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Research Article

Impact of Utilizing Various Healthy Alternative Sweetening and Bulking Agents on the Characteristics and Economic Viability of Spreadable Chocolate

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Abstract:

The presence of sugar in spreadable chocolate serves a dual purpose as both a sweetening and bulking agent; it can constitute over fifty percent of the total mass of the final product, and it plays an important role in enhancing the sought-after creamy texture, mouthfeel, and caloric density of the product; however, its consumption is linked to various health issues, including obesity, type 2 diabetes, and metabolic syndrome. The present study was designed to assess six suggested healthier and low-calorie plant-derived substitutes for sugar in spreadable chocolate, which encompass banana puree, date puree, fig puree, prune puree, sweet potato puree, and *Stevia rebaudiana* syrup, obtained through hot pressurized water extraction (HPW), to ascertain the alternative that most closely resembles the commercial product with respect to its chemical, sensory, and rheological properties, as well as economic viability. Chemical constituents (moisture, crude protein, crude fat, and crude fiber) were determined according to AOAC methods. Total stevioside and total Rebaudioside in the syrup were ascertained through High-Performance Liquid Chromatography (HPLC) analyses; texture profile analysis was conducted to determine the rheological properties; and sensory evaluation was conducted to evaluate samples based on color, taste, odor, texture, and overall acceptability, employing a standard hedonic rating scale ranging from 9 to 1, then data were statistically analyzed using analysis of variance (ANOVA); differences among means were determined using Tukey's test at $p < 0.05$. Our Results revealed that chocolate utilizing *Stevia rebaudiana* syrup emerged as the most advantageous substitute, delivering the lowest caloric value (mean=368.1 kcal/100 g) and moderate carbohydrate content (mean=32.63 g/100 g), while preserving a high level of sensory acceptability comparable to that of the sucrose-based reference. Rheological properties further revealed that stevia syrup-based chocolate displayed a smooth and cohesive texture similar to the control sample, underscoring its appropriateness for health-conscious and low-calorie formulations without sacrificing quality. This study proposes *Stevia rebaudiana* syrup as the preeminent selection for the formulation of low-calorie spreadable chocolate, and it emphasizes the need for further investigations to establish the optimal incorporation ratios.

1. Introduction

Chocolate products represent some of the most widely consumed confectionery items globally, particularly esteemed by children due to their palatable flavor profile and substantial energy density. In addition to being a major source of energy, chocolate possesses notable nutritional attributes when produced with high-quality ingredients. The formulation of chocolate—predominantly consisting of cocoa, sugar, cocoa butter, fats, emulsifiers, and flavor agents plays a crucial role in influencing its quality and consumer acceptance (El-Kalyoubi et al., 2011). Nevertheless, the growing awareness of the health risks associated with excessive intake of sugar and saturated fats has catalyzed an increasing consumer inclination towards healthier options. Stevia, a natural sweetener extracted from the leaves of Stevia rebaudiana, has surfaced as a viable alternative to sucrose. Its glycosides are reported to be up to 300 times sweeter than sucrose while yielding zero caloric content (de Andrade et al., 2024). Beyond its sweetness, stevia is associated with various health advantages, including antihypertensive and anti-inflammatory effects, which render it a functional ingredient in formulating healthier food products (Kotowicz et al., 2024). Contemporary consumer trends underscore the demand for not only products that satiate hunger but also those that promote physical and mental well-being while mitigating the incidence of diet-related illnesses (Reis et al., 2017). In this framework, substituting unhealthy ingredients such as sugar and fats in food products with more nutritious alternatives is imperative for reducing caloric intake. Previous investigations have explored the use of fruit and vegetable-derived purees, including pawpaw fruit puree (Wiese and Duffrin, 2003), avocado puree (Wekwete and Navder, 2008), applesauce (Hayek and Ibrahim, 2013), and eggplant puree (Ali et al., 2020), as replacements for these adverse compounds in various food items, including chocolate spreads.

The objectives of this study were to evaluate the effectiveness of use of six plant-derived sweetening and bulking agents—banana puree, date puree, fig puree, prune puree, sweet potato puree, and stevia syrup—as substitutes for sugar in chocolate spreads. The alternatives will be evaluated concerning their chemical composition, rheological characteristics, sensory qualities, and economic viability. By juxtaposing these substitutes against a sucrose-based control, the study aims to discern

the alternative that most effectively reconciles health benefits, consumer acceptability, and economic practicality, thereby contributing to the advancement of healthy and innovative food products.

2. Materials and Methods

2.1. Materials

The materials utilized in this investigation included sucrose sugar, palm oil, vanilla, raw cocoa powder, dried milk powder, banana, date, fig, prune, and sweet potato were purchased from local market in in the Gharbia Governorate, Egypt. Additionally, *Stevia rebaudiana* green leaves were acquired from the Sugar Crops Research Center located in the Kafr El-Sheikh Governorate, Egypt. All chemicals and reagents employed in this research adhered to analytical grade standards and were sourced from Sigma Company.

2.2. Methods

2.2.1. The Extraction of Stevia syrup

The extraction of Stevia syrup from the leaves of *Stevia rebaudiana* was accomplished employing the hot water extraction (HPW) methodology, which proficiently isolates steviol glycosides as per the procedure delineated by (Németh and Jánosi,2019). Furthermore, the percentages of total stevioside and total Rebaudioside were ascertained through High-Performance Liquid Chromatography (HPLC) analyses, as described by (Németh and Jánosi, 2019), while total soluble solids (TSS) were quantified using a refractometer. The concentrations of total soluble carbohydrates were determined utilizing the Anthrone method as specified by (Plummer, 1990).

2.2.2. Preparation of plant alternatives purees and formulation of chocolate samples

The fruits were thoroughly washed by tap water to eliminate any soil particles and contaminants, while the sweet potatoes were subjected to boiling for a duration of 30 minutes; subsequently, all ingredients were mashed and blended until a homogeneous texture was achieved, and finally stored in plastic bags within the refrigerator, following the protocol established by (Ali et al., 2020). The formulation of chocolate samples was executed in accordance with the percentages indicated in the commercial product, albeit with certain modifications; thus, the control sample formulation comprised sugar (55%), palm fat (30%), skimmed milk powder (7%), cocoa powder (7%), vanillin, and salt (1%). In this formulation, sugar was substituted with fruit purees at the same proportion (55%) to prepare the other samples under investigation, and the chocolate spreads were produced using a straightforward mixing process in line with the methods outlined by (El-Hadad et al., 2011).

2.2.3. The chemical analysis

Chemical analysis of samples (moisture, crude protein, crude fat, and crude fiber) were investigated according to the Association of Official Analytical Chemists (A.O.A.C. 2016). Subsequently, carbohydrate content was computed by difference. The caloric content was estimated following the standards set by (FAO/WHO, 1974), which attribute 4 kcal/g to proteins and carbohydrates, and 9 kcal/g to fats.

2.2.4. Texture profile analysis

Textural characteristics of treated samples were evaluated using the Brookfield Pro CT V1.2 Build 9 apparatus. A TA4/1000 probe was employed to penetrate each formulation at a speed of 2 mm/s to a depth of 7.5 mm into each sample, conducted over two cycles, with a load cell capacity of 1000g; both test speed and return speed were maintained at 2 mm/s, and the force was documented in grams, consistent with the methodology described by (Prasanth Kumar et al. ,2016).

2.2.5. Sensory evaluation

The samples were organoleptic ally analyzed by 10 well-trained members from the Nutrition and Food Science Department at the Faculty of Home Economics, Al-Azhar University, Egypt. The panelists were requested to evaluate the samples based on color, taste, odor, texture, and overall acceptability of the chocolate spread, employing a standard hedonic rating scale ranging from 9 (like extremely) to 1 (dislike extremely). Sensory evaluation of chocolate spread treatments was done according to by (Rodrigues et al., 2024).

2.2.6. Economic viability

The expenses associated with raw materials were calculated for each formulation based on prevailing local market prices. The production cost per 100 g of chocolate spread was determined, and cost efficiency was evaluated across the various samples.

2.2.7. Statistical Analysis

All experiments were conducted in triplicate, and data were analyzed using analysis of variance (ANOVA). Differences among means were determined using Tukey's test ($p < 0.05$). Statistical analyses were performed using SPSS software (version 25). Data was plotted using Microsoft Excel 2016.

3. Results

3.1. Chemical Composition of different investigated sweetening and bulking agents

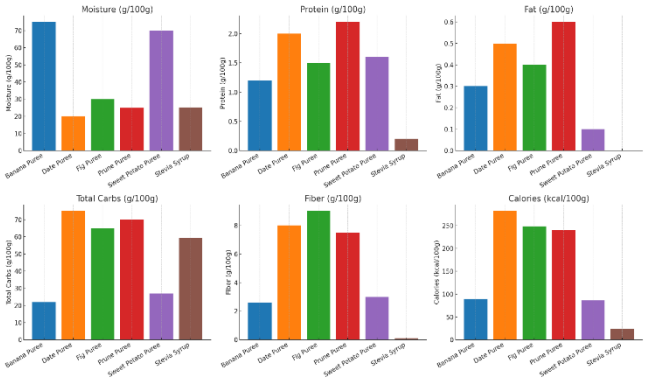

Figure 1. Chemical Composition of different investigated sweetening and bulking agents.

Figure 1 indicates a significant difference in nutritional profiles of the investigated sweeting and bulking agents,

Stevia syrup exhibited the lowest caloric value (mean=24 kcal/100g) and carbohydrate content (mean=59.34 g/100g), aligning with its role as a low-calorie sweetening agent. In contrast, date puree contained the highest carbohydrate mean= (75.0 g/100g) and calorie content (mean=282 kcal/100g), while sweet potato and banana purees were characterized by higher moisture content, making them suitable for formulations requiring enhanced water retention.

3.2. Physio-chemical characteristics of extracted stevioside syrup

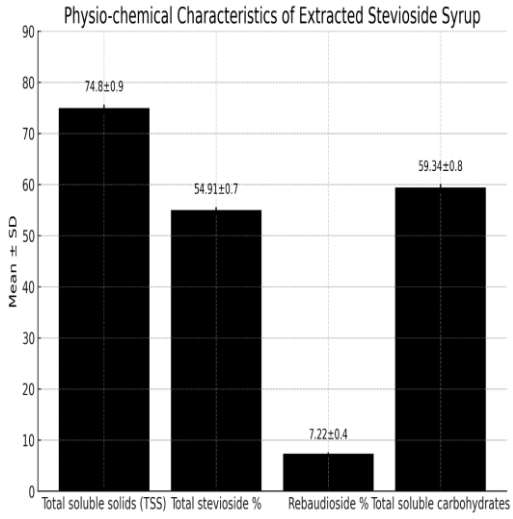

Figure 2. Physio-chemical characteristics of extracted stevioside syrup.

Figure 2 indicates that extracted stevioside syrup demonstrated high total soluble solids (mean=74.8±0.9) and a significant concentration of stevioside (mean=54.91±0.7%). Additionally, the syrup contained rebaudioside at (mean=7.22±0.4%), contributing to its sweetening potential. The total soluble carbohydrate content was (mean=59.34±0.8%), reinforcing its functionality as a concentrated sweetening agent with minimal caloric contribution.

3.3. Chemical composition of the spreadable chocolate formulas

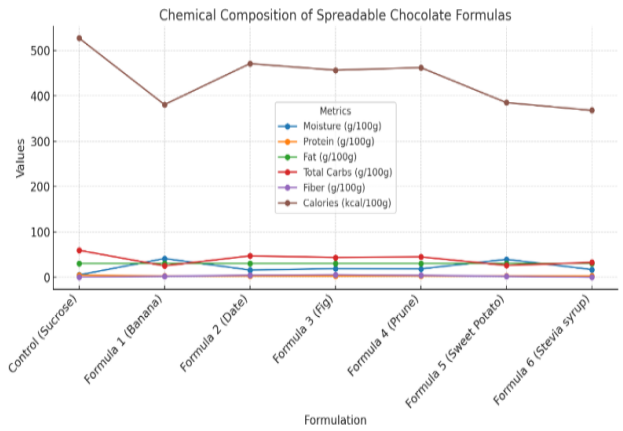

Figure 3. Chemical composition of the spreadable chocolate formulas.

Figure 3 indicates that the chocolate formulations significantly varied based on the sweetening agents used. The stevia-based formula had the lowest calorie content (mean=368.1 kcal/100g) and a moderate carbohydrate level (mean=32.63 g/100g), making it the most suitable for low-calorie applications. Conversely, formulations incorporating date and fig purees were calorie-dense (mean=471.2 and 456.8 kcal/100g, respectively) but also rich in dietary fiber (mean=4.9 and 5.5 g/100g).

3.4. Rheological features of the spreadable chocolate formulas

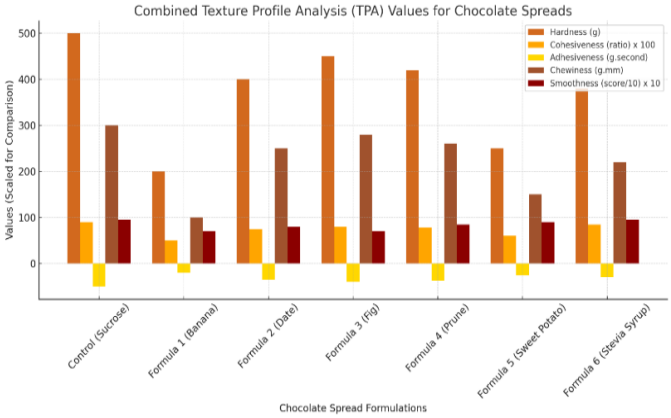

Figure 4. Rheological features of the spreadable chocolate formulas.

Figure 4 indicates that the rheological properties highlighted a significant textural differences among formulas. The control (sucrose-based) and stevia syrup-based formulas exhibited the highest smoothness, with the latter showing comparable adhesiveness and cohesiveness metrics to the control. Formulations with date and fig purees achieved intermediate hardness and smoothness scores. In contrast, formulations with banana and sweet potato purees exhibited lower hardness and cohesiveness.

3.5. Sensory features of the spreadable chocolate formulas

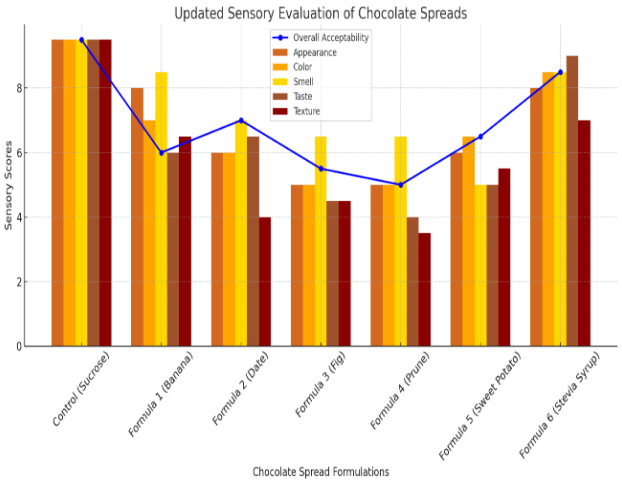

Figure 5. Sensory features of the spreadable chocolate formulas.

Figure 5 indicates that the sensory evaluation identified the sucrose-based control as the most preferred across all attributes. Among alternative sweeteners, the stevia syrup

formulation achieved the highest acceptability, driven by high scores in taste and texture. Formulations with banana and sweet potato purees received moderate sensory ratings, whereas fig and prune-based formulations were less favored due to lower taste and texture scores.

3.6. Cost analysis of the spreadable chocolate formulas

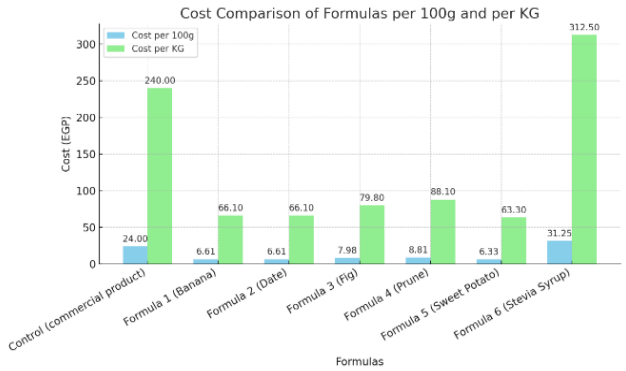

Figure 6. Cost analysis of the spreadable chocolate formulas

Figure 6 indicates that the cost analysis revealed significant economic variability among the formulations. Banana and sweet potato-based formulations were the most cost-effective (6.33–6.61 EGP/100g), while the stevia syrup-based formulation incurred the highest cost (31.25 EGP/100g). Date and fig-based formulations were moderately priced (7.98–8.81 EGP/100g), positioning them as cost-effective options with higher nutritional value.

4. Discussion

4.1. Chemical Properties of Spreadable Chocolate Formulations:

Changes in the chemical properties of experimental spreadable chocolate are shown in Figure 3.

The chemical composition represents a pivotal element in the assessment of sweetening and bulking agents, as it exerts a direct influence on the health assertions and the functional capabilities of the resultant product (Piekara et al., 2020). Low-calorie and low-carbohydrate sweeteners hold particular significance in meeting consumer preferences for healthier substitutes for sucrose, which has been linked to heightened risks of obesity, type 2 diabetes, and cardiovascular diseases (Malik et al., 2010). The present study indicated that stevia syrup possessed the least caloric value (24 kcal/100 g) and carbohydrate concentration (59.34 g/100 g), thereby emphasizing its appropriateness as a low-calorie sweetening agent. This observation is consistent with its classification as a non-nutritive sweetener sourced from natural origins. In contrast, date puree exhibited the highest caloric (282 kcal/100 g) and carbohydrate levels (75.0 g/100 g), which aligns with the concentrated natural sugar profile inherent to dates. Notably, sweet potato and banana purees were distinguished by their elevated moisture content, rendering them beneficial for applications necessitating water retention and a soft texture. Our findings corroborate previous research that underscores stevia's minimal caloric impact and low carbohydrate profile. (Goyal et al., 2010) highlighted stevia's potential in low-calorie formulations owing to its pronounced sweetness intensity and negligible caloric contribution. Conversely, the elevated caloric value of date puree is in agreement with the analysis conducted by (Al-Farsi and Lee, 2008), which documented the considerable sugar and energy density of dates.

Nevertheless, the efficacy of fruit purees in moisture retention contrasts with investigations centered on conventional sugar substitutes such as polyols, which prioritize caloric reduction over moisture enhancement (O'Donnell and Kearsley, 2012). This distinction accentuates the dual functionality of fruit purees in augmenting both texture and nutritional merit. The observed variations in caloric and carbohydrate profiles are fundamentally rooted in the biochemical composition of the substances evaluated. The low caloric value of stevia is attributable to its active compounds, predominantly steviol glycosides, which impart intense sweetness without delivering substantial energy (Prakash et al., 2008). In contrast, the naturally occurring fructose and glucose present in date puree account for its elevated caloric and carbohydrate content and the significant moisture content found in banana and sweet potato purees can be ascribed to their inherent water-binding properties, which enhance their efficacy in maintaining product softness and facilitating spread-ability (Sayas-Barberá et al., 2023).

4.2. Rheological Properties of Spreadable Chocolate Formulations:

Rheological properties, encompassing attributes such as smoothness, adhesiveness, cohesiveness, and hardness, play a pivotal role in the assessment of the textural quality of spreadable chocolate; these properties significantly affect consumer acceptance, manufacturing efficiency, and the stability of shelf life (Bourne, 2002). Our findings, as illustrated in Figure 4, reveal notable distinctions among the various formulations, whereby the control (sucrose-based) and stevia syrup-based formulations demonstrated the highest levels of smoothness, accompanied by comparable metrics of adhesiveness and cohesiveness. In contrast, the formulations based on date and fig purees exhibited intermediate levels of hardness and smoothness, while the formulations incorporating banana and sweet potato purees manifested the lowest levels of hardness and cohesiveness, thus indicating less favorable textural characteristics.

Mohamed et al. (2019) elucidated that the incorporation of date syrup into sweet potato starch enhances the rheological properties, specifically by augmenting gel strength, adhesiveness, and cohesiveness when mixed at optimal ratios. However, elevated concentrations of syrup may diminish gel stiffness due to the excess moisture and sugar that interfere with the gelatinization of starch. This observation is partially consistent with our results, wherein the date puree evidenced intermediate smoothness and hardness in our investigation; nevertheless, the lower cohesiveness observed in the sweet potato-based formulations could be attributed to differences in processing techniques or puree composition when juxtaposed with the starch-date syrup gels examined in (Mohamed et al., 2019).

Sorour et al. (2016) reported that spreads formulated with banana puree exhibited lower viscosity and cohesiveness relative to other fruit purees, a phenomenon attributable to the high moisture content and low fiber composition of bananas. Consequently, the incorporation of additives such as gums became necessary to enhance the texture, which corroborates our findings that banana-based formulations displayed diminished hardness and cohesiveness. Both investigations underscore the notion that the inherent composition of bananas results in reduced structural integrity unless supplemented by thickeners.

The date puree utilized in our study yielded intermediate textural properties; this moderate performance may signify a compromise between its textural enhancement capabilities and its elevated moisture and sugar content. This behavior parallels the findings presented in (Mohamed et al., 2019), wherein date syrup enhances both sweetness and viscosity within formulations, yet its efficacy is contingent upon the proportion used; excessive incorporation may lead to undesirable liquidity in the final product due to its high sugar content, as highlighted by (Mohamed et al., 2019).

4.3. Sensory properties of Spreadable Chocolate Formulations:

Sensory evaluation is of paramount importance in the formulation of reduced-sugar or alternative-sweetener products. This process facilitates the identification of consumer preferences grounded in taste, texture, and overall acceptability, which are essential determinants for the commercial viability of novel food items (Souza et al., 2022). The results of sensory evaluation revealed that the sensory parameters, including taste, texture, and overall acceptability of spreadable chocolate treatments, that the stevia syrup-based sample garnered the most favorable acceptability scores, particularly concerning taste and texture, whereas formulations employing banana and sweet potato purees received moderate evaluations, and those based on figs and prunes were ranked lower, predominantly due to less favorable sensory characteristics.

Prior research (Cempaka et al., 2021) substantiates that sucrose is regarded as the benchmark for sweetness, enhancing both flavor and texture in chocolate products. This is consistent with our observations, where spreads formulated with sucrose achieved the highest sensory acceptability ratings. The sensory perception of sucrose as a reference standard is widely recognized, attributed to its efficacy in balancing flavor and texture in food applications. Sucrose frequently serves as a comparative standard against which alternative sweeteners are assessed, particularly in relation to sweetness intensity and consumer preference (Wee et al., 2018).

Additional investigations (Hajela et al., 2017) reveal that stevia, notwithstanding its unique sweetness profile, can yield favorable sensory results when adeptly integrated into chocolate formulations. Research has indicated that its slightly bitter aftertaste can be effectively concealed by complementary ingredients, rendering it a viable sugar substitute with considerable acceptability, which resonates with our findings. Stevia, characterized by its high sweetness intensity—approximately 250 to 300 times that of sucrose—presents a lower-calorie alternative, thereby appealing to individuals endeavoring to decrease their caloric consumption (Oleson and Murphy, 2017).

Although our study observed moderate consumer ratings for formulations based on banana and sweet potato, other investigations (Olaniran et al., 2024) propose that these ingredients may attain enhanced acceptability when employed in specific contexts or when paired with complementary flavors, contrasting with our results. The diminished sensory ratings for formulations containing banana, sweet potato, fig, and prune may be linked to their distinct intrinsic flavors, which can interfere with or dilute the conventional chocolate profile if not meticulously balanced, as these fruits possess pronounced flavor characteristics that may not integrate seamlessly with chocolate, resulting in diminished consumer preference.

4.4. Cost analysis of the investigated Spreadable Chocolate Formulations:

The execution of a comprehensive cost analysis for processed food products is paramount in enhancing economic efficiency and facilitating informed decision-making; it serves to identify cost-efficient production methodologies and optimize the utilization of ingredients, thereby assuring the provision of healthier and more affordable options. Furthermore, it addresses the pressing issue of food insecurity by augmenting access to nutritious food supplies (Owade et al., 2022). The cost analysis of diverse formulations predicated on banana, sweet potato, stevia syrup, date, and fig indicates significant economic variability, which can be ascribed to multiple factors including the costs of raw materials, processing techniques, and nutritional attributes. Formulations based on banana and sweet potato emerged as the most economically viable, with price points oscillating between 6.33 to 6.61 EGP/100g. This comparatively low cost can be attributed to the prevalent availability and reduced production expenses associated with these ingredients, which are recognized as staple crops within Egypt (Scott, 2021). Conversely, the formulation utilizing stevia syrup was identified as the most expensive, priced at 31.25 EGP/100g; this elevated cost is likely a consequence of the extraction and processing methodologies necessitated for the production of stevia syrup (Németh and Jánosi, 2019).

5. Conclusions

Current study highlights the potential of stevia syrup as a prominent alternative to sucrose in the formulation of spreadable chocolate, offering notable caloric reduction, beneficial rheological properties, and high levels of sensory acceptability. While fruit purees provide distinct nutritional and flavor benefits, their application may be more aptly suited for niche or specialty products. The incorporation of these findings into industrial formulations has the potential to facilitate the development of healthier and more sustainable chocolate spreads, effectively addressing the evolving preferences of health-conscious consumers.

Limitations and future directions

Subsequent research endeavors could explore the rheological and sensory repercussions of varying ratios of stevia employed as both a bulking and sweetening agent, in addition to assessing the long-term stability of the proposed formulations.

Author Contributions: Alyaa N. Abdel-Fattah: Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Writing – original draft, review and editing. Zainab A. Salem, Neveen M. Zeima, and Essam Mohamed Elsebaie: Conceptualization, Supervision, Visualization, and review. All authors made significant contributions to the final manuscript and all approved the manuscript for final submission.

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Institutional Review Board Statement: "Not applicable".

Informed Consent Statement: Participants in the sensory evaluation gave informed consent, ensuring their voluntary involvement and anonymity. Fair treatment and risk assessment techniques were implemented to prioritize participant safety in accordance with the World Medical Association's Code of Ethics (Declaration of Helsinki) and approved by the Department Council's Scientific Committee in March 2024.

Data Availability Statement: All data are available upon request with permission from the original author; for any data or questions regarding the stud, please contact with the corresponding author: Alyaa Nasr Abdel-Fattah at: alyaanasr42@gmail.com ; Tel.: +20-1019451747.

Conflicts of Interest: The authors declare that there is no conflict of interest regarding the publication of this paper.

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