Physicochemical and Sensory Assessment of Low-Calorie Millet based Sustainable Chocolate

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Abstract

Nowadays, the consumption demand of consumers tends to be the healthy, nutritious, minimally processed, or functional type of food products. This study uses cocoa powder, cocoa butter, erythritol, finger millet flour, and lemongrass extract (decoction method) to produce nutritional, functional millet-based chocolate. The sensory and physicochemical analysis of developed chocolate was determined. Finger millet appeared to show high calcium content and was also abundant in fibre; erythritol is a low-calorie sweetener with no aftertaste. The results show that inulin, rich in dietary fibre and which promotes intestinal health, is also of benefit to society. We also flavour the chocolate developed by us with lemongrass infusion. This is an accepted danger to consumer prosperity and at times was even more popular than having some sugar in foods during a comparative sensory evaluation. Thus, the millet-based confectionery of chocolate has huge potential as a nutritional food product.

Keywords

Millet chocolate, erythritol, lemongrass extract, inulin, sensory evaluation, functional chocolate.

1. Introduction

Chocolate is a worldwide most desired sweet, with its rich flavor, creamy feel, and recharging properties. However, the majority of classical chocolate types usually contain a high sugar and saturated fat content, which has a lead role in the increased rate of weight gain, diabetes, and other metabolic disorders. The growing informed demand of the irrevocable health consequences of weary amounts of sugar and fats is the reason nutrient-dense and functional chocolates are drastically **(Velciov *et al*., 2021) [53].** Enriched with beneficial components, additives fortified chocolates are a way healthier option than usual ones. In this context, finger millet (*Eleusine coracana*) is a valuable ingredient by offering a rich nutritional profile, containing dietary fibers, essential minerals (like calcium, iron, and magnesium), and bioactive compounds such as phenolics and flavonoids. Mixing finger millet flour with chocolate by increasing its fiber and micronutrient contents will turn it into a healthier choice that is satisfactory to the health-conscious consumer. However, the development of a chocolate-based millet implies a rather definite formulation which besides maintaining the mouthfeel typical of traditional chocolate should give the chocolate its proper texture. One of the main issues is to overcome the natural sandy texture of millet flour while still giving it a smooth and palatable taste **(Somarajan K and Morya, 2022) [6].**

To counter this, erythritol had been set aside as a low-calorie sweetener having a barely noticeable effect on blood sugar, therefore ultimately decreasing the calorie count without taking away the chocolate's sweet taste **(Mazi and Stanhope, 2023) [31].** Furthermore, inulin, a natural prebiotic fiber, is used for both digestion

support and fat accomplishment, hence redefining the texture and creaminess of the chocolate. While this one was the major active substance used in the trial, lemongrass (*Cymbopogon citratus*) extract, which is famous for its antioxidant nature and distinctive scent, was still used by the author. The bioactive compounds from lemongrass are extracted using the decoction method, which not only magnify their flavor but also multiply their functional attributes in the chocolate. These natural bioactive not only provide antioxidant activity but also give possible health benefits by reducing oxidative stress and inflammation **(Tazi *et al.,* 2024) [51].**

The purpose of the study is to research and evaluate millet-based chocolate by investigating its physicochemical, textural, and nutritional properties. The main aim is to formulate a functional chocolate alternative that is healthier and tastes well by combining the advantages of finger millet, erythritol, inulin, and lemongrass extract. The study is about the composition optimization for the sake of keeping the original taste, texture, and sense of candies while its nutritional profile is improved. Moreover, the amount of water, ash, fat, protein, and fiber content in the chocolate will be tested to see if they are at the required standard. The main objective of this study is to devise a balanced formula that will offer valuable insights concerning the prospects of milk-based chocolate as a realistic, safe, and healthy option for modern consumer trends. The research would be customized to satisfy newer consumer preferences **(Joseph *et al.*, 2022) [22].**

2. Material and Method

The raw material used in this study including cocoa powder, cocoa butter, erythritol, inulin, soy lecithin, finger millet flour, and lemongrass extract (decoction method). Finger millet flour and cocoa powder was sourced from a local market, while erythritol, inulin and cocoa butter were purchased from an online marketplace (Amazon). All ingredients were of food-grade quality and stored under appropriate conditions before use.

2.1 Formulation and development of millet-based chocolate

All ingredient were weighed accurately, cocoa butter is melted on pan and then mixing of the dry raw material Cocoa Powder, Erythritol, Inulin, Finger Millet flour. The proper mixing of the dry raw material in melted cocoa butter to get the fine consistency then lemongrass extract (decoction method) **(Sathe and Shah, 2024) [43]** was added for flavour infusion. Further soy lecithin was added as emulsifier for precise texture. **(Hadjikinova, 2023) [15], (Pal *et al.,* 2024) [37].** Finally, the prepared chocolate was poured in moulds and kept in freeze to set. Authentication of chocolate preparation is completed by under the School of Food technology, MIT ADT University. The six formulations prepared for millet-based chocolate is mentioned in Table no. 01.

2.2 The decoction method of lemongrass extract

The fresh lemongrass leaves were dried in hot air oven at 60°C for 5 hrs after proper wash with water. The dry lemongrass leaves grinded in mixer to make fine powder. After that, pluck 40gm of lemongrass powder and mix it with 700ml of distilled water. Distilled water was used to boil lemongrass leaves powder. Decoction method is where ¼ of the water is reduced for 1 to 2 hours. It is very important to avoid excessive heating. The excess water in the extract was removed using heating mantle instrument. After the evaporation process, left it to dry for few 2 to 3 days in room temperature for

natural evaporation. It will produce sticky and reddish lemongrass extract **(Sathe and Shah, 2024) [43].**

Table No. 01 Formulation of millet-based chocolate

INGREDIENTS (%)	T0	T1	T2	T3	T4	T5
Cocoa Powder	30	28	26	24	22	20
Cocoa Butter	27	27	27	27	27	27
Erythritol	30	30	30	30	30	30
Inulin	10	10	10	10	10	10
Lemongrass Extract	2.5	2.5	2.5	2.5	2.5	2.5
Soy lecithin	0.5	0.5	0.5	0.5	0.5	0.5
Finger Millet	0	2	4	6	8	10

3. Evaluation of Chocolate

3.1 Sensory Evaluation

The sensory evaluation was conducted by a panel of 20 members, including faculty from the School of Food Technology.

3.2 Proximate Analysis

The proximate analysis of millet-based chocolate and control sample was done by **AOAC 2000 [4]** and recommended for moisture, ash, fat, protein and carbohydrate by **(Velciov et al., 2021) [53].**

3.2.1 Moisture content

The hot air oven method helped determine moisture content with millet-based chocolate because it stands as a standard technique for food sample water analysis. A formula allowed for computation of water content:

Percent (%) moisture content = (Weight of moisture removed x 100) / (Weight of sample

$$= [(W2 - W3) \times 100] / (W2 - W1)$$

Where, **W1** is the weight of the empty petri plate, **W2** is the weight of the petri plate with the sample before drying, and **W3** is the weight after drying. This analytical method supports shelf-life determination and stability tests for millet-based chocolate by measuring its moisture content so that extreme moisture levels maintain product texture together with microbial growth and product quality.

3.2.2 Ash content

A muffle furnace combustion procedure enabled the evaluation of ash components in millet-based chocolate. The ash material measure using the following calculation formula:

Percent (%) ash content = (Ash content x 100) / Weight of sample

$= [(W4 – W5) \times 100] / W4$

The weight measurement process involves weighing three substances which start with **W4** equal to **(W2 - W1)** while ending at **W5** representing **(W2 - W3)**. Millet-based chocolate contains total inorganic minerals that determine its nutritional value and functional properties and are recorded as ash content.

3.2.3   Fat Content

The Soxhlet method worked in crude fat digestion in millet-based chocolate as the standard method for general fat analysis. The fat was calculated in per cent by a formula:

%Crude Fat = [Weight of fat / Weight of sample]×100

Where, **Weight of extracted fat** = (Final weight of flask – Empty flask weight).

The fat content in millet-based chocolate is important in determining its texture, mouthfeel, and overall sensory properties, ensuring a smooth and rich consistency.

3.2.4   Protein content

Millet-based chocolate protein content was determined by the micro-Kjeldahl method, The formula for protein content:

% N = [*(sample−blank) × N of acid* ×0.014 ×D.F.] / [*Aliquot taken × wt. of sample*] ×100

Where, **N** is Normality of HCl and **D.F.** is dilution factor

Protein (%) = % N × 6.25

3.2.5   Crude Fibre

Crude Fibre was determined by using **AOAC 2005** method followed by **Igbabul et al., (2014) [17]** with the help of hot air oven dried sample take in crucible and add

1.25% sulphuric acid and NaOH solution in automatic fibre estimation machine. At 525 °C for 4-5 hrs residue is placed in muffle furnace. The calculation for crude fibre,

Crude fibre % by wt = W1-W2 / W × 100

Where, W1 is wt of sample before ashing, W2 is wt of sample after ashing and W is wt of sample taken.

3.2.6   Total Carbohydrate

The carbohydrate was estimated by subtracting from 100 with the addition of moisture, ash, Fat content, Protein content, Crude Fibre. The determined value is known as total carbohydrate (%),

Carbohydrate (%) = 100- (Moisture + Ash + Fat + Protein + Fibre)

3.2.7   Energy value

The energy value of the samples was determined by multiplying the protein and carbohydrate by 4 and fat content by 9, followed by **Ali et al. (2021) [2].**

Energy Value = (Protein × 4) + (Total carbohydrate × 4) + (Fat × 9)

3.3   Micronutrients analysis

3.3.1   Minerals

Minerals like calcium, Potassium and Iron was analyzed by Inductively coupled plasma optical emission spectroscopy **(ICP-OES)** method and followed by **(Shamilowa, 2019) [47].**

3.3.2   Vitamins

Vitamin C and Vitamin E was determined by **IS 5838: 1970 method** by **(Pathak et al., 2018) [39].**

3.4   Physico-chemical analysis

3.4.1 Sugar Content

The **Lane-Eynon titration** procedure is a classical method used to determine

reducing sugars in a quantitative way based on their ability to reduce copper (II) in a blue-coloured solution known as Fehling's solution to red/orange insoluble copper (I) oxide (Cu_2O) in an alkaline medium. The reaction is not a neutralization but a redox reaction, in which the reducing sugar, such as glucose or fructose gives up some of its electrons and is oxidized, while Cu^{2+} is reduced to Cu_2O. Fehling's solution is made up of a solution A, which is copper sulfate and a solution B, which is alkaline tartrate, the beer reaction medium. During titration, the sample is the heated with Fehling's solution and as the reaction proceeds, the blue color disappears. The end-point of the titration is reached when the blue color disappears completely, often with the assistance of the internal indicator methylene blue followed by **(Buiarelli *et al.,* 2016) [10].**

Reducing sugar (g/100 g) = (Glucose equivalent from titration × dilution factor × volume) ÷ sample weight × 100.

3.4.2 Antioxidant activity

The DPPH method is used for analyses of antioxidant activity using the 0.1mM DPPH solution in methanol followed by **Jaćimović *et al.,* 2022 [20].** The antioxidant activity calculated in percentage formula:

$$\% \text{ DPPH} = \frac{\text{Abs Control} - \text{Abs Sample}}{\text{Abs Control}} \times 100$$

3.4.3 Total Phenolic Content

Utilizing modified techniques based on **Wahyono *et al.,* (2020) [56]**, The Total Phenolic Content (TPC) of the sample was measured. Using a gallic acid standard calibration curve, TPC values were calculated into mg GAE/100 grams sample.

3.4.4 Phytic acid Content

The amount of phytic acid in samples was measured according to the method described by **Ovuakporie *et al.,* (2019) [35].** The phytic acid content was calculated by the following formula:

$$\textbf{Phytic acid } \% = \frac{\text{Titre Value} \times 0.00195 \times 1.19}{2} \times 100$$

3.4.5 Flavonoid content

The flavonoid content of the sample using the aluminium chloride colorimetric method recommended by **Indiarto *et al.,* (2024) [19]**, widely used to measure flavonoids in plant foods. A standard calibration curve was made using quercetin and flavonoid content expressed in mg of quercetin equivalent (mg QE) per 100 g sample. This method also allows one to estimate the antioxidant capacity of the sample since flavonoids confer health benefits because of their free radical-scavenging and anti-inflammatory capabilities.

3.4.6 Free Fatty Acid

The official method is **AOAC 940.28** titration method recommended by **Divya *et al.,* (2017) [12].** The volume of KOH consumed (the titre value) was recorded and another formula was used to calculate the acid value:

$$\textbf{Acid Value} = \frac{\text{Titre value} \times \text{Normality of KOH} \times 56.1}{\text{Weight of sample(g)}}$$

3.5 Techno-Functional properties analysis

3.5.1 Water Activity (aW)

The water activity of millet-based chocolate sample of 1gm was determined by water activity meter recommended by **(Arepally *et al.,* 2023) [5].**

3.5.2 Viscosity

Determine the millet-based chocolate sample (T0 and T4) viscosity with a Brookfield Viscometer according to (**Thuy et al., 2020) [52].** Having uniform or consistent viscosity is of greatest importance in ensuring the mouthfeel, moldability, and coating properties of chocolate products.

3.5.3 Oil holding capacity

The oil holding capacity (OHC) of the chocolate samples was determined as a measure of their capacity to absorb and hold oil, and hence contribute to maintaining texture, mouthfeel, and flavour retention in chocolate recommended by **Delgado-Ospina et al.,2021 [11].** OHC was determined with the formula:

Oil Holding Capacity (g/g)=
Weight of sample / Weight of oil retained

3.5.4 Water holding capacity

The water holding capacity (WHC) of millet-based chocolate to assess its ability to retain water that affects texture along with moisture preservation and storage duration recommended by **Delgado-Ospina et al.,2021 [11].**

WHC (g/g)=
Weight of water retained by the sample/ Weight of dry sample

3.6 Statistical analysis

Each of the tests was done in triplicates, and the results have been provided as mean values with their respective standard deviations (mean ± SD). One-Way Analysis of Variance (ANOVA) was carried out to check for significant differences between the sample group. This is appropriate because only one factor (independent variable) was manipulated at a time in each experiment. A statistician did his analysis by using SPSS software, version 23, created by IBM Corporation, Chicago, USA,

followed by performing Tukey's post hoc test after ANOVA to pinpoint exactly which sample groups had significant differences between each other recommended by **(Wong et al., 2024) [52].** Significance was given to any result with $p < 0.05$, which means there is less than 5% probability that the differences occurred by chance.

4. Result and Discussion

4.1 Sensory Evaluation

T1 through T5 millet-based chocolates underwent sensory evaluation compared to the control (T0) which detected substantial differences from ingredient modifications. Among all formulations T4 which featured 8% finger millet and 22% cocoa powder and 30% erythritol and 10% inulin and 2.5% lemongrass extract and maintained the standard amounts of cocoa butter (27%) and soy lecithin (0.5%) achieved the highest overall acceptability score (8.10) which closely approached the control (8.20). The research proves that combining finger millet with functional ingredients results in enhanced sensory characteristics which do not reduce product acceptability. The taste and flavor scores as well as texture ratings improved across the T1 to T4 sequence when finger millet content increased and reached an optimal point before declining in T5 (10% millet). The findings of **Dhanavath Srinu et al., (2021) [47]** showed that the 1.5% spice chocolate formulations achieved an average acceptability score of 7.90 while the millet-based T4 formulation scored an 8.10. This shows that millet-based formulations in terms of sensory properties provided better outcomes than chemically flavoured spices. It shows not only the positives of functional chocolate develop with millet, but also the need to optimize functional ingredients ratios in order to produce appealing sensorial properties**.**

Graph No. 01 Sensory evaluation of millet-based chocolate

Sensory Evaluation of Millet-based Chocolate
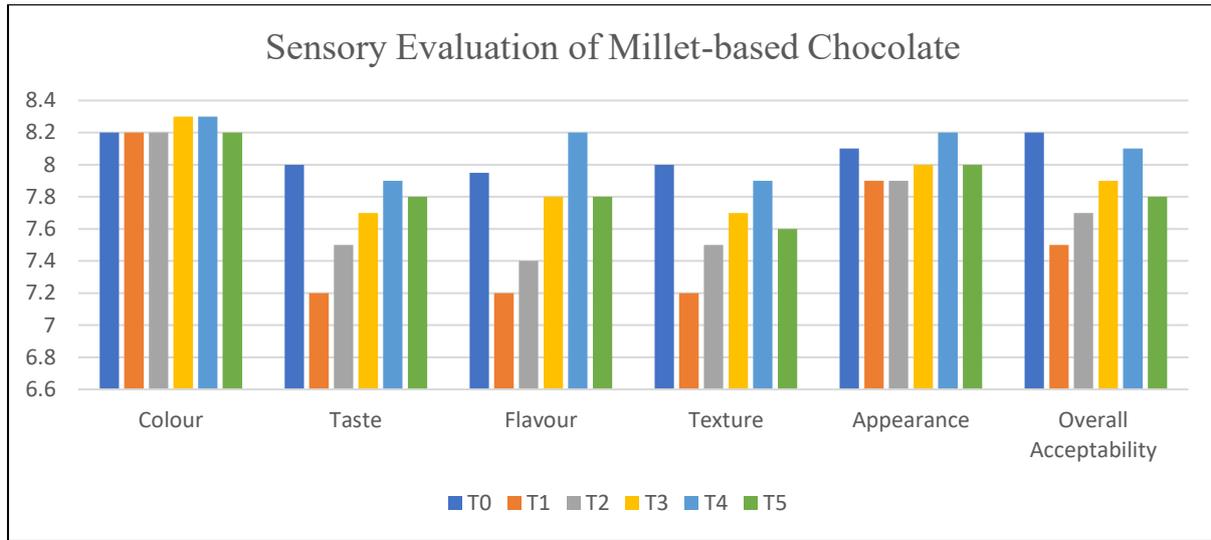
Table No. 02 Sensory evaluation of control and selected chocolate sample

Sample	Colour	Taste	Flavour	Texture	Appearance	Overall Acceptability
T0	8.20	8.00	7.95	8.00	8.10	8.20
T1	8.20	7.20	7.20	7.20	7.90	7.50
T2	8.20	7.50	7.40	7.50	7.90	7.70
T3	8.30	7.70	7.80	7.70	8.00	7.90
T4	8.30	7.90	8.20	7.90	8.20	8.10
T5	8.20	7.80	7.80	7.60	8.00	7.90

4.2 Proximate Analysis
Table No. 03 Proximate analysis of control and selected chocolate sample

Parameter	T0 (Mean ± SD)	T4 (Mean ± SD)
Moisture Content (%)	3.0 ± 0.02^b	3.21 ± 0.01^a
Ash Content (%)	1.7 ± 0.02^b	1.8 ± 0.02^a
Fat Content (%)	26.5 ± 0.10^a	25.5 ± 0.10^b
Protein Content (%)	6.5 ± 0.06^b	6.8 ± 0.05^a
Crude Fibre (%)	2.1 ± 0.04^b	2.7 ± 0.03^a
Carbohydrate (%)	60.2 ± 0.13^a	59.9 ± 0.11^b
Energy (Kcal/100g)	505.3 ± 1.00^a	496.30 ± 1.03^b

Mean values ±standard deviations from the triplicate analysis (n =3). a, b, c Different superscript letters in the same column indicate a significant difference (P < 0.05) detected between the samples.

4.2.1 Moisture Content

Ilori *et al.,* (2021) [18] stated that typically moisture levels in a chocolate product fall between 5% and 7%. This moisture level is desirable for long-term product stability against microbial growth. The current study values for moisture content for the T0 or control sample showed to be 3.0 ± 0.02^b %, with the T4 or sample selected for study at 3.21 ± 0.01^a %. Thus, the T4 sample had a higher moisture percentage than the T0 sample primarily due to finger millet

possessing higher water holding and water retention characteristics than regular chocolate ingredients. **Onifade** *et al.,* **(2022) [34]** very closely matched this trend with reported moisture content for retailed cocoa powder samples in Nigeria, ranging from 4.38% to 19.82%, with many of the samples exceeding the maximum limit of 5% recommended for cocoa powders. The authors attributed this to the hygroscopic property of cocoa powders and further highlighted the ingredient properties and packaging/storage conditions would significantly influence the final moisture content. The moisture values noted in this study are relatively low when comparing to the standard, this suggests that the millet-based chocolate retains, in general, more moisture than the control but still not exceeding microbiological safe limits. This indicates that the addition of millet makes no difference in the moisture-dependent stability or shelf-life of the chocolate anyway. It can still be reasonably concluded that chocolate can in fact be made with millet without compromising the stability of the product whatsoever.

4.2.2 Ash Content

The amount of ash in chocolate matches its mineral elements according to the available information. The measured ash content of T0 reached 1.7 ± 0.02^b % which was lower than sample T4 that had an ash content of 1.8 ± 0.02^a %. A higher amount of finger millet flour results in increased ash since finger millet flour contains abundant minerals including calcium, iron, phosphorus and magnesium. The research by **Ndife Joel** *et al.,* **(2013) [31]** discovered that whole grain and millet ingredients produce rapid increases in food product mineral content. **Ilori et al., (2021) [18]** documented that Nigerian cocoa hybrid chocolates show ash content ranges from 2.24% to 2.65% which indicates substantial

mineral increase as a result of different formulations. The increased ash content demonstrates that finger millet chocolates function as enhanced mineral supplements to traditional chocolates.

4.2.3 Fat Content

The fat content of chocolate changes based on the kind of ingredient used like finger millet milk or flour, as per **Kanchana & Parameshwari (2021) [22].** Research on finger millet milk chocolates put fat content to 7.13 g/100 g which is less than standard recipes on chocolates because high-fat ingredients were replaced with millet ingredients. In the present study, fat content of T0 [(control sample) was 26.5 ± 0.10^a %; T4 (sample selected) had very little fat content decrease to 25.5 ± 0.10^b % which is a reduction of 1%]. This can be attributed to the fact that cocoa powder was partially replaced by finger millet flour which is lesser in fat content as compared to cocoa-based ones. **Wadikar** *et al.* **(2007) [50]** also documented such findings wherein the application of the millet-based formulation led to a moderate lowering of the fat content without compromising product stability. Though fat content is reduced slightly, the cocoa butter content is ensured at 27%; thus, T4 is never deprived of the desirable texture, melting properties, and snap attributes typical of high-grade chocolate. That means the chocolate made on millet is thus nutritionally enriched alternatives, to be fairly less fat and ideal for health-oriented consumers, while preserving sensory acceptability.

4.2.4 Protein Content

Ali *et al.,* **(2021) [3]** state that the content of protein in low-calorie chocolates varies from 4.59% to 5.15%, depending upon the various formulations involving fiber isolates and sweeteners. Theoretically, in this case, the control sample, T0, had a protein content of 6.5 ± 0.06^b %, whereas

the selected sample, T4, had 6.8 ± 0.05^a %, a total increase of 0.97%. This increase results from the addition of the finger millet flour, which has an inherent protein level of 6-8%, thus improving the nutritive makeup of the chocolate formulation. By similar measure, **Onifade et al., (2022) [34]** found that the protein level was between 2.1% and 4.55% for the commercial cocoa powder samples, with such values respectively lower than that of the T4 chocolate samples developed in this work. Such as set of comparisons gives clear evidence for including millet flour, where the enriched protein profile was higher than the cocoa-based formulations. Furthermore, there is also the advantage of protein enrichment of the T4 sample in functional properties such as emulsification, foamability, and nutrition, making it more suited for health-conscious individuals. Accordingly, finger millet-based chocolates could well be regarded as protein-fortified functional foods associated with enhanced health benefits over regular chocolate products.

4.2.5   Crude Fibre

To determine the effects of finger millet flour supplementation on crude fiber contents, T0 and T4 were subjected to analysis. Finger millet with very high inherent dietary fiber content contributed 2.7 ± 0.03^a % of crude fiber in T4, which was 0.6 % higher than that of 2.1 ± 0.04^b % for T0. According to **Igbabul et al. (2014) [17]**, millet-based flours considerably raised the fiber content of food products as in this increase. Crude fiber thus is responsible for glycaemic impact, satiety, and intestinal health, thus making finger millet chocolate superior to traditional formulations. In other words, a consumer who desires consuming functional chocolate with a higher dietary fiber level can take advantage of the increases in fiber content seen in T4.

4.2.6 Carbohydrate

Finger millet contains a lot more carbohydrates than the mentioned chocolates according to **Kanchana & Parameswari (2021) [22]**. Such is the case that the millet is known for its high complex carbohydrates and fiber content, therefore making it likely to have some effect on the level of carbohydrates. As for their findings, they measured the level of carbohydrates at 65.38 g/100 g with the finger millet chocolates added and then in control chocolates it was at 61.6 g/100 g. The authors supported this fact stating that it shows that millet contributes to the increase in the carbohydrate level. The carbohydrates at T0 level were shown to be 60.2 ± 0.13^a % but at T4 the level was 59.9 ± 0.11^b %, indicating 0.3 % decrement. The base fact for this decrement is that the substitutes in these chocolates were used with finger millet flour, which had lower carbohydrate content than that in standard chocolate. **Ndife Joel et al. (2013) [31]** in their study have also drawn conclusions with view of replacement with whole grain high in fiber components in chocolate production, resulting in decreased amount of total carbohydrates, but instead they've improved on functional attribute on the improved product. Chocolates at T4 level are acceptable in spite of the fact that their carbohydrate amounts have been reduced because artificial chocolate foods are known to be allowed to contain carbohydrates since they provide energy, but in the case at hand, the energy is coupled with the nutrients from the millet.

4.2.7   Energy

Ali et al. (2021) [2] claim that the energy value of light chocolate may vary depending on the composition of the ingredients, mainly by replacing traditional high-calorie components with structural

analogs, i.e. fiber isolates and sugar alcohols. According to the results of the study, the energy value of dark chocolate varied from 508.33 to 544.89 kcal per 100 g of the product depending on the formulation of the product. The study presented in this work evaluated the energy value of the control product (T0) is 505.3 ± 1.00^a kcal and the selected sample (T4) is 496.3 ± 1.03^b kcal, which is reduced by 9.0 kcal. The reduction in energy value by almost 9 kcal can be explained by the replacement of cocoa powder with finger millet flour and the fact that erythritol (a zero-calorie sweetener) – like other sugar substitutes – does not bring extra calories as opposed to traditional sugars. **Joel et al., (2013) [21]** reported that a single serving of traditional chocolate has a caloric content of approximately 498.39 kilocalories. Therefore, T0's ($505.3 \pm 1.00a$ kcal) was marginally greater than and T4's ($496.30 \pm 1.03b$ kcal) was marginally lower than the value reported above. Using erythritol along with other alternative ingredients and so on, helped to have great taste and made the energy content of the food really low experiences without compromising overall acceptability in a taste and nutrition aspects these are lengthy findings. A small energy differences between the control & experimental samples may suggest an effective low calorie millet chocolate that can provide an equivalent taste & nutritional profile with a potential decrease in calorie load.

4.3 Micronutrients analysis

Table No. 04 Micronutrients analysis of control and selected chocolate sample

Parameter	T0 (Mean ± SD)	T4 (Mean ± SD)
Calcium (mg/100g)	36.40 ± 0.80^b	52.10 ± 1.00^a
Potassium (mg/100g)	410.30 ± 2.10^a	326.80 ± 2.30^b
Iron (mg/100g)	3.75 ± 0.05^a	3.29 ± 0.06^b
Vitamin C (mg/100g)	0.80 ± 0.03^b	1.50 ± 0.04^a

Mean values ±standard deviations from the triplicate analysis (n =3). a, b, c Different superscript letters in the same column indicate a significant difference ($P < 0.05$) detected between the samples.

4.3.1 Minerals

The mineral content of the chocolate samples was established by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES), a sensitive technique for multi-element analysis in food matrices. Presently, in the current study, the T4 sample (millet chocolate) showed an increase of calcium 52.10 ± 1.00^a mg compared to T0 (control sample) which contained 36.40 ± 0.80^b mg. This indicates the contribution of finger millet, a cereal with high density calcium. This increase will support the development of fortified chocolates that can improve bone health and daily mineral nutrition. The potassium level (mg) dropped in T4 (326.80 ± 2.30^b mg) in relationship to T0 (410.30 ± 2.10^a mg), and likely the result of cocoa decline, which is a rich source of potassium. The iron level also saw a little drop in T4 (3.29 ± 0.06^b mg) compared to T0 (3.75 ± 0.05^a mg), also the result of ingredients replacing each other, although finger millet contains iron. These results are similar to those reported by **Oliveria et al., (2021)** that calcium, potassium, and iron may be the chief minerals found in chocolate; however, they are dependent upon the type

of ingredients and processing. Since T4 was essentially the highest in calcium, the other essential minerals were probably controlled. This is in line with the purpose of creating an even more functional and nutritionally complete chocolate product.

4.3.2 Vitamin C

The Vitamin analysis revealed that the T4 chocolate had higher Vitamin C amounts in comparison to control T0. Vitamin C was reported to increase from 0.80 ± 0.03^b mg in T0 to 1.50 ± 0.04^a mg in T4. This enhancement of the Vitamin C content is associated with the upscaled nutritional value of the T4 formulation probably as a result of increased bioactive and antioxidant contents; the same trend was also witnessed in rising phenolic and flavonoid contents. Vitamin C is a strong antioxidant that is soluble in water and provides protection to chocolate against oxidative degradation and can be helpful in maintaining immune health. Interestingly, (**Pathak *et al*., 2018) [39]** showed comparable results, as they recorded vitamin C content of 5.88 mg/100g in the fortified sample of biscuit biscuits using papaya pulp powder, where the fortified sample was significantly higher than the control. Moreover, both their study and the present one used the same estimation method IS:5838:1970 for Vitamin C analysis, allowing the results to be comparable despite the difference in the product matrices (biscuits vs. chocolate). This similar trend in Vitamin C enhancement in both studies highlights that including bioactive-rich ingredients such as papaya or lemongrass extract can strengthen the antioxidant and nutritional profiles of food products. Therefore, the improved processing and formulation practised in T4 retained vitamins effectively, thereby finding T4 nutritionally and functionally superior to the control.

4.4 Physico-chemical analysis

Table no. 05 Physico-chemical analysis of control and selected chocolate sample

Parameter	T0 (Mean ± SD)	T4 (Mean ± SD)
Antioxidant activity (%)	58.20 ± 0.80^b	62.70 ± 0.90^a
Sugar content (%)	36.20 ± 0.20^a	34.50 ± 0.17^b
Total Phenolic Content (mg GAE/g)	60.20 ± 1.10^b	68.70 ± 1.20^a
Flavonoid Content (mg QE/g)	22.60 ± 0.40^b	27.40 ± 0.50^a
Phytic Acid Content (mg/g)	0.80 ± 0.02^a	0.72 ± 0.01^b
Free Fatty Acid (mg/g)	0.45 ± 0.02^a	0.41 ± 0.01^b

Mean values ±standard deviations from the triplicate analysis (n =3). a, b, c Different superscript letters in the same column indicate a significant difference (P < 0.05) detected between the samples.

4.4.1 Antioxidant activity

A study conducted by **Jaćimović *et al*., 2022 [20]** revealed that antioxidant action in dark chocolate increases with increasing cocoa content because it contains large amounts of polyphenols and flavonoids, the main bioactive compounds responsible for scavenging activity. In our experimental study, we set out to determine the antioxidant activity in the control sample T0 and in the selected millet-based chocolate sample T4. The antioxidant activity for T0 was 58.20 ± 0.80^b % versus 62.70 ± 0.90^a % for T4, which clearly implies that lemongrass extract and finger millet can increase the antioxidant activity, as observed. The DPPH assay, which agrees with the one done by **Jaćimović *et al*., 2022 [20]**, whose DPPH, FRAP, and TAC procedures for the determination of antioxidant activities were all assessed in

dark chocolates, provided those values. All these extractions found an agreement with our findings that more bioactive compounds present in the system with more cocoa content will manifest greater antioxidant capacity. The overall results for the present study, though with a millet and herb enrichment were along similar lines, point toward the inclusion of these natural extracts positively impacting antioxidant activity in the selected chocolate formulations.

4.4.2 Sugar content

Both control sample (T0) and T4 (chocolate sample made from millet) were analyzed for sugar content using Lane-Eynon titration, one of the classical analytical methods under redox or oxidation/reduction analysis. It includes thiosulfate reduction of Cu2+ in two clear solutions labelled Fehling's solution. The underlying principle of this method is that reducing sugar like glucose and fructose reduces copper (II) ions (Cu2+) in Fehling's solutions to purple precipitates of copper (I) oxide (Cu2O). Loss of blue color (Cu2+) was put as an end point used with methylene blue as the internal indicator. In this study, chocolate sample T0 had a sugar content value of 36.20 ± 0.20^a % while T4 had a slightly lower figure of 34.50 ± 0.17^b % (-1.7%). This is a decrease likely to occur because part of the sugar is replaced by erythritol, which is a non-reducing sugar alcohol not partaking in redox reactions and cannot be detected by Lane-Eynon method. In addition to this, the finger millet flour added, which has a high content of dietary fiber, might have increased crude fiber levels, thereby reducing free sugars. This is in line with the results obtained by **Sewwandi *et al*., (2020) [45]**, who quantified the sugar content in marketed fruit nectars using the same titration method and reported sugars from 9.17 to 18.38 g/100 mL in the indicated products, thus validating the accuracy of the technique employed.

4.4.3 Total Phenolic content

The total phenolic content (TPC) was measured according to an adjusted Folin-Ciocalteu method by **Wahyono et al., (2020) [56]**, which stated that a phenolic will react with the reagent, resulting in a blue complex at 765 nm. The TPC value for T0 (control) sample was 60.20 ± 1.10^b mg GAE/g, whereas T4 sample (millet-based chocolate) contained a much higher amount of 68.70 ± 1.20^a mg GAE/g. Increase in TPC in T4 has been attributed to the added lemongrass decoction high in natural phenolics as well as finger millet flour, contributing to the total amount of different polyphenols in this sample. Antioxidant phenolic compounds are mostly responsible for a significant experience and influence on the functional properties of foods. Consonant trends were observed by **Indiarto et al., (2024) [19]** where they stated that improvement in total phenolics was reflected by test samples containing phenolic-rich encapsulated clove bud extract in chocolate drinks, indicating the synergistic ability of natural botanicals to enhance capacity. As a result, T4 with a higher phenolic content would thus carry brighter possibilities for healthy functional chocolate products.

4.4.4 Flavonoid content

Among all quantitative assessment methods for flavonoids in foods, the Aluminium chloride colorimetric method stands out as the most standard procedure. The total flavonoid content (TFC) measurement of chocolate samples happened through the aluminium chloride colorimetric approach. The sample extract which utilized 80% methanol as solution underwent treatment with aluminium

chloride solution (2%) and potassium acetate and ethanol and distilled water. The solution needed to sit undisturbed at room temperature for a duration of 30–60 minutes. UV-Visible spectrophotometer was used to measure the absorbance at 415 nm. Researchers used a standard graph of quercetin to determine the values which then appeared as mg of quercetin equivalent (QE) per gram of sample. The flavonoid content analysis showed T4 chocolate millet reached 27.40 ± 0.50^a mg QE/g while T0 control reached only 22.60 ± 0.40^b mg QE/g. Research indicates that the combination of finger millet flour with high natural flavonoids and lemongrass extract with high polyphenolic and antioxidant content explains this increase. The conclusions from **Indiarto et al., (2024) [19]** agree that adding phenolic-rich plant extracts like encapsulated clove bud to chocolate drinks significantly strengthens flavonoid content. The elevated levels of flavonoids in T4 demonstrate enhanced antioxidant properties which makes the millet-based chocolate formulation an excellent health-promoting functional food.

4.4.5 Phytic acid content

The content of phytic acid was determined in the chocolate samples using the procedure outlined in **Ovuakporie et al., (2019) [35]**, which involved leaving 0.2 g of sample overnight in 100 ml of HCl (strong hydrochloric acid), filtering it and then titrating against a standard solution of iron chloride by use of an ammonium thiocyanate indicator. The analysis revealed that sample T0 (control sample) had a relatively high amount of phytic acid at 0.80 ± 0.02^a mg/g, compared with the one with the least amount which is sample T4, with 0.72 ± 0.01^b mg/g of phytic acid. This reduction might be attributed to processing conditions and reformulation that may facilitate phytic acid destabilization. Since

it is known that phytic acid inhibits mineral uptake through insoluble complexation, the lower level found in sample T4 is evidence of nutritional enhancement and likelihood of improved mineral bioavailability, respectively, promoting health and functional quality of the processed chocolate.

4.4.6 Free Fatty acid

In the present study, Free Fatty Acid (FFA) was found to be 0.45 ± 0.02^a mg/g in the control sample (T0) which is a collective lesser than that in our choice of millet-based chocolate (T4) at 0.41 ± 0.01^b mg/g perhaps showing a very minor improvement in oxidative stability. This improvement is likely attributed to the substitution of anti-oxidants and anti-microbial properties thought to be in the lemongrass extract and the partial substitution of fat-filled cocoa solids with fiber filled finger millet flour which may lower total space for lipid hydrolysis. Compared to the study by **Divya et al., (2017) [12]**, whose FFA values ranged from 0.131 % to 0.43%, the present study was examined with chocolate variants composed of coconut oil, coconut cream, and coconut milk. Accordingly, T0 and T4 samples in the present study fall well within this range with optimal FFA values reported by **Divya et al., (2017) [12].** As per result reported, the coconut oil had the lowest FFA at 0.13 % while the highest FFA was from the coconut milk at 0.43% which solidifies ingredient composition as a contributing factor to oil oxidative stability. Therefore, it can also be said that millet- and lemongrass-based chocolate showing FFA values that are acceptable is also a remarkable demonstration of freshness and stability in the current study.

4.5 Techno-Functional properties analysis

Table no. 06 Functional properties analysis of control and selected chocolate sample

Parameter	T0 (Mean ± SD)	T4 (Mean ± SD)
Water Activity (aW)	0.44 ± 0.01^a	0.39 ± 0.01^b
Viscosity (cP)	4800 ± 80^b	5900 ± 100^a
Oil Holding Capacity (g/g)	1.82 ± 0.04^b	2.42 ± 0.05^a
Water Holding Capacity (g/g)	4.50 ± 0.10^b	5.30 ± 0.15^a

Mean values ±standard deviations from the triplicate analysis (n =3). a, b, c Different superscript letters in the same column indicate a significant difference ($P < 0.05$) detected between the samples.

4.5.1 Water activity

water activity measurement of the controlled (T0) and selected fortified formulation (T4) so that a microbial stability because of storage capacity of the product being tested. For control, the water activity was 0.44 ± 0.01^a, much higher than that of the chocolate millet formulation (T4) of 0.39 ± 0.01^b. The decrease in water activity of T4 can be attributed to the inclusion of functional agents, such as inulin and erythritol, which are noted for retaining free water; and controlled processing techniques such as decoction and optimized tempering, which ensure reduced moisture availability. Low water activity is very important for chocolate and chocolate products because they significantly enhance shelf-life, inhibit microbial growth, and maintain textural integrity. Accordingly, any food product having aw lower than 0.6 is normally considered microbiologically stable since, at such low aw levels, the growth and reproduction of nearly all spoilage microorganisms and molds are inhibited. Therefore, T4 having an aw value of 0.39 shows it is a stable product that can have a long shelf life with a very low microbial risk. This correlates well with the findings of **Vishnupriya et al., (2021) [54]**, which observed lower water activity with storage time in vacuum-dried and tray-dried chocolate samples, showing microbial and oxidative stabilization during storage. Therefore, water activity decrease in T4 is more favourable for physicochemical stability, hence suitable for storage for long periods without quality.

4.5.2 Viscosity

The properties or viscosity of chocolate made from millet was analyzed using Brookfield Viscometer with spindles as described by **Thuy et al., (2020) [51]**. The viscosity of the control sample (T0) was 4800 + 80 cP and the optimized millet chocolate sample (T4) had a viscosity of 5900 + 100 cP, thus implying a greater viscosity for the T4 sample. This finding shows the attributes of the millet flour, erythritol, inulin and lemongrass extract likely created better structural matrix and improved water binding ability for the chocolate. Identical findings were observed in the findings of **Thuy et al., (2020) [52]** with cocoa powder mixtures with emulsifiers such as polysorbate and sorbitan monostearate at 0.55−0.70%, where viscosity increased compared to were the emulsifiers were not added (4338 cP). They additionally stated that blending with increasing amount of emulsifier and cocoa butter thickness with more stable emulsions occurred. The sample T4's increased viscosity may have resulted in a better ability to mold and coat, with a smooth and creamy mouthfeel, similar to the processing benefit seen in many emulsifier-stabilized models. Collectively, these findings emphasize the importance of the formulation as it relates to contributing the rheological and functional properties of chocolate-type products.

4.5.3 Oil holding capacity

This confirms that the oil retention capability of the tested chocolate samples has indicated that sample T4 displays a notable divergence from the control T0 since it recorded a measured OHC value of 2.42 ± 0.05^a g/g compared to 1.82 ± 0.04^b g/g in T0, respectively, thereby depicting the ability of T4 in oil absorption and retention. This enhanced oil-holding capacity T4 would thus contribute improved mouthfeel, texture, and flavor retention, three attributes extremely prized in chocolate confectioneries. The enhanced oil-holding capacity might be due to the greater phenolic and flavonoid content of the T4 sample for the more tightly bound matrix provide greater oil-retaining ability. Moreover, the lowest noted water activity level in T4 could help stabilize the oil phase with lower oil migration. Similarly, **Ozolina et al., (2024) [36]** found that faba bean and lentil flours had a greater oil-holding capacity due to protein denaturation and process-induced matrix modification that attest to the concept of functional ingredient modification as a factor in enhancing fat retention in formulated foods. So, it may be stated that T4 thus not only signifies functional enrichment but also ranking sensorially higher than the control in regard to OHC.

4.5.4 Water holding capacity

The WHC of the millet-based chocolate (T4) showed significant WHC higher than the control sample (T0) by 0.80 ± 0.10 g/g and the difference is statistically significant to have a lower WHC value in the control sample. The enhanced moisture retention of the T4 formulation compared the control due to increased fiber and protein due to the millet flour. The dietary fibers' hydrophilic environment and the protein-polysaccharide interactions function to absorb and bind water within the matrix of the formulation which results in better sample texture and extended shelf life. These findings account with observed results by **Delgado-Ospina et al., (2021) [11]** studied cacao agro-industrial chain high-fiber co-products and measured their water-holding capacity through vortex mixing 0.3 g samples with 10 mL of water which were left to hydrate overnight before centrifugation at 3000 rpm for 20 minutes to extract the water-absorbed sample from the remaining water and solids. Their findings determined that high dietary fiber products and processing methods like lyophilization improved WHC in cacao shell and pod husk by quite some margin. Yet, **Abdo et al., (2022) [1]** found a reduced WHC in lupin-based chocolate formulations attributed to the increase of dark chocolate's proportion to the formulations because of the declining protein levels from dark chocolate and the interference from the high solute from water binding. These parallels support the greater functional effect found in millet-based chocolate regarding moisture management and texture stability.

5. Summary and Conclusion

The study gives high emphasis on the advantages in terms of the environmental conditions on the one hand, and the health benefits of the finger millet-based chocolatery as an alternative to regular chocolate formulations on the other. With the addition of finger millet flour, the product had an increased fiber composition and the micronutrient profile was raised also which rendered it a better option for healthy consumption. erythritol and inulin acted as an energy hog in replacing sugar, only that erythritol and inulin did this without losing any of the taste and, most importantly, texture. Moreover, the addition of lemongrass extract led to an improved

antioxidant effect, which in turn led to multiple health gains. The chemistry studies confirmed only the moisture, ash, fat, protein, and fiber levels and highlighting the quality of the chocolate that has been developed. The way protein is broken down is the Micro-Kjeldahl method, while the way fat is measured is by Soxhlet extraction. Further analysis of the moisture and ash content was done using hot air oven and muffle furnace methods, respectively. These tests were important as they confirmed the product met food safety and quality standards. Sensory evaluation involving 20 panels and including the members of the faculty had very positive results in terms of the food's sensory attributes of taste, texture, and overall palatability. The millet-associated taste remained the most wanted one during the communal use of this new product by having a superb feeling in the mouth due to achieving smooth buttery texture accompanied by mild bitterness or sweetness. It was the first delight without the common grittiness. This study reveals that millet-based chocolate is an effective and nutritious alternative to the traditional chocolate. To enhance accessibility of plant-based beverages, holistic research and pilot projects need to be performed which should include the optimization of formulations and scale-up production, storage, and addition of other functional ingredients such as probiotics, plant proteins, or polyphenol-rich extracts. Researching on the developing the complementary food products and fermentation technology will also be a significant strategy to expand the shelf life of dairy products. In addition, incorporating hard-to-replicate-functional ingredients could be a viable alternative, fostering the development of thermally resistant foods tailored to the needs of targeted malnutrition populations. It became clear

through maximum studies of two control samples of chocolate products that T4 had much nutritional and functional properties than that of control chocolate (T0). The presence of finger millet flour and lemongrass extract resulted in a modest increase in moisture content as well as that of ash content, which signifies high mineral content, yet it holds desirable stability too. In minimal levels, the fat and carbohydrate contents reduced but were more increased in T4 when it came to protein, crude fiber, calcium, as well as vitamins (C and E) to give it that nutritional profile. Also, fat and sugar levels had lesser levels in T4, which will lead to its functionalities as a healthy chocolate. It indicated that phytic acids and free fatty acids were lowered and thus showed improvements in antioxidant activity, total phenolic content, and flavonoids without deteriorating at all, indicating a better antioxidant potential and freshness. T4 was also characterized as possessing lower water activity, fairly changed in color property yet still acceptable, had higher viscosity, and had a much better oil holding capacity, so as enhanced textural and sensory, and shelf-life qualities. Generally, the millet-based chocolate (T4) can be summed up as making a nutritionally better, functionally rich, and consumer-acceptable substitute of conventional chocolates, thus favouring those health-oriented consumers and paving the way for functional chocolate product development in itself.

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