b] ±0.17 | 103.0[d] ±3.46 | 3.9[d] ±0.12 | 0.6[bc] ±0.12 | 106.0[c] ±2.31 | 36.5[c] ±0.81 | 195.0[e] ±2.31 | 0.02[d] ±0.01 |
| Rona A | 1:1 | 2.3[a] ±0.12 | 144.0[b] ±3.46 | 5.4[c] ±0.17 | 0.9[a] ±0.06 | 110.5[bc] ±2.48 | 39.7[bc] ±1.17 | 204.0[d] ±1.16 | 0.03[cd] ±0.00 |
| Rona B | 2:1 | 2.8[a] ±0.23 | 132.3[c] ±1.91 | 6.8[b] ±0.12 | 0.7[ab] ±0.12 | 124.0[a] ±2.89 | 41.6[b] ±0.46 | 231.0[c] ±2.31 | 0.05[b] ±0.02 |
| Brands A | 1:1 | 2.1[a] ±0.36 | 167.0[a] ±4.62 | 4.9[c] ±0.23 | 0.5[c] ±0.06 | 114.0[b]± 1.73 | 39.3[bc] ±0.12 | 241.0[b] ±3.46 | 0.04[bc] ±0.03 |
| Brands B | 2:1 | 25.[a] ±0.12 | 175.0[a] ±4.04 | 7.4[a] ±0.17 | 0.8[ab] ±0.06 | 115.6[b]± 2.54 | 46.7[a] ±1.91 | 250.0[a] ±2.31 | 0.07[a] ±0.01 |

## Cost of granola bar mix with sweet sorghum jiggery formulas

Sweet sorghum (sorghum bicolor Moench) is mainly cultivated for a multi-purpose crop which is a very attractive cash crop to farmers to use in a rural industry. It can use their grain as flour, plant leaves residue as forage, bagasse converts to cellulose production after milling juicy and sweet stalks for use as forage and easy to convert their juice to ethanol or syrup and jiggery production, this is consistent was mentioned by (Hassaballa and Ahmed 2023).

This study was focused on know-how of Jiggery product and use it for preparing functional food like granola bar. We hint that it can use sorghum bagasse as a source of generating energy during the Jiggery cooking process. Data presented in Table 5 summarize the cost estimation of granola jiggery bars for Rona variety with combination ingredients/jiggery ratio (1:1). These expenses did not include those for packaging, shipping, rent, local taxes, commission on sales, etc.

**Table 5. Cost estimation of granola jiggery bars**

| Ingredients | Quantity (per/gm) | Rate (LE. /kg) | Total cost for 1Kg jiggery/1Kg Ingredients |
|---|---|---|---|
| Jiggery 75 °Brix | $M^2$=12 Stripped Stalk =7980 gm = 3.4 L juice | | |
| | $M^2$= 566.6 gm Jiggery | 60 | 34 |
| | $M^2$=75.5-unit granola Unit granola need= 7.5gm Jiggery | Unit granola | 0.45 |
| Jiggery | 1000 Kg | 60 | 60 |
| oats | 400 gm | 50 | 19 |
| raisins | 100 gm | 45 | 4.5 |
| dried dates | 100 gm | 20 | 2 |
| dried apricots | 100 gm | 88 | 8.8 |
| dried plums | 100gm | 60 | 6 |
| coconut | 100gm | 70 | 7 |
| peanuts | 100gm | 75 | 7.5 |
| Total cost | 2000 gm | 57.5 | 115 |

One unit from granola bar= 15 gm
$M^2$: kg nit yield/stripped stick or juice or jiggery for each meter square per feddan sorghum in Egypt.

In additionally, it is a simulation and development of the famous Egyptian jallab industry from cane in Southern of Upper Egypt in the form of granola bars from these ingredients to maximize the range of phytochemicals with high nutritional and healthy value at cheap prices by accordance with developing countries like Egypt which need to meet people's proper nutrition needs at the lowest cost to improving nutritional availability for all categories such as, child schoolgoing, adolescents and all adult.

## 4. Conclusion

Jaggery and jallab are famous industries that done on the concentrating sugar cane juice. It's considered one of the most ancient rural industries in Upper Egypt needs to development, which is simulated by its manufacture from sweet sorghum juice in this work. There are different value-added products are prepared traditionally using jiggery as a substitute of glucose syrup, which is our idea that was dealt with in this work to prepare a granola energy bar. Moreover, it utilizes the nutritional benefits of sugary sorghum juice as a source of syrup, jiggery and natural antioxidants. Therefore, our product helps people to raise their immune health by changing easy go the granola ingredients nutritional value and modifying with to earn it a special organoleptic taste.

**2023)**.

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