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Sensory attributes and potential health benefits: an untrained consumer panel's evaluation of peruvian dark chocolate at varying cocoa levels (40%, 60%, 72%)

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RESUMEN

Introducción: El chocolate negro es considerado un alimento funcional por su elevado contenido de compuestos bioactivos, como polifenoles, flavonoides y metilxantinas, relacionados con beneficios cardiovasculares y protección antioxidante. Sin embargo, la aceptación del consumidor puede verse influenciada por el porcentaje de cacao, el cual afecta tanto las características sensoriales como el potencial saludable del producto.

Objetivo: Evaluar la aceptabilidad sensorial de formulaciones de chocolate negro peruano con diferentes porcentajes de cacao (40 %, 60 % y 72 %) y analizar la relación entre el contenido de cacao y las preferencias del consumidor.

Metodología: Se evaluaron tres muestras de chocolate negro con 40 %, 60 % y 72 % de sólidos de cacao, mediante un panel de 66 consumidores jóvenes no entrenados (entre 18 y 40 años). Se valoraron los atributos sensoriales de color, aroma, sabor, textura y aceptabilidad general utilizando una escala hedónica de 9 puntos. El análisis estadístico se realizó con la prueba de Kruskal–Wallis y comparaciones post hoc de Mann–Whitney ($p < 0.05$).

Resultados: Se encontraron diferencias significativas en el sabor ($p = 0.041$) y en la aceptabilidad general ($p = 0.017$), siendo el chocolate con 40 % de cacao el más preferido. No se observaron diferencias significativas en color, aroma ni textura. La preferencia por menores contenidos de cacao se atribuye a una menor percepción de amargor y astringencia.

Conclusiones: Aunque los chocolates con mayor porcentaje de cacao ofrecen mayores beneficios para la salud, sus atributos sensoriales intensos pueden limitar la aceptación del consumidor. Optimizar el contenido de cacao resulta clave para equilibrar funcionalidad nutricional y preferencia sensorial.

PALABRAS CLAVE

Alimentos funcionales, Aceptabilidad del consumidor, Beneficios para la salud, Cacao peruano, Flavonoides.

ABSTRACT

Introduction: Dark chocolate is considered a functional food due to its high content of bioactive compounds such as polyphenols, flavonoids, and methylxanthines. These components are associated with cardiovascular health benefits and antioxidant protection. However, consumer acceptance of dark chocolate can vary depending on its cocoa content, which influences both sensory characteristics and health potential.

Objective: To evaluate the sensory acceptability of Peruvian dark chocolate formulations with different cocoa percentages (40 %, 60 %, and 72 %) and explore the relationship between cocoa content and consumer preferences.

Methodology: Three dark chocolate samples with varying cocoa solid content (40 %, 60 %, and 72 %) were evaluated by

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66 untrained young adult consumers (aged 18–40 years). Sensory attributes including color, aroma, flavor, texture, and overall acceptability were assessed using a 9-point hedonic scale. Data were analyzed using the Kruskal–Wallis test and Mann–Whitney U post hoc comparisons ($p < 0.05$).

Results: Significant differences were found in flavor ($p = 0.041$) and overall acceptability ($p = 0.017$), with the 40 % cocoa chocolate rated most favorably. No significant differences were observed in color, aroma, or texture. Lower cocoa content was associated with higher consumer preference, likely due to reduced bitterness and astringency.

Conclusions: Despite the greater health benefits of high-percentage dark chocolate, intense sensory attributes may hinder consumer acceptability. Balancing cocoa content is essential to ensure both nutritional functionality and consumer satisfaction.

KEYWORDS

Functional foods, Consumer acceptability, Health benefits, Peruvian cocoa, Flavonoids.

INTRODUCTION

Dark chocolate is recognized as a functional food due to its high polyphenol content—particularly catechins, anthocyanins, and proanthocyanidins—which confer antioxidant properties that support cardiovascular health and reduce oxidative stress, despite its bitter and astringent flavor potentially affecting consumer acceptability[1]. Peru has emerged as a key global cocoa exporter, with a 129% increase in cocoa exports in early 2025, reaching US$333 million across 34 markets, led by the United States (23%)[2]. The export portfolio includes cocoa beans (39%), butter (30%), and powder (10%). Government programs have strengthened 157 cocoa organizations in 11 regions, while Peru cultivated 198,213 hectares in 2023, producing 165,886 tons and ranking eleventh globally. Distinctive Peruvian varieties such as CAP-39, INDES-CES, and CCN-51 are valued for their agronomic and phytochemical properties.

Cocoa (*Theobroma cacao L.*) is one of the most phytonutrient-rich crops, containing over 300 compounds, including polyphenols (catechins, anthocyanins, proanthocyanidins), methylxanthines (theobromine, caffeine), and amino acids such as tryptophan, tyrosine, and arginine, which contribute to its antioxidant, anti-inflammatory, cardiometabolic, and neuroprotective effects[3]. Cocoa also provides high levels of fat (25.6%), protein (20.4%), fiber, essential minerals and bioactive compounds as seen in Figure 1. However, high concentrations of certain compounds can compromise sensory acceptability by increasing bitterness and astringency, underscoring the need to balance health benefits and palatability through optimized cultivation and processing. Despite being often misclassified as ultra-processed, high-quality dark chocolate typically contains minimal ingredients and retains significant nutritional value, supporting its inclusion in a balanced diet when consumed in moderation[3].

Polyphenols have garnered significant scientific interest due to their potential health benefits; however, considerable vari-

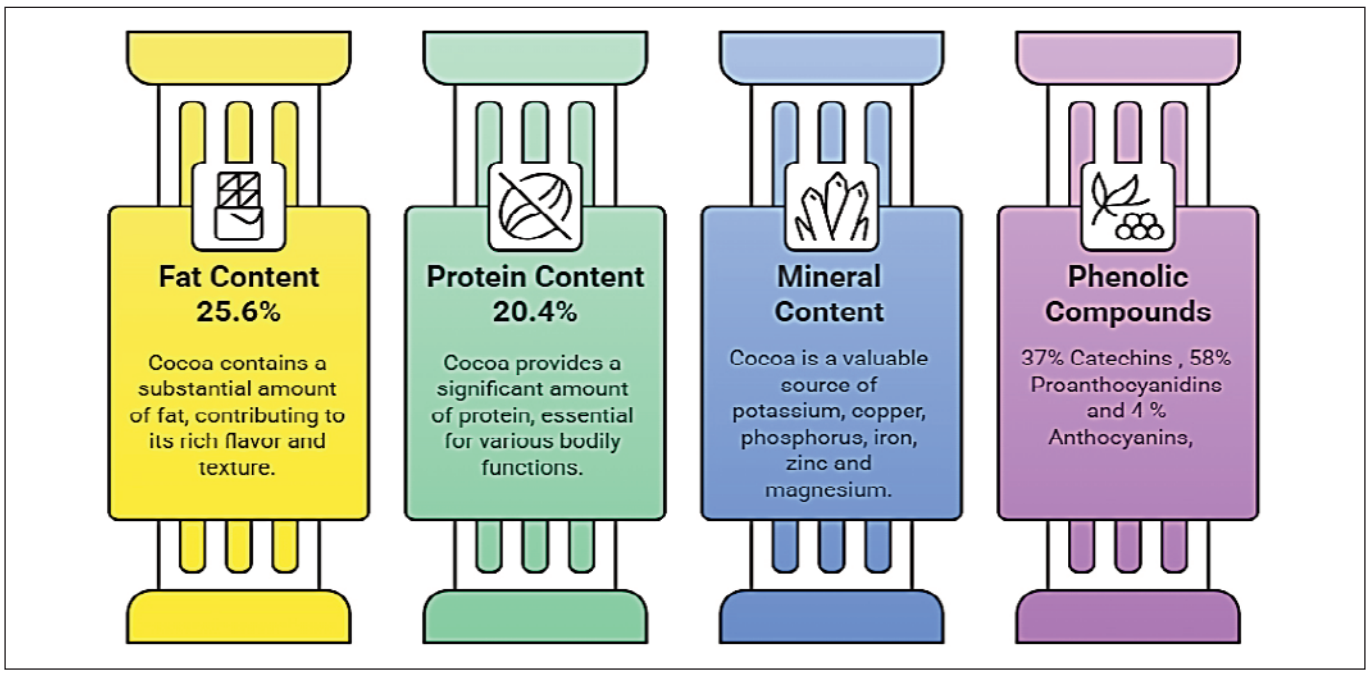

Figure 1. Nutritional and Bioactive Composition of Cocoa: Macronutrients, Minerals, and Phenolic Compounds

ability exists within this diverse class of compounds. Cocoa and cocoa-derived products, particularly chocolate, are recognized as important dietary sources of flavan-3-ols, primarily epicatechin and its associated proanthocyanidins. Research on these compounds has yielded valuable insights into their bioavailability and metabolic pathways. Notably, native (–)-epicatechin demonstrates superior bioavailability compared to its stereoisomers produced during thermal processing (such as roasting) and alkalization treatments. Following absorption, phase II conjugates of epicatechin, along with phenolic acid metabolites that do not retain intact flavanol structures, can be detected in plasma and urine. The gut microbiota plays a crucial role in the metabolism of flavanols, facilitating the conversion of non-absorbed compounds into valerolactone derivatives. Research has demonstrated that these microbial metabolites can achieve plasma concentrations that are approximately five times greater than those of epicatechin conjugates[4]. Although the complete physiological significance of these metabolites remains to be fully elucidated, emerging evidence suggests their potential implications for human health. The complex metabolic transformations of cocoa flavanols, which encompass both host enzymatic modifications and microbial bioconversion, underscore the necessity for a comprehensive investigation into their bioactive potential beyond that of the parent compounds.

Cardiovascular Effects of Dark Chocolate: Mechanisms and Clinical Evidence

Dark chocolate, rich in flavonoids and methylxanthines, has been extensively studied for its cardiovascular benefits, primarily attributed to antioxidant, anti-inflammatory, and vasodilatory effects. Epidemiological and clinical studies support an inverse association between moderate dark chocolate intake and cardiovascular disease risk, including hypertension, stroke, and myocardial infarction[3,4]. These effects are linked to improved endothelial function via enhanced nitric oxide bioavailability, downregulation of pro-inflammatory genes, and inhibition of oxidative stress pathways such as NOX-2. A meta-analysis of 31 trials reported significant reductions in both systolic and diastolic blood pressure, especially with chocolate consumption delivering ≥900 mg of flavanols per day[5]. Randomized trials further confirm improvements in arterial stiffness, pulse wave velocity, and flow-mediated dilation following high-cocoa dark chocolate intake[6-8].

Additionally, Mendelian randomization analyses provide genetic evidence supporting a causal relationship between dark chocolate consumption and reduced risk of essential hypertension[4]. While cocoa solids correlate positively with theobromine content—another bioactive compound with potential vasomodulatory properties—evidence also suggests hormonal interactions may enhance vascular effects in specific populations, such as women across menstrual phases[5]. Despite these promising findings, further long-term studies are needed to define optimal dosages and fully elucidate the complex mechanisms underlying these cardioprotective effects.

Cardiometabolic and Systemic Health Benefits of Dark Chocolate

Numerous clinical trials and meta-analyses have demonstrated that dark chocolate, particularly due to its high cocoa and flavonoid content, exerts beneficial effects on cardiometabolic health. Regular consumption has been associated with improved lipid profiles, including reductions in total cholesterol, LDL, triglycerides, and increases in HDL concentrations[9,10]. Additional studies report reductions in body weight and BMI after cocoa supplementation[11], without promoting weight gain even at high cocoa concentrations.

Cardiovascular benefits extend to blood pressure regulation[12], anti-inflammatory effects marked by reduced CRP levels and potential anticancer actions through antiproliferative mechanisms[10]. In diabetic populations, meta-analyses and RCTs show that cocoa or dark chocolate can significantly reduce LDL cholesterol, fasting glucose, and inflammatory markers while improving hemoglobin A1c and HDL levels[9,13]. Notably, cocoa flavonoids may also support microvascular function, as suggested by improved retinal blood flow in healthy subjects. Together, these findings as seen in Figure 2, support the inclusion of high-cocoa dark chocolate as a functional dietary component, particularly when integrated with lifestyle interventions, though further research is needed to define optimal intake and long-term outcomes[13].

Anti-inflammatory, Anticancer, and Cognitive Benefits

Cocoa flavonoids —particularly catechins and epicatechins— exhibit a range of bioactive effects, including antioxidant, anti-inflammatory, and neuroprotective properties, that may contribute to the prevention of chronic diseases. These compounds neutralize reactive oxygen species, reduce inflammation associated with cancer development, and help maintain proper cell cycle regulation, thereby limiting the risk of malignant transformation[14]. Furthermore, cocoa flavonoids have demonstrated the ability to induce apoptosis in cancer cells and inhibit tumor angiogenesis, restricting vascular support essential for tumor growth and metastasis[14-16]. In the neurological domain, acute consumption of dark chocolate has been linked to enhanced memory and cognitive performance, supporting the neuromodulatory effects of cocoa flavanols. Figure 3 illustrates these proposed mechanisms, highlighting the interconnected pathways through which cocoa bioactives may exert protective effects against cancer and support cognitive health.

Therefore, this study aimed to assess the sensory acceptability of dark chocolate formulations with varying cocoa con-

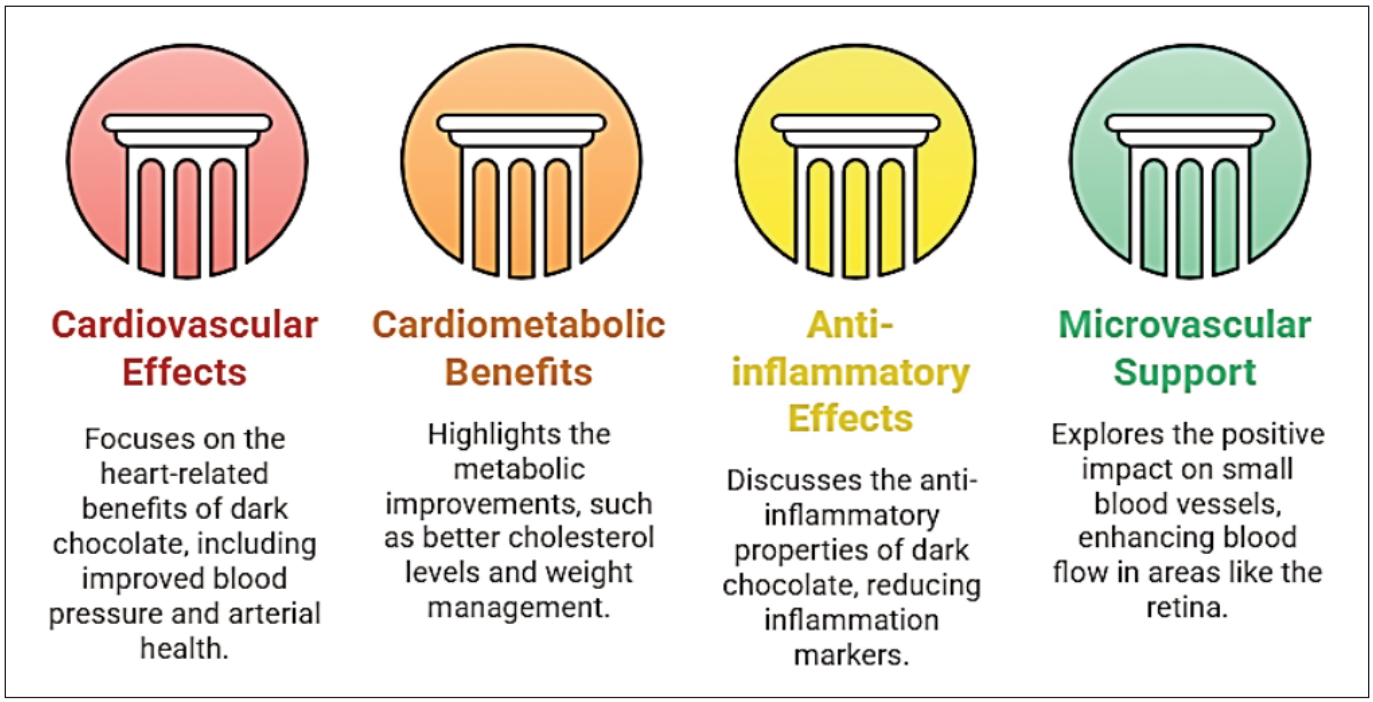

Figure 2. Mechanistic Insights into the Health Effects of Dark Chocolate: Cardiovascular, Metabolic, and Anti-inflammatory Roles

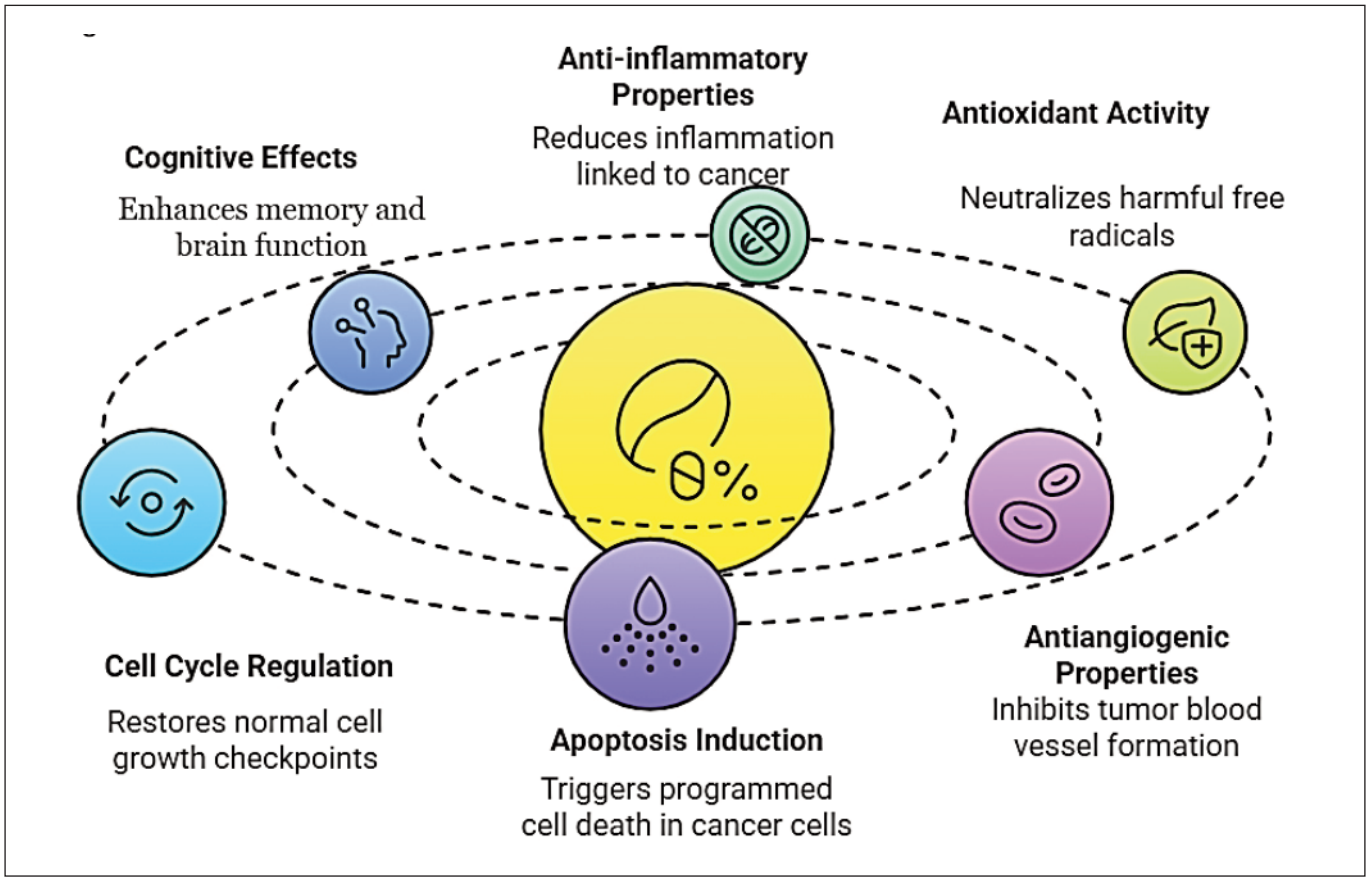

Figure 3. Health-related benefits of cocoa flavonoids: Antioxidant, anticancer, and neurocognitive effects

tent (40%, 60%, and 72%) among young adult consumers, in order to explore how cocoa percentage influences sensory perception and overall preference—key factors for aligning health benefits with consumer appeal.

MATERIALS AND METHODS

Sensory evaluation

Three types of Peruvian chocolates with 40%(Commercial name: *La Ibérica*), 60% and 72% cocoa (both with the commercial name *Orquídea*) were evaluated in an untrained panel (n=66) (See Figure 4.). The sensory evaluation utilized a nine-point scale: "Dislike Extremely", "Dislike Very Much", "Dislike Moderately", "Dislike Slightly", "Neutral", "Like Slightly", "Like Moderately", "Like Very Much" and "Like Extremely"[17-19].

Statistical Methodology

In the analysis of sensory evaluation data, the Statistical Package for the Social Sciences (SPSS 25) software was employed. The sensory analysis of three chocolate formulations (40%, 60%, and 72% cacao) involved the evaluation of five attributes: color, aroma, flavor, texture, and overall acceptability. To assess the distribution of the data, the Kolmogorov-Smirnov test was applied, yielding p-values less than 0.05 for all variables, indicating a significant deviation from normality. In contrast, Levene's test showed p-values greater than 0.05 across all attributes, confirming the assumption of homogeneity of variances. Given the violation of normality but compliance with homoscedasticity, the non-parametric Kruskal-Wallis test was selected as the most appropriate method to compare median sensory scores among the three formulations. This statistical approach ensures robust and reliable interpretation of sensory differences in the presence of non-normal data distributions. In instances where statistical significance was observed in the attributes of flavor and overall acceptability, Mann-Whitney post hoc tests were conducted for pairwise comparisons between the formulations.

RESULTS

A descriptive analysis of the sensory attributes evaluated (color, aroma, flavor, texture, and overall acceptability) was conducted for the three chocolate formulations (40%, 60%, and 72% cocoa) to observe trends in panelist preferences. For the

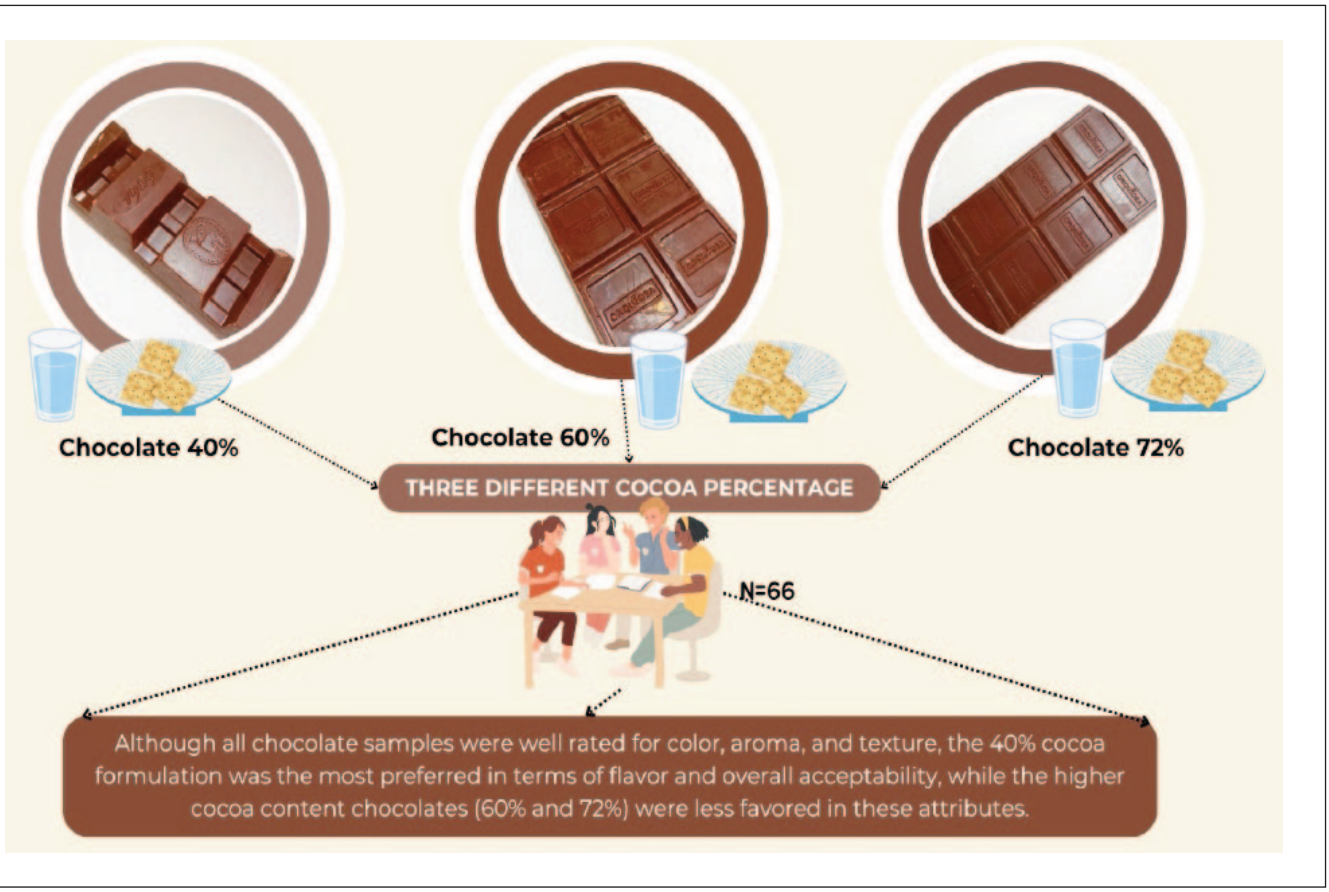

Figure 4. Experimental Design for Sensory Testing of Chocolate Samples with Varying Cocoa Percentages

Table 1. Descriptive statistics of the three formulations of Peruvian commercial Dark Chocolate (40%; 60% y 72% of cacao

Cacao		N	Mean	Standard Deviation	Standard Error	Confidence Interval for Mean at 95%		Min	Max	Test	Sig.
						Lower Limit	Upper Limit				
Color	40%	66	7,45	1,255	,154	7,15	7,76	3	9	Kruskal-Wallis	.315
	60%	66	7,23	1,148	,141	6,95	7,51	4	9		
	72%	66	7,30	1,289	,159	6,99	7,62	4	9		
	Total	198	7,33	1,229	,087	7,16	7,50	3	9		
Aroma	40%	66	7,12	1,494	,184	6,75	7,49	4	9	Kruskal-Wallis	.383
	60%	66	7,02	1,493	,184	6,65	7,38	3	9		
	72%	66	6,77	1,537	,189	6,39	7,15	3	9		
	Total	198	6,97	1,508	,107	6,76	7,18	3	9		
Taste	40%	66	7,45	1,338	,165	7,13	7,78	4	9	Kruskal-Wallis	.041
	60%	66	6,98	1,687	,208	6,57	7,40	3	9		
	72%	66	6,59	1,921	,237	6,12	7,06	2	9		
	Total	198	7,01	1,695	,120	6,77	7,25	2	9		
Texture	40%	66	7,35	1,246	,153	7,04	7,65	4	9	Kruskal-Wallis	.225
	60%	66	7,27	1,222	,150	6,97	7,57	4	9		
	72%	66	6,97	1,324	,163	6,64	7,30	3	9		
	Total	198	7,20	1,269	,090	7,02	7,37	3	9		
Overall acceptance	40%	66	7,68	1,152	,142	7,40	7,97	5	9	Kruskal-Wallis	.017
	60%	66	7,12	1,524	,188	6,75	7,50	3	9		
	72%	66	6,95	1,573	,194	6,57	7,34	3	9		
	Total	198	7,25	1,456	,103	7,05	7,46	3	9		

attribute color, the 40% cocoa formulation received the highest mean score (M = 7.45; SD = 1.26), followed closely by the 72% cocoa (M = 7.30; SD = 1.29) and the 60% cocoa formulation (M = 7.23; SD = 1.15). All three formulations received high scores within a narrow range (min = 3, max = 9), indicating a favorable perception of color across all samples. Regarding aroma, the highest mean was also observed for the 40% cocoa (M = 7.12; SD = 1.49), followed by 60% (M = 7.02; SD = 1.49), and 72% (M = 6.77; SD = 1.54). A slight decline in aroma appreciation was noted as cocoa content increased. For the flavor attribute, more pronounced differences were observed among the samples. The 40% cocoa formulation again had the highest mean (M = 7.45; SD = 1.34), whereas the 72% cocoa formulation received the lowest (M = 6.59; SD = 1.92). Flavor showed the greatest variability among panelist ratings, with scores ranging from 2 to 9. In terms of texture, all formulations received mean scores above 6.9, with the 40% cocoa formulation leading slightly (M = 7.35; SD = 1.25), suggesting consistent textural quality among the samples. For overall acceptability, the 40% cocoa sample was again rated the highest (M = 7.68; SD = 1.15), followed by the 60% (M = 7.12; SD = 1.52) and 72% cocoa formulations (M = 6.95; SD = 1.57). These results point to a clear preference among panelists for the chocolate with lower cocoa content across all sensory attributes.

As shown in Table 2, the 72% cocoa chocolate had the highest energy, fat, and fiber content, while the 60% cocoa sample contained the highest carbohydrate level. Bioactive compound concentrations, including polyphenols, procyanidins, flavanols (epicatechin + catechin), and antioxidant capacity (ORAC), increased with cocoa percentage, approximately doubling from 40% to 72%.

In general, the maximum score for all attributes was 9, while minimum scores ranged from 2 to 5. This indicates moderate dispersion in the responses, with an overall tendency toward high ratings. The Kruskal-Wallis test was applied to determine whether there were significant differences among the formulations with respect to the sensory attributes of color, aroma, flavor, texture, and overall acceptability. The results revealed statistically significant differences in flavor ($H = 6.412$; $p = 0.041$) and overall acceptability ($H = 8.126$; $p = 0.017$). No significant differences were observed for color ($p = 0.315$), aroma ($p = 0.383$), or texture ($p = 0.225$). Given the significant findings in flavor and overall acceptability, post hoc pairwise comparisons were conducted *using* the Mann-Whitney U test. For the flavor attribute, a statistically significant difference was found between the 40% and 72% cocoa formulations ($U = 1638.000$; $p = 0.012$), with the 40% formulation receiving higher ratings. However, no significant differences were observed between the 40% and 60% ($p = 0.141$), or between the 60% and 72% cocoa samples ($p = 0.281$) (Table 3). Regarding overall acceptability, significant differences were identified between the 40% and 60% cocoa formulations ($U = 1747.500$; $p = 0.043$) and between the 40% and 72% cocoa formulations ($U = 1596.000$; $p = 0.006$), with the 40% formulation again being rated more favorably. No significant difference was found between the 60% and 72% cocoa formulations ($p = 0.458$)(Table 4).

In summary, the results indicate that the 40% cocoa formulation was the most positively evaluated in terms of flavor

Table 2. Nutritional Composition and Bioactive Compounds of Dark Chocolate by Cocoa Percentage (per 100 g and 20 g)

Sample	Energy (Kcal/ 100g)	CHO (g)	Sugar (g)	FIB (g)	FAT (g)	SFA (g)	Cocoa Solids	TP (mg GAE)[(a)]	TPR (mg)[(a)]	FLAV (EC + CAT) (mg)[(a)]	ORAC (µmol TE)[(a)]
40%	550	55.00	45.00	<4	30	20	~40%	600 - 1,200	200 - 450	30 - 80	6,000 - 12,000
60%	547	62.20	NR	NR	31.1	NR	~60%	900 - 1,800	300 - 650	45 - 120	9,000 - 18,000
72%	622	44.40	40.00	8.9	44.4	26.7	~70-72%	1,050 - 2,100	350 - 750	50 - 140	10,500 - 21,000
40%	110	11.00	9.00	<1	6	4	~40%	120 - 240	40 - 90	6 - 16	1,200 - 2,400
60%	109	12.44	NR	NR	6.2	NR	~60%	180 - 360	60 - 130	9 - 24	1,800 - 3,600
72%	124	8.88	8.00	1.8	8.9	5.3	~70-72%	210 - 420	70 - 150	10- 28	2,100 - 4,200

Abbreviations: CHO, carbohydrates; PRO, protein; FAT, total fat; FIB, dietary fiber; TP, total polyphenols; TPR, total procyanidins; FLAV, flavanols (epicatechin [EC] + catechin [CAT]); ORAC, oxygen radical absorbance capacity; GAE, Gallic Acid Equivalents; TE, Trolox Equivalents (ORAC method); NR= Not Reported

(a) Data for bioactive compounds are presented as ranges derived from a synthesis of four published studies on commercial dark chocolate[20–23].

Table 3. Mann-Whitney Test statistics of the three formulations of Peruvian commercial Dark Chocolate (40%; 60% y 72% of cacao) on flavor sub-analysis

40% - 60%		60% – 72%		40% – 72%	
	Color		Color		Color
Mann-Whitney U	1862,500	Mann-Whitney U	1946,000	Mann-Whitney U	1638,000
Wilcoxon W	4073,500	Wilcoxon W	4157,000	Wilcoxon W	3849,000
Z	-1,471	Z	-1,077	Z	-2,505
Asymp. Sig. (2-tailed)	,141	Asymp. Sig. (2-tailed)	,281	Asymp. Sig. (2-tailed)	,012

Table 4. Mann-Whitney Test statistics of the three formulations of Peruvian commercial Dark Chocolate (40%; 60% y 72% of cacao) on Overall_Acceptability sub-analysis

40% - 60%		60% – 72%		40% – 72%	
	Color		**Color**		**Color**
Mann-Whitney U	1747,500	Mann-Whitney U	1596,000	Mann-Whitney U	2019,500
Wilcoxon W	3958,500	Wilcoxon W	3807,000	Wilcoxon W	4230,500
Z	-2,028	Z	-2,753	Z	-,743
Asymp. Sig. (2-tailed)	,043	Asymp. Sig. (2-tailed)	,006	Asymp. Sig. (2-tailed)	,458

and overall acceptability, suggesting a sensory preference among panelists for chocolates with lower cocoa content in this study.

DISCUSSIONS

The results of this study indicate a clear preference for the 40% cocoa chocolate formulation across all assessed sensory attributes, particularly in flavor and overall acceptability. These findings are partially consistent with those of Torres-Moreno et al., 2012[24], who reported significant variability in chocolate acceptability depending on cocoa bean type and roasting duration, with flavor identified as the primary determinant of consumer choice. While all three formulations (40%, 60%, and 72% cocoa) in our study received favorable ratings for color, aroma, and texture, statistically significant differences were observed only for flavor ($H = 6.412$; $p = 0.041$) and overall acceptability ($H = 8.126$; $p = 0.017$), as determined by the Kruskal–Wallis test.

These results suggest that increasing cocoa content significantly influences flavor perception, with a noticeable trend toward decreased preference as cocoa solids increase—likely due to the bitterness and astringency associated with higher phenolic compound concentrations. Post hoc analyses confirmed these findings: the 40% cocoa chocolate was rated significantly higher in flavor than the 72% formulation ($U = 1638.000$; $p = 0.012$), and in overall acceptability compared to both the 60% ($U = 1747.500$; $p = 0.043$) and 72% formulations ($U = 1596.000$; $p = 0.006$). No significant differences were observed between the 60% and 72% samples, suggesting that acceptability may stabilize or decline beyond a certain cocoa threshold among untrained consumers.

Unlike Torres-Moreno et al., 2012, who identified a bimodal distribution of preferences suggesting divergent consumer segments, our untrained panel of 66 participants showed less dispersion and generally high acceptance scores. This reduced polarization may reflect familiarity with local chocolate profiles and highlights the importance of cultural context in sensory evaluation. These findings emphasize the need to balance bioactive compound concentrations with sensory appeal when developing higher-cocoa chocolate products. Although the functional health benefits of dark chocolate are well documented, sensory characteristics remain crucial for consumer acceptance, particularly in populations more accustomed to sweeter profiles.

Torres-Moreno et al., 2012 also found that regular chocolate consumers assigned significantly higher scores than non-consumers, supporting the role of consumption frequency in shaping preferences. This aligns with the work of Duffy et al.[25], who showed that sensory acceptability depends not only on flavor but also on exposure and adaptation. Similar trends have been observed in other bitter foods and beverages, where repeated consumption leads to increased liking[26,27]. These findings suggest that familiarization is a viable strategy for increasing acceptance of higher-cocoa chocolates, thereby enhancing both enjoyment and health outcomes[28]. Our study also aligns with Martins et al. (2023), who found that chocolates with higher concentrations of theobromine, caffeine, and anthocyanins were less preferred due to increased bitterness and astringency. Similarly, our 40% cocoa formulation received significantly higher scores for flavor ($p = 0.012$) and overall acceptability ($p = 0.006$) than higher cocoa variants. While Martins et al. identified fruity and caramel notes as key drivers of acceptance, our 40% sample was distinguished by its balance in texture ($M = 7.35$) and aroma ($M = 7.12$) [29]. This variation may reflect differences in cocoa origin, genetic profile, and manufacturing practices. Regarding texture, all three formulations scored highly (>6.9) without significant differences ($p = 0.225$), contrasting with Martins et al.[29], who reported negative correlations between texture and melting characteristics. The use of commercial chocolate in our study likely contributed to this consistency, as industrial formulations often standardize textural quality regardless of cocoa concentration. The intense flavors of high-cocoa chocolates may also mask aromatic and textural attributes, which were more perceptible and positively evaluated in the 40% sample. Although we did not chemically analyze the chocolates, our sensory results support the hypothesis that higher concentra-

tions of bioactive compounds—such as those described by Martins et al.—may decrease acceptance among casual consumers. Future research should incorporate compositional analyses of Peruvian chocolates to directly correlate chemical profiles with sensory attributes[29].

These findings have important implications for the Peruvian chocolate industry. While Martins et al.[29], propose using cocoa hybrids to enhance flavor in high-cocoa formulations, our results suggest that lower cocoa percentages (40%) may be more appealing to mass-market consumers without sensory training. This does not preclude the marketability of higher cocoa chocolates but highlights the need for educational efforts and gradual exposure to promote their acceptance, particularly in light of their health-promoting properties[28]. It is important to note that differences in sample type limit comparisons with studies like Martins et al.[29], which used cocoa samples of known genetic origin.

Future studies should explore the integration of chemical analysis with consumer segmentation (e.g., regular vs. occasional consumers) and assess how nutritional information may influence preference. When compared with Leite et al. (2013)[30], who evaluated Brazilian cultivars at a fixed cocoa concentration (67%), our study—focusing on variable cocoa percentages—revealed more pronounced differences in consumer preference. While Leite et al.[30] reported consistently high acceptance across cultivars, our findings suggest that cocoa content exerts a stronger influence on sensory perception than origin alone. Specifically, the 40% cocoa formulation received the highest overall acceptability (M = 7.68), outperforming the 60% and 72% variants. This supports the view that a lower intensity of bitterness and a better balance with sweetness appeal more to untrained consumers. Both studies identified flavor as the most discriminating attribute, and while texture remained consistently rated across all samples, our results suggest a decline in aroma scores as cocoa content increased (6.77 vs. 7.12). This underscores the heightened sensitivity to flavor in untrained panels and supports the use of intermediate cocoa formulations (40–60%) as an optimal balance between sensory appeal and potential health benefits.

Marketing strategies should account for consumer familiarity and sensory training levels. While Leite et al.[30] emphasized differences between cultivars, our findings reinforce the influence of cocoa percentage as a key factor in acceptance. For broad-market appeal, tailoring products to specific demographic profiles—particularly by balancing flavor intensity and bitterness—may be critical to consumer satisfaction. Consistent evidence suggests that repeated exposure enhances acceptance of dark chocolate's sensory characteristics. Studies indicate that regular consumers rate dark chocolate more favorably than occasional consumers, and this adaptation process parallels that observed with other bitter foods. Gradual exposure to higher-cocoa chocolates in younger populations may foster long-term appreciation for healthier formulations. Moderate consumption of dark chocolate with high cocoa content (≥70%) has been associated with cardiovascular benefits, largely due to its polyphenolic compounds. A standard 20 g serving provides approximately 100–120 kcal and 5–8 g of added sugar, while contributing ~70–150 mg of procyanidins and ~10–28 mg of flavanol monomers (epicatechin + catechin) (Table 2). These flavanols enhance endothelial function through increased nitric oxide bioavailability, reduce oxidative stress, and exert anti-inflammatory effects, together supporting vascular health. Consistent with these observations, Miller et al. (2009) reported that a typical serving of dark chocolate delivers higher levels of antioxidants and procyanidins than many commonly consumed foods[20]. Incorporating 20–40 g of high-cocoa dark chocolate into the diet may therefore represent a practical strategy to increase total dietary polyphenol intake, which has been broadly associated with reduced cardiometabolic risk and improved overall health outcomes.

From a public health perspective, targeted interventions are warranted to encourage higher-cocoa chocolate consumption among younger consumers. Educational initiatives should highlight the dose-dependent health effects of cocoa bioactives, particularly their roles in cardiovascular and cognitive function. Nutrition education can also mitigate initial sensory resistance by emphasizing adaptation strategies and long-term benefits. These findings suggest opportunities for collaboration between the food industry and public health efforts. Intermediate products (60–72% cocoa) could function as transitional options, bridging the gap between low-cocoa confections and more healthful high-cocoa alternatives. Marketing strategies that associate dark chocolate with active, health-conscious lifestyles may further enhance its appeal among younger demographics. Although current preferences tend toward lower cocoa percentages, this trend represents an opportunity rather than a limitation. With strategic product development, education, and exposure, younger consumers can be guided toward higher-cocoa dark chocolate, aligning industry growth with improved public health outcomes.

CONCLUSIONS

This study revealed that cocoa percentage significantly affects the sensory perception of chocolate, particularly in the attributes of flavor and overall acceptability, where statistically significant differences were found ($p = 0.041$ and $p = 0.017$, respectively). The 40% cocoa formulation was significantly preferred over the 72% and 60% formulations in terms of flavor and overall acceptability. These results indicate a distinct preference among younger consumers for chocolate with 40% cocoa, attributed to its more balanced sensory profile and reduced bitterness. Although preference leaned toward lower cocoa content, this insight presents opportunities for

product development and educational strategies to guide consumers toward formulations with greater health benefits.

Future research should prioritize the development and evaluation of intervention strategies aimed at enhancing the acceptance of higher-cocoa dark chocolate among younger demographics. This may involve conducting longitudinal studies to monitor shifts in preference subsequent to controlled exposure protocols, as well as examining the optimal cocoa content thresholds that effectively balance health benefits with sensory acceptability. Furthermore, investigations should consider how product formulation and presentation—such as the pairing of complementary flavors or the provision of health-related information—could potentially improve the initial acceptance of higher-cocoa chocolates.

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