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Abstract

The factors influencing consumer acceptability of hot cocoa-based beverages prepared with pure cocoa powders were studied. Five samples originating from various regions were selected, including ~~both~~ alkalized and non-alkalized (natural) ~~cocoa powders~~, and ~~both~~ regular and fat-reduced cocoa powders. Sensory evaluation of the samples was conducted using a 5-point just-about-right (JAR) scale and a 9-point hedonic scale, with a total of 116 participants ~~involved in the study~~. Principal Component Analysis (PCA) highlighted the relationship between acceptability and alkalization, fat content, and phenolic composition. Alkalized samples received higher scores than natural ones in color (6.9 vs 5.6), smell (5.9 vs 5.7), flavor (5.8 vs 4.9), texture (6.0 vs 5.7) and overall (6.0 vs 5.2), ~~all acceptability categories~~, while regular cocoa powders received higher scores than low-fat samples ~~were evaluated less favorably than regular cocoa powder samples~~ in color (6.6 vs 5.8), smell (6.3 vs 5.4), flavor (5.9 vs 4.8), texture (6.2 vs 5.6) and overall (6.1 vs 5.1). ~~Additionally,~~ A phenolic content above 30 g GAE/kg d.w. ~~resulted in~~ decreased the preference. Comprehensive insights on the effect of fat reduction and alkalization ~~process~~ on ~~the~~ physicochemical and sensory properties of cocoa are provided, contributing to the ~~intricate~~ array of factors influencing the acceptability of cocoa ~~products~~. It is important to note that the origin may also influence cocoa composition, underscoring the need for further studies to explore this ~~variable~~.

Key words: Cocoa powder; just-about-right scale; alkalization; ~~consumer perception, acceptability,~~ hedonic scaling; willingness-to-buy

1. Introduction

Cocoa is derived from the fatty seeds known as 'cocoa beans' obtained from the *Theobroma cacao* tree. These beans are processed into a paste called 'cocoa liquor', which contains non-fat cocoa solids and cocoa butter. By removing the cocoa butter from the liquor, 'cocoa powder' is obtained (Beg, Ahmad, Jan, & Bashir, 2017). The cocoa powder market was valued at USD 2.610 billion in 2020, and is expected to grow at a compound annual growth rate (CAGR) of 3.69% until 2027, reaching USD 3.369 billion by that date (Knowledge Sourcing Intelligence 2022). Moreover, Europe is projected to hold a significant market share in the global cocoa powder industry during this period. In addition to its pleasant flavor and aroma, the health benefits attributed to cocoa are further driving its market growth (Knowledge Sourcing Intelligence 2022). The health benefits linked to cocoa are primarily attributed to the robust antioxidant activity of cocoa polyphenols, notably flavonoids (Ried, Fakler, & Stocks, 2017). Among these, the primary flavonoids found in cocoa include flavan-3-ols (mainly catechin and epicatechin), their oligomers and polymers (procyanidins) (Gu, House, Wu, Ou, & Prior, 2006). Cocoa also contains other flavonoids such as ~~epicatechin,~~ quercetin and isoquercetin, flavones such as luteolin and apigenin, ~~alongside~~ flavanones such as naringenin, ~~and as well~~ anthocyanins and phenolic acids. These compounds are associated with various benefits for the cardiovascular system, reduction in insulin resistance, anti-inflammatory properties, positive effects on gut microbiota and enhancement of cognitive function, as reviewed by Palma-Morales et al. (2023). Additionally, cocoa harbors interesting compounds like methylxanthines, with theobromine being the primary one present in cocoa beans, accompanied by lesser quantities of caffeine and theophylline. These compounds exert physiological and psychological effects on humans (Franco, Oñatibia-Astibia, & Martínez-Pinilla, 2013).

Nevertheless, the composition of cocoa and its derived products varies significantly, reliant on the genotype of the cocoa plant, geographic location, farming methods, and various manufacturing processes, among other influential elements (Carrillo Hormaza, Londoño, & Gil, 2014; Meng, Jalil, & Ismail, 2009; Miller et al., 2009). Despite the acknowledged health benefits associated with the bioactive compounds present in cocoa, the high levels of polyphenols and methylxanthines impact its taste and confer astringency and bitterness (Febrianto & Zhu, 2020) mostly in a negative way. Consequently, the processing of cocoa beans becomes essential to develop an appealing color, taste and flavor while mitigating the astringency and bitterness typically found in cocoa. However, these processing methods alter the qualitative and quantitative composition of bioactive compounds (Goya, Kongor, & de Pascual-Teresa, 2022). Fermentation, drying, roasting and, specially, alkalization reduce the phenolic and methylxanthine contents within cocoa (Sioriki et al., 2021; Valverde García, Pérez Esteve, & Barat Baviera, 2020). Alkalization, a technique involving the infusion of cocoa with an alkaline solution and subjecting it to specific temperatures (between 60-130ºC) and pressures (between 0.10 and 1.22 MPa) for durations lasting from 5 to 180 minutes, is an optional process but is very useful to reduce generally undesirable attributes such as astringency, acidity and bitterness, resulting in a darker color and an easier solubility of cocoa (Valverde García et al., 2020). These alterations could be expected to influence the consumer acceptance of cocoa (Pathare, Opara, & Al-Said, 2013).

In this regard, different scales can be applied for the sensory evaluation of cocoa products. The just-about-right (JAR) scale, widely used in new product development as a consumer research technique, is employed to determine whether the sensory attributes present in the food are optimally balanced or, on the contrary, if their intensity is excessive or deficient. This method employs scales for different attributes, prompting consumers to indicate whether each attribute reaches the ideal point "Just about right" or has either "too little" or "too much" of the different attributes (Fernández Segovia, García Martínez, & Fuentes López, 2018; Song, Xia, & Zhong, 2021). In food sensory analysis, JAR scales are often combined with hedonic measures, such scales for global acceptance and purchase intention. In this way, more complete results can be obtained as it is possible to know how deviations from JAR for specific attributes affect the overall acceptance or purchase decision (Fernández Segovia et al., 2018). On the other hand, the hedonic scale and the purchase intention scale measure consumer preferences and acceptability (Aribah, Sanjaya, Muhammad, & Praseptiangga, 2020; Fernández Segovia et al., 2018). The JAR scale has previously been used in the sensory analysis of cocoa drinks (Juvinal et al., 2023), while the hedonic scale is more commonly used in the evaluation of both chocolate and cocoa drinks (Aribah et al., 2020; Brown, Warren, Ingraham, Ziegler, & Hopfer, 2023; Dimas Rahadian, Maya Marettama, Fauza, & Rachmawanti Affandi, 2022; Ndife, Bolaji, Atoyebi, & Umezurulke, 2013; Wagner, Wilkin, Szymkowiak, & Grigor, 2023).

Relatively few studies have investigated the attributes that may affect the acceptability of different cocoa products by consumers so far. A sensory evaluation of chocolate demonstrated that samples perceived as astringent scored lower in flavor, aroma, and texture attributes and in overall acceptability. In terms of color, lighter-colored samples were favorably evaluated (Ndife et al., 2013). In another sensory study of different cocoa percentage (36%, 70%, and 85%) dark chocolate samples, the 70% sample was the most preferred, followed by the 36% and 85% samples, with significant differences noted between the most bitter (85%) and the other samples (Wagner et al., 2023). Additionally, a sensory analysis of 70% cocoa dark chocolate revealed that cocoa fat content significantly decreases the perceived intensities of bitter taste, cocoa flavor and drying mouthfeel, and increased the perceived intensity of sweetness, but does not significantly affect chocolate liking (Brown et al., 2023). However, there is a lack of studies focused on evaluating the effect of alkalization. In the lone exception, a study analyzing two cocoa beverages (one prepared with alkalized cocoa and the other with non-alkalized cocoa), descriptive analysis favored alkalized cocoa due to attributes like color intensity, viscosity, chocolate flavor, sweetness, and bitter aftertaste but consumer acceptability was comparable for both beverages. Combining consumer acceptability data and descriptive sensory data highlighted specific attributes as positive indicators, such as chocolate flavor, viscosity, and bitter aftertaste. Interestingly, the darker color resulting from the alkalized cocoa powder does not increase consumer preference (Juvinal et al., 2023). Nevertheless, cold beverages were used in this occasion.

Against this backdrop, this research aimed to investigate the factors that might affect the cocoa powder-based hot beverages acceptability. Emphasis was placed on the alkalization process which has a direct impact in the phenolic content composition. The goal is to identify a cocoa powder with a compelling array of bioactive compounds and widespread acceptability for potential use in upcoming clinical trials.

2. Materials and methods

2.1. Chemicals

Gallic acid and the pure standards catechin, caffeine and theobromine were acquired from Sigma-Aldrich (St. Louis, MO, USA), while Na2CO3 was purchased from BDH AnalaR (Poole, UK). Ultrapure water was obtained from a Milli-Q system (Millipore, Bedford, MA, USA). Lastly, HPLC-grade water, Folin–Ciocalteu reagent, acetid acid, acetonitrile, sodium acetate and methanol were acquired from Merck KGaA (Darmstadt, Germany).

2.2. Samples

Five samples (Figure 1) were chosen based on the findings from a previous study (Razola-Díaz et al., 2023). Samples from four different origins were included: West Africa, Dominican Republic, Ivory Coast and Peru (Table 1). Two alkalized cocoa powder (samples 2 and 4) and three non-alkalized cocoa powder (samples 1, 3 and 5) were chosen. According to the International Food Standards of the Codex Alimentarius, "cocoa powder" contains >200 g/kg fat, and "fat-reduced cocoa powder" contains between 100 and 200 g/kg fat (FAO & WHO, 2022). Among the samples, two were cocoa powder (samples 3 and 4) and three were fat-reduced cocoa powder (samples 1, 2 and 5), so that all possible combinations of alkalization and fat level were included (Table 1). The total content of phenolic (TPC) compounds, flavan-3-ols and methylxanthines was also considered ~~taken into account~~ (Table 2), so that the samples with the highest and the lowest total content of phenolic, flavan-3-ols and methylxanthines were included.

2.3. Total phenolic content

Briefly, the total phenolic content (TPC) in cocoa powder samples was determined using the Folin–Ciocalteu spectrophotometric method. To summarize, 100 µL of phenolic extract from cocoa was combined with 500 µL of the Folin–Ciocalteu reagent. Following this, 6 mL of bi-distilled water was added, and the mixture was agitated for one minute. Subsequently, 2 mL of 15% (w/v) Na2CO3 was added, and the volume was adjusted to 10 mL with bi-distilled water. The flasks were then placed in darkness for 2 hours, and measurements were taken at 750 nm and 25 °C using a UV-visible spectrophotometer (Spectrophotometer 300 Array, UV-Vis, single beam, Shimadzu, Duisburg, Germany). Gallic acid was utilized to construct the calibration curve ranging from 0.001 to 1 g/kg. The results are presented as g gallic acid equivalents (GAE)/kg dry weight (d.w.).

2.4. Procyanidin content

The procyanidin content in the cocoa samples was determined following the methodology previously outlined by Gómez-Caravaca et al. (2016). An Agilent 1200-LC system (Agilent

Technologies, Palo Alto, CA, USA) equipped with a vacuum degasser, autosampler, binary pump, and DAD was used for the chromatographic determination. The column was a Poroshell 120 EC-C18 (4.6 mm × 100 mm, particle size 2.7 µm) (Agilent Technologies, Palo Alto, CA, USA). The temperature was established at 25°C. Mobile phases consisting of 10 mL/L acetic acid (A) and acetonitrile (B) and the following gradient elution: 0 min, 0.8% B; 5.5 min, 6.8% B; 16 min, 20% B; 20 min, 25% B; 25 min, 35% B; 29 min, 100% B; 32 min, 100% B; 34 min, 0.8% B; 36 min, 0.8% B. The column was allowed to equilibrate for 3 minutes before each analysis. A sample volume of 3 µL was injected, and a flow rate of 0.8 mL/min was employed. MS analysis were carried out using a 6540 Agilent Ultra-High-Definition Accurate-Mass q-TOF-MS coupled to the HPLC, equipped with an Agilent Dual Jet Stream electrospray ionization (Dual AJS ESI) interface in negative ionization mode at the following conditions: drying gas flow (N2), 12.0 L/min; nebulizer pressure, 50 psi; gas drying temperature, 370°C; capillary voltage, 3500 V; fragmentor voltage, and scan range were 3500 V and m/z 50–1500, respectively. Automatic MS/MS experiments were carried out using the followings collision energy values: m/z 100, 30 eV; m/z 500, 35 eV; m/z 1000, 40 eV; and m/z 1500, 45 eV. (Gómez-Caravaca, López-Cobo, Verardo, Segura-Carretero, & Fernández-Gutiérrez, 2016). Catechin was utilized as the standard for quantifying flavan-3-ols at six concentration levels ranging from 0.01 to 0.65 g/kg. Moreover, the correction factors proposed by Robbins et al. were applied (Robbins et al., 2009). The results are presented as g catechin equivalents (CE)/kg d.w.

2.5. Caffeine and theobromine

Finally, the determination of caffeine and theobromine followed the procedure previously outlined by Alañon et al. (2016). An Agilent 1200 Series system (Agilent Technologies, Palo Alto, CA, USA) equipped with a quaternary pump delivery system, a degasser, an autosampler, and a photodiode array detector (DAD) set at 264 nm was utilized for the analyses. An Agilent Zorbax Eclipse XDB-C18 column 5 µm, 150 × 4.6 mm ID (Agilent Technologies, Palo Alto, CA, USA) was employed. The mobile phase consisted of water (A), 0.2 mol/L sodium acetate/methanol 840/160 mL pH 4.4 (B), methanol (C), and acetonitrile (D). The gradient elution program was as follows: 25% B at 0 min, 25% B and 75% C for 3 min, 25% B and 50% D for 10 min, and 25% B for 25–40 min. The injection volume was 100 µL, and the flow rate was maintained at 1 mL/min. Standard curves for caffeine and theobromine were constructed at six concentration levels ranging from 0.04 to 1.25 g/kg for quantification purposes. The results are expressed as g/kg d.w. All analyses were carried out in triplicate.

Table 1: Cocoa powders samples used in the study. The samples were chosen based on a previous study (Razola-Díaz et al., 2023) and varied in origin, alkalization, and fat level.

	Origin	**Alkalized**	**Fat level**
Sample 1	West Africa	Not alkalized	Fat reduced (110 g/kg fat)
Sample 2	West Africa	Alkalized	Fat reduced (120 g/kg fat)
Sample 3	Dom. Rep.	Not alkalized	Cocoa powder (210 g/kg fat)
Sample 4	Ivory coast	Alkalized	Cocoa powder (230 g/kg fat)
Sample 5	Peru	Not alkalized	Fat reduced (120 g/kg fat)

Table 2: Nutritional and chemical composition of the cocoa powder samples. Nutritional information were provided by the manufacturers and are given as values per 100 g of product. Phenolic and flavan-3-ol content of cocoa extracts were analyzed by HPLC-FLD and methylxanthines content of cocoa extracts analyzed by HPLC-DAD, expressed as g/kg dry weight (d.w.). All analyses were carried out in triplicates. Chemical composition data are given as means (M) with 95% confidence intervals (C.I.). Degrees of Freedom (d.f.), test statistic (F) and significance value (p) from ANOVA are also given. Different superscript letters within the same column indicates significant differences ($p < 0.05$) according to Tukey's test.

	Nutritional information						
	Energy (kj)	Total fat (g)	Saturated fat (g)	Carbohydrates (g)	Sugars (g)	Proteins (g)	Salt (g)
Samples							
Sample 1	1297.0	11.0	7.0	15.0	2.0	23.0	0.060
Sample 2	1251.0	12.0	7.4	14.1	1.9	22.0	0.025
Sample 3	1548.1	21.0	13.0	9.0	0.4	19.4	0.040
Sample 4	1606.7	23.0	14.0	9.0	0.0	19.0	0.040
Sample 5	1338.9	12.0	7.0	28.0	1.4	19.0	0.000

	Phenolic and flavan-3-ol content														
	TPC (g GAE/kg d.w.)					Cat + Epicat (g CE/kg d.w.)					Procyanidins (g CE/kg d.w.)				
	M	95% C.I. [low, high]	d.f	F	p	M	95% C.I. [low, high]	d.f	F	p	M	95% C.I. [low, high]	d.f	F	p
Samples			4	702.8	< 0.0001			4	112027.0	< 0.0001			4	180084.3	< 0.0001
Sample 1	34.2^{b}	[33.9 ,34.5]				4.20^{b}	[4.19, 4.21]				1.13^{b}	[1.13, 1.13]			
Sample 2	9.2^{e}	[7.3 ,11.1]				1.10^{e}	[1.09, 1.11]				0.11^{e}	[0.10, 0.12]			
Sample 3	28.7^{c}	[27.6 ,29.8]				4.13^{c}	[4.12, 4.14]				0.61^{c}	[0.61, 0.61]			
Sample 4	13.5^{d}	[11.0 ,16.0]				2.24^{d}	[2.23, 2.25]				0.25^{d}	[0.25, 0.25]			
Sample 5	57.4^{a}	[55.6 ,59.2]				7.82^{a}	[7.79, 7.85]				2.09^{a}	[2.09, 2.09]			

	Methylxanthines content															
	Caffeine (g/kg d.w.)					Theobromine (g/kg d.w.)					Total methylxanthines (g/kg d.w.)					T/C ratio
	M	95% C.I. [low, high]	d.f	F	p	M	95% C.I. [low, high]	d.f	F	p	M	95% C.I. [low, high]	d.f	F	p	~~M~~
Samples			4	115.8	< 0.0001			4	6.9	0.006			4	50.2	< 0.0001	
Sample 1	13.6^{b}	[13.5, 13.7]				8.9^{b}	[8.3, 9.5]				22.5^{bc}	[21.8 ,23.2]				0.7

Sample 2	14.2[b]	[10.2, 18.2]				13.3[ab]	[13.2, 13.4]				27.5[b]	[23.5 ,31.5]				0.9
Sample 3	5.4[c]	[5.3, 5.5]				14.0[a]	[12.9, 15.1]				19.4[c]	[18.2 ,20.7]				2.6
Sample 4	11.2[b]	[11.1, 11.3]				12.3[ab]	[9.7, 14.9]				23.5[bc]	[20.9 ,26.1]				1.1
Sample 5	27.1[a]	[27.0, 27.2]				12.1[ab]	[9.2, 15.0]				39.2[a]	[36.3 ,42.1]				0.4

Figure 1. Visual illustration of the samples (Samples 1 to 5 from left to right) in powder (top) and beverage (bottom) form.

2.6. Sample preparation and serving

Cocoa powders were obtained from the Spanish market based on the nutritional composition of cocoa while the semi-skimmed milk (16 g/L fat, 48 g/L carbohydrates, 31 g/L protein and 1.3 g/L salt, Hacendado, Granada, Spain), was purchased from a supermarket.

The evaluation was a two-step process. Attributes were previously explained to the participants. The first step consisted of the evaluation of the cocoa powder while the second one included the evaluation of the cocoa-based beverage. For that end, 3 g of cocoa powder was poured into a transparent cup for participants to first assess three attributes about the cocoa powder (appearance of color and the aroma intensity and sweetness). Semi-skimmed milk was then heated at 70 °C and 100 mL was added to each participant to dissolve the powder in the milk (Figure 1) for the further evaluation of the different attributes of the cocoa beverage i.e., appearance of color and the aroma intensity and sweetness, the basic tastes sweet, bitter, and sour, the flavor of earthy, and texture and mouthfeel of astringent, soluble, creamy, lumpy and sticky. Serving temperature was 52.3 ± 1.5 °C. Finally, the overall intensity was evaluated. The serving order was 1-2-3-4-5.

2.7. Sampling and Inclusion Criteria

The study sample was non-probabilistic, with inclusion criteria being people over 18 years of age of both genders. The sample size was set beforehand according to current guidelines for sensory acceptability studies where >100 tested consumers are considered an adequate number (Dooley, Lee, & Meullenet, 2010). A total of 116 participants took part in the study (mean age 27 ± 11.5 y, 78 % women), whereof 59 % were regular consumers of cocoa-based beverages. The study took place on seven consecutive days in Spring 2023. Participants took part in the study on a voluntary basis and received no compensation for their time. The study was conducted in agreement with the Declaration of Helsinki, and all data were recorded according to the Spanish Organic Law of Personal Data Protection (LOPD) 15/1999. The study received approval from the ethics committee at University of Granada (N˚ 4008/CEIH/2024).

2.8. Sensory evaluation

Sensory evaluation of the samples was carried out using a 5-point just-about-right (JAR) scale and a 9-point hedonic scale for different attributes of color, aroma, taste, and texture. Additionally, the hedonic scale included the overall acceptability of the cocoa beverage. JAR scale was used to quantify the appropriateness of the intensity of the sensory attributes using a bipolar scale (1="too little" of the characteristic, 3="JAR", 5="too much" of the characteristic). Hedonic scale ranged from 1="dislike extremely" to 9="like extremely". A willingness to buy (WTB) question was also included in the tasting sheet (1="I would surely not buy it", 3="I would maybe buy it", 5="I would surely buy it") also asked to gauge purchase intention.

2.9. Data Analysis

One-way Analysis of Variance (ANOVA) was used to test for significant differences ($\alpha = 0.05$) between means of samples, alkalization and fat level on an aggregate level, both for the liking scores (color, smell, flavor, texture and overall) and for the JAR scores, to compare liking means between the scores of "JAR" and "too little / "too much". The 5 -point JAR scale was converted into a 3-point JAR for the sake of simplicity as well as to avoid having categories with no or very few data points. When significant differences were found, the ANOVA was followed by post-hoc analysis of significant differences by Tukey's Honestly Significant Differences (HSD) test. Percentages for use of the JAR scale (i.e., number of consumers ticking the different points of the JAR scale relative out of the 116 that took part in the study) was also calculated to aid in the interpretation of the severity of the different deviations from JAR.

To visualize the differences between samples and the correlation between variables, Principal Component Analysis (PCA) was performed on a matrix containing the mean liking scores (color, smell, flavor, texture and overall), willing to buy WTB score, origin, processing, nutritional value, phenolic and methylxanthines content for each sample. The analysis was performed on mean-centered, standardized data using the FactoMineR package (Le Dien & Pagès, 2003) in the statistical environment R (R Core Team, 2021).

3. Results

3.1. Liking scores and Willingness to buy – Samples effect

There were significant differences ($p < 0.001$) between two or more samples for all liking scores (color, smell, flavor, texture and overall) (Table 3). Samples 4 and 3 received the highest liking score in smell, flavor, texture and overall, whereas samples 2 and 4 received the highest liking score in color.

Four of the five cocoa samples were, on average, more liked than disliked with an average mean liking score of 5.7, slightly over the neutral point of the 9-pt hedonic scale (5). Only sample 5 was, on average, slightly disliked with a mean liking score of 4.6. Samples 4 and 3 were both slightly liked with an average liking score of 6.4 and 6.0, respectively.

The mean flavor and overall liking scores were highly correlated with WTB (Pearson's $r = 0.9$). Accordingly, the consumers had in general significantly higher WTB sample 4, followed by sample 3 and least WTB sample 5, followed by sample 1 (Table 3). Color, smell, and texture were moderately correlated (Pearson's $r = 0.5$) with the WTB scores.

Regular consumers of cocoa-based beverages (59% of the sample) were significantly ($p = 0.01$) more willing to buy cocoa powder in general. The consumers who typically consume cocoa-based beverages also liked the flavor of the cocoa samples (Mean = 5.4), on average, significantly ($p = 0.043$) more than those who did not (Mean = 5.1). The gender and age of the consumers had no significant effect on either liking scores (gender $p=0.708$, age $p=0.582$) or WTB (gender $p=0.914$, age $p=0.246$), based on an ANOVA analysis.

3.2. Liking and ~~WTB~~ Willingness to buy – Effect of alkalization and fat level

Both the alkalization process and the fat level of the samples had a significant influence on all liking scores and WTB (Table 3). Specifically, the alkalized samples (Samples 2 and 4) received a higher liking score in all liking categories, and the effects were significant for color, flavor, texture and overall. Also, the WTB was significantly higher for the alkalized than the non-alkalized samples.

The fat reduced samples were significantly liked less in all liking categories, and the WTB was likewise significantly lower than the regular cocoa powders.

Table 3: Mean liking and WTB scores (N=116), pooled 95% confidence intervals for each sample (cocoa 1-5), and for alkalization (alkalized and not alkalized) and fat level (cocoa powder and fat reduced). Liking was measured on a 9-point scale went from 1 to 9 corresponding to "dislike extremely" to "like extremely". WTB was measured on a 5-point scale from 1 to 5 corresponding to "surely no" to "surely yes". Results are given as means (M) with 95% confidence intervals (C.I.) for sample, alkalization, and fat level. Degrees of Freedom (d.f.), test statistic (F) and significance value (p) from ANOVA are also given. Means that do not share superscript are significantly different according to Tukey's HDS test.

Table 3.

	Color					Smell					Flavor				
	M	95% C.I. [low, high]	d.f	F	p	M	95% C.I. [low, high]	d.f	F	p	M	95% C.I. [low, high]	d.f	F	p
Samples			4,575	63.8	< 0.0001			4,575	16.1	< 0.0001			4,575	18.2	< 0.0001
Sample 1	6.1^{c}	[5.8 ,6.4]				6.0^{a}	[5.7, 6.3]				4.8^{bc}	[4.4, 5.1]			
Sample 2	7.0^{a}	[6.7 ,7.2]				5.3^{b}	[5.0, 5.6]				5.3^{b}	[5.0, 5.7]			
Sample 3	6.4^{bc}	[6.1 ,6.7]				6.1^{a}	[5.8, 6.4]				5.5^{b}	[5.1, 5.8]			
Sample 4	6.8^{ab}	[6.6, 7.1]				6.5^{a}	[6.2, 6.7]				6.4^{a}	[6.0, 6.7]			
Sample 5	4.2^{d}	[3.9, 4.5]				5.0^{b}	[4.7, 5.3]				4.4^{c}	[4.0, 4.7]			
Alkalization			1,578	88.2	< 0.0001			1,578	1.7	0.190			1,578	33.8	< 0.0001
Alkalized	6.9^{a}	[6.7, 7.1]				5.9	[5.7, 6.1]				5.8^{a}	[5.6, 6.1]			
Not alkalized	5.6^{b}	[5.4 ,5.7]				5.7	[5.5, 5.9]				4.9^{b}	[4.7, 5.1]			
Fat level			1,578	32.9	< 0.0001			1,578	39.0	< 0.0001			1,578	43.6	< 0.0001
Cocoa powder	6.6^{a}	[6.4 ,6.8]				6.3^{a}	[6.1, 6.5]				5.9^{a}	[5.7, 6.2]			
Fat reduced	5.8^{b}	[5.6 ,5.9]				5.4^{b}	[5.3, 5.6]				4.8^{b}	[4.6, 5.0]			

	Texture					Overall					WTB				
	M	95% C.I. [low, high]	d.f	F	p	M	95% C.I. [low, high]	d.f	F	P	M	95% C.I. [low, high]	d.f	F	p
Samples			4,575	9.7	< 0.0001			4,575	22.0	< 0.0001			4,575	26.9	< 0.0001
Sample 1	5.8^{a}	[5.6, 6.1]				5.3^{b}	[5.0, 5.6]				2.5^{cd}	[2.3, 2.7]			
Sample 2	5.9^{a}	[5.6, 6.2]				5.5^{b}	[5.2, 5.8]				2.8^{bc}	[2.6, 3.0]			
Sample 3	6.2^{a}	[6.0, 6.5]				5.8^{b}	[5.5, 6.1]				3.0^{b}	[2.8, 3.2]			
Sample 4	6.1^{a}	[5.8, 6.4]				6.5^{a}	[6.2, 6.8]				3.5^{a}	[3.3, 3.7]			
Sample 5	5.1^{b}	[4.9, 5.4]				4.5^{c}	[4.2, 4.8]				2.1^{d}	[1.9, 2.3]			
Alkalization			1,578	4.3	0.039			1,578	30.5	< 0.0001			1,578	40.3	< 0.0001
Alkalized	6.0^{a}	[5.8, 6.2]				6.0^{a}	[5.8, 6.2]				3.1^{a}	[3.0, 3.3]			
Not alkalized	5.7^{b}	[5.6, 5.9]				5.2^{b}	[5.0, 5.4]				2.5^{b}	[2.4, 2.6]			
Fat level			1,578	18.6	< 0.0001			1,578	49.9	< 0.0001			1,578	67.7	< 0.0001
Cocoa powder	6.2^{a}	[6.0, 6.4]				6.1^{a}	[5.9, 6.3]				3.2^{a}	[3.1, 3.4]			
Fat reduced	5.6^{b}	[5.5, 5.8]				5.1^{b}	[4.9, 5.3]				2.5^{b}	[2.3 , 2.6]			

3.3. Relationships between design levels, instrumental variables, and sensory variables

As just established, both the alkalization and cocoa fat level affected consumer liking significantly. From Table 2, ~~we know that~~ alkalization and fat level were associated to differences in the nutritional-, phenolic- and methylxanthines content in the samples. Specifically, the alkalization process significantly decreases the phenolic content (Razola-Díaz et al., 2023), and the cocoa fat level increases the energy, saturated fat and decreased the sugar, proteins and carbohydrates.

The first two dimensions of the PCA (Figure 2) explained over 80 % of the data variance demonstrating a strong underlying structure with clear correlations between variables and visually showing the difference between samples in regards of alkalization, fat content, liking, nutrition, phenolic and methylxanthines content. The first ~~dimension~~ principal component (Dim 1, 57.8% of expl. variance) showed the difference in the liking and separated mainly between samples 3 and 4 from samples 5 (accordingly, these samples contributed 9.9 %, 27.2 % and 58.6 %, respectively, to the first principal component). This can clearly be seen when looking at the factors significantly (all $p < 0.05$) and negatively correlated to Dim 1, and they are the liking of color, flavor, texture, and overall liking, which corresponded to Samples 3 and 4. Dim 1 also explained the difference in the phenolic and methylxanthines content. In fact, polymer, antioxidant activity measured by ABTS assay, total phenolic, carbohydrate and caffeine content, were significantly (all $p < 0.05$) and positively correlated to Dim 1. Higher values in all these variables were associated with Sample 5, consistently with the values reported in Table 2.

The second dimension (Dim 2) explained 23.3 % of the data variance. Dim 2 explained mainly variation in protein content which was significantly (both $p < 0.05$) and negatively correlated to Dim 2, and primarily associated with samples 1 and 2. From Figure 2 ~~it can also be seen that~~ color liking was highly associated with the alkalization process. Further ~~it can be seen that~~ the samples classified as cocoa powder are highly associated with energy, total fat and saturated fat and the fat reduced samples are associated with sugar. Only Samples 1 and 2 are highly protein-associated, but not Sample 5 which is also non-alkalized.

The third and fourth PCA dimensions (12 % and 6.8 % of the data variance, respectively) are not shown here, but interested readers can find these results in the online supplementary material to this paper (Part A).

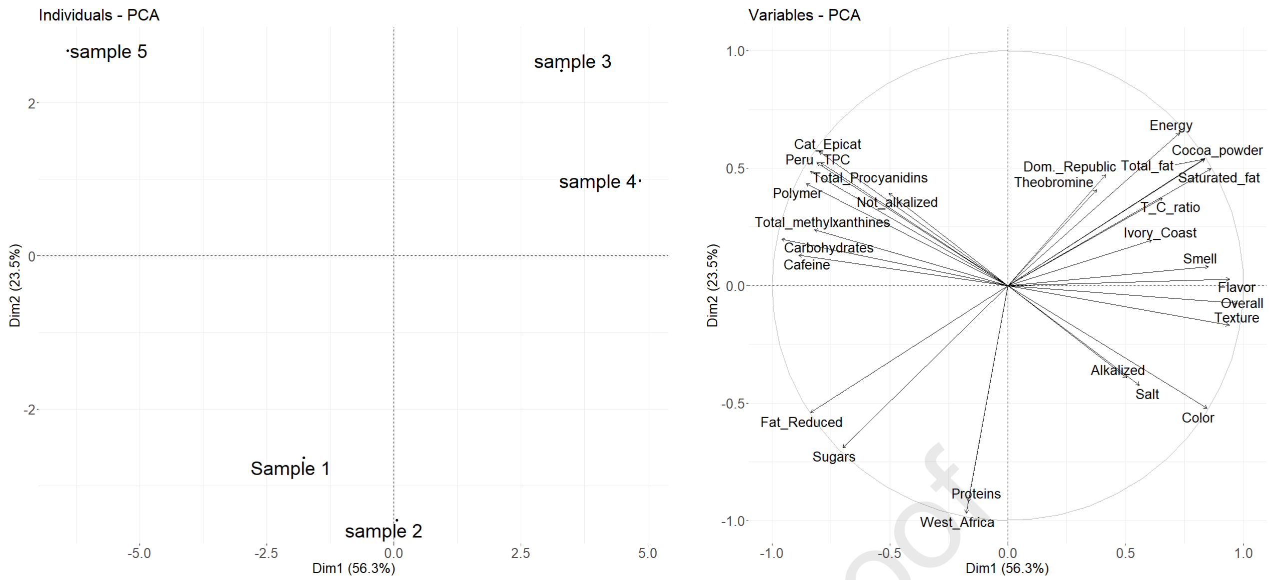

Figure 2: PCA analysis of the cocoa samples (left) representing the correlations of the liking scores, instrumental measurements, and cocoa fat level with the first two principal components.

3.4. Just About Right scores

The mean liking score, the difference in mean liking between *"Just about right"* and *"too much/not enough",* the percentage of consumers voting for each JAR category, and the p-values, can be found in Table 4. The first three attributes were evaluated on the cocoa powder, and the remaining ones were evaluated when the powder was mixed with milk.

Table 4: Mean overall liking score (N=116, 9-point hedonic liking score scale went from 1 to 9 corresponding from "dislike extremely" to "like extremely") sample 1-5, difference in mean liking between *"just about right"* and "*too much/not enough"* (Δ), and the percentage of consumers voting for each JAR category (%). The first three attributes are aroma evaluation of the cocoa powder, the next three attributes are the are aroma evaluation of the cocoa-based beverages. The remaining attributes are flavor, mouthfeel, texture, and the final attribute an overall evaluation of the cocoa-based beverages. TM: Too much, JAR: Just about right, TL: too little.

		Sample 1				Sample 2				Sample 3				Sample 4				Sample 5				Mean of all samples			
Attribute	JAR	Liking	(Δ)	(%)	p-val	Liking	(Δ)	(%)	p-val	Liking	(Δ)	(%)	p-val	Liking	(Δ)	(%)	p-val	Liking	(Δ)	(%)	p-val	Liking	(Δ)	(%)	p-val
Cocoa powder																									
Color	TM	5.2	-0.3	4.3	0.428	5.5	0.1	87.9	0.836	5.9^{a}	1.1	89.7	0.040	6.5^{a}		100	<0.000	0.0		0.0	0.904	6.0^{a}	0.7	56.4	<0.001
	JAR	5.5		51.7		5.4		12.1		4.8^{a}		9.5		0.0^{b}		0.0		4.6		6.0		5.3^{b}		15.9	
	TL	5.1	-0.4	44.0		0.0		0.0		3.0^{a}	-1.8	0.9		0.0^{b}	0.0	0.0		4.5	-0.1	94.0		4.7^{c}	-0.6	27.8	
Intensity	TM	5.7	0.4	16.4	0.077	5.7	0.2	30.2	0.783	6.6^{a}	0.9	23.3	0.020	6.5	0.3	74.1	0.493	4.3	-0.3	48.3	0.552	5.8^{a}	0.3	38.4	0.013
	JAR	5.4		61.2		5.4		24.1		5.6^{ab}		38.8		6.2		19.8		4.6		25.9		5.4^{ab}		34.0	
	TL	4.8	-0.6	22.4		5.5	0.0	45.7		5.4^{b}	-0.2	37.9		6.9	0.7	6.0		4.7	0.1	25.9		5.3^{b}	-0.2	27.6	
Sweet	TM	5.1	0.0	40.5	0.364	5.9	0.6	3.4	0.171	5.7	0.0	9.5	0.492	6.3	-0.2	6.9	0.253	4.5	0.4	25.9	0.063	5.7	0.2	17.2	0.575
	JAR	5.1		34.5		5.4		21.6		5.7		37.9		6.5		27.6		4.1		26.7		5.5		29.7	
	TL	5.5	0.4	25.0		6.5	1.1	75.0		6.4	0.7	52.6		7.3	0.8	65.5		5.1	1.0	47.4		5.5	0.0	53.1	
Cocoa-based beverage																									
Color	TM	5.2	-0.3	4.3	0.549	5.6	0.4	86.2	0.405	6.0	0.4	44.8	0.229	6.5	1.3	92.2	0.053	0.0		0.0	0.141	6.0^{a}	0.6	45.5	<0.001
	JAR	5.5		44.8		5.2		13.8		5.6		47.4		5.3		6.9		6.0		2.6		5.5^{ab}		23.1	
	TL	5.2	-0.3	50.9		0.0		0.0		5.1	-0.5	7.8		7.0	1.8	0.9		4.5	-1.5	97.4		4.7^{b}	-0.8	31.4	
Intensity	TM	5.7^{ab}	-0.1	13.8	0.008	6.0	0.3	18.1	0.273	6.4^{a}	0.3	25.9	<0.001	6.7	0.6	42.2	0.148	4.4	-0.6	20.7	0.129	6.0^{a}	0.3	24.1	<0.001
	JAR	5.8^{a}		31.9		5.7		25.9		6.1^{a}		47.4		6.2		45.7		4.9		36.2		5.8^{a}		37.4	
	TL	4.9^{b}	-0.9	54.3		5.3	-0.4	56.0		4.6b	-1.4	26.7		6.6	0.4	12.1		4.2	-0.7	43.1		4.9^{b}	-0.8	38.4	
Sweet	TM	5.9^{a}	0.4	16.4	0.018	5.4	-0.5	4.3	0.436	6.2^{ab}	0.0	12.1	0.005	7.0	0.5	12.9	0.228	4.8^{ab}	-0.2	29.3	0.018	5.7^{a}	-0.2	15.0	<0.001
	JAR	5.5^{ab}		35.3		5.9		20.7		6.2^{a}		48.3		6.5		41.4		5.0^{a}		27.6		5.9^{a}		34.7	
	TL	4.9^{b}	-0.6	48.3		5.4	-0.5	75.0		5.1^{b}	-1.0	39.7		6.3	-0.2	45.7		4.0^{b}	-1.0	43.1		5.2^{b}	-0.7	50.3	
Bitter	TM	4.8^{b}	-0.8	35.3	0.028	5.0^{b}	-1.0	40.5	0.015	5.5^{b}	-0.9	48.3	0.033	6.2	-0.5	37.9	0.255	3.8^{b}	-1.1	24.1	0.043	5.2^{b}	-0.8	37.2	<0.001
	JAR	5.6^{a}		40.5		6.0^{a}		37.9		6.4^{a}		31.0		6.7		39.7		4.9^{a}		31.0		6.0^{a}		36.0	
	TL	5.5^{ab}	-0.2	24.1		5.5^{ab}	-0.5	21.6		5.5^{ab}	-0.8	20.7		6.5	-0.2	22.4		4.5^{ab}	-0.4	44.8		5.3^{b}	-0.6	26.7	

Sweet	TM	7.0[ab]	0.8	0.9	0.002	6.3	0.2	2.6	0.069	6.3[ab]	-0.4	3.4	<0.001	7.6	1.0	6.0	0.055	5.4[a]	0.4	19.8	<0.001	6.0[a]	-0.1	6.6	<0.001
	JAR	6.2[a]		18.1		6.2		19.8		6.6[a]		32.8		6.6		35.3		5.0[a]		31.0		6.1[a]		27.4	
	TL	5.1[b]	-1.2	81.0		5.3	-0.9	77.6		5.3[b]	-1.3	63.8		6.3	-0.4	58.6		3.8[b]	-1.2	49.1		5.2[b]	-1.0	66.0	
Sour	TM	4.4	-0.9	0.9	0.088	4.3	-1.2	2.6	0.084	5.6	-0.4	3.4	0.747	5.6[b]	-1.3	6.0	0.045	4.1	-1.0	19.8	0.128	4.7[b]	-1.1	6.6	<0.001
	JAR	5.3		18.1		5.5		19.8		5.9		32.8		6.9[a]		35.3		5.0		31.0		5.8[a]		27.4	
	TL	5.4	0.1	81.0		5.7	0.2	77.6		5.7	-0.2	63.8		6.4[ab]	-0.5	58.6		4.4	-0.6	49.1		5.5[a]	-0.3	66.0	
Earthy	TM	5.0	-0.4	13.8	0.658	4.9	-0.7	26.7	0.080	4.6[b]	-1.7	19.0	0.001	6.5	0.2	17.2	0.624	4.3	-0.3	27.6	0.799	5.0[b]	-0.7	20.9	0.001
	JAR	5.4		26.7		5.7		25.9		6.3[a]		25.0		6.3		27.6		4.6		21.6		5.7[a]		25.3	
	TL	5.3	-0.1	59.5		5.8	0.1	47.4		5.9[a]	-0.5	56.0		6.6	0.3	55.2		4.5	-0.1	50.9		5.6[a]	-0.1	53.8	
Astringent	TM	5.0	-0.1	20.7	0.362	5.1	-0.8	30.2	0.127	5.3	-0.8	21.6	0.134	5.8[b]	-1.0	19.0	0.042	4.0	-0.6	15.5	0.454	5.1[b]	-0.7	21.4	0.003
	JAR	5.2		32.8		5.9		31.9		6.1		42.2		6.8[a]		34.5		4.6		25.9		5.8[a]		33.4	
	TL	5.5	0.3	46.6		5.5	-0.5	37.9		5.6	-0.5	36.2		6.5[ab]	-0.3	46.6		4.6	0.0	58.6		5.5[ab]	-0.3	45.2	
Soluble	TM	5.8	0.4	21.6	0.062	5.4	-0.2	37.1	0.826	5.8	0.1	75.9	0.955	6.0	-0.5	7.8	0.615	4.9	0.5	31.9	0.307	5.5	0.0	34.8	0.930
	JAR	5.4		49.1		5.6		45.7		5.7		22.4		6.5		35.3		4.4		31.9		5.5		36.9	
	TL	4.9	-0.5	29.3		5.7	0.1	17.2		6.0	0.3	1.7		6.5	-0.1	56.9		4.3	-0.1	36.2		5.5	0.0	28.3	
Creamy	TM	5.4	0.0	4.3	0.938	5.9[ab]	-0.2	10.3	0.026	6.8[a]	0.6	14.7	<0.001	6.5	0.0	9.5	0.826	6.3[a]	1.0	7.8	<0.001	6.4[a]	0.3	9.3	<0.001
	JAR	5.4		20.7		6.1[a]		28.4		6.2[a]		35.3		6.5		39.7		5.3[a]		23.3		6.0[a]		29.5	
	TL	5.3	-0.1	75.0		5.2[a]	-0.9	61.2		5.1[b]	-1.1	50.0		6.4	-0.2	50.9		4.0[b]	-1.3	69.0		5.1[b]	-0.9	61.2	
Lumpy	TM	4.9	-0.4	23.3	0.156	5.6	0.5	13.8	0.328	4.5	-1.3	1.7	0.584	6.3	-0.4	50.9	0.448	4.5	-0.2	23.3	0.888	5.5	0.0	22.6	0.978
	JAR	5.3		42.2		5.2		31.0		5.8		14.7		6.7		31.0		4.7		19.8		5.5		27.8	
	TL	5.6	0.3	34.5		5.7	0.5	55.2		5.8	0.0	83.6		6.6	-0.1	18.1		4.4	-0.2	56.9		5.5	0.0	49.7	
Sticky	TM	4.7	-0.6	17.2	0.133	4.5[b]	-1.2	19.0	0.004	5.4	-0.4	12.1	0.593	6.0	-0.6	18.1	0.221	4.4	-0.3	12.1	0.688	5.0[b]	-0.6	15.7	0.008
	JAR	5.3		22.4		5.7[a]		31.0		5.7		27.6		6.5		29.3		4.7		31.9		5.6[a]		28.4	
	TL	5.5	0.1	60.3		5.8[a]	0.1	50.0		5.9	0.2	60.3		6.6	0.1	52.6		4.4	-0.3	56.0		5.6[a]	0.0	55.9	
Intensity	TM	5.3	-0.1	31.0	0.583	5.6	-0.1	32.8	0.716	5.8	-0.1	31.9	0.763	6.6	0.1	45.7	0.704	4.5	-0.3	29.3	0.340	5.6[a]	0.0	34.1	0.009
	JAR	5.5		36.2		5.6		37.9		5.9		46.6		6.4		34.5		4.8		33.6		5.7[a]		37.8	
	TL	5.1	-0.3	32.8		5.3	-0.3	29.3		5.6	-0.3	21.6		6.3	-0.2	19.8		4.2	-0.6	37.1		5.1[b]	-0.5	28.1	

~~The results showed that~~ The consumers found the five samples quite different. With regards to the evaluation of the cocoa powder, most of the consumers found Samples 2, 3, 4 to have *"too much color",* and Sample 5 as having *"too little color".* Around half of the consumers found the color to be *"JAR"* for Sample 1. The same tendency was found for Samples 1, 2, 4 and 5, when the consumers were evaluating the cocoa-based beverages. More consumers found Sample 3 *"JAR"* when it came to the color in the cocoa-based beverage.

Also, the aroma intensity and sweetness were evaluated in, both, the cocoa powder, and the cocoa-based beverage. No significant liking difference was found between *"JAR", "too little"* / *"too much"*, in the cocoa powder of both aroma intensity and sweetness. There were, however, significant differences between *"JAR", "too little"* / *"too much"* in the cocoa-based beverage of both aroma intensity and sweetness. In general, the aroma intensity was liked significantly less when found *"too little"*, and this was also significant for Samples 1 and 3.

As expected, when looking at all samples merged, the consumers had a higher liking when the cocoa-based beverage was found to be *"JAR"* and had significant liking decrease when the beverage is either found to be *"too little"* and *"too much"* bitter, *"too little"* sweet and *"too much"* sour. Attributes having a significantly increase or decrease from *"JAR"* when *"too little"* or *"too much"* are shown in Figure 3. For Samples 1, 2, 3 and 5 the liking significantly decreased when the beverage was found "too bitter". In Samples 1, 3 and 5 there was a significant liking decrease when the beverage was *"not sweet enough".* And only in Sample 4 there was a significant liking decrease when the beverage was *"too sour".*

In general, there was a significant liking decrease when the flavor earthy was found to be *"too earthy".* When the cocoa-based beverage was found *"too astringent"* in mouthfeel, there was a general and significant liking decrease. Samples 2, 3 and 5 was found to have a significant liking decrease when the cocoa-based beverage had a *"not creamy enough"* texture, and this was also found in general for all samples. Also, in general a "*too sticky"* texture generated a significant drop in liking, and this was also found in Sample 2. Only the texture attributes "sticky" and "lumpy" had no general nor sample specific significant liking changes. The overall liking of the cocoa-based beverage significantly decreased in general when the samples were found *"not intense enough".*

4 Discussion

This research aimed to investigate the factors influencing the acceptability of five samples of cocoa powder to identify a cocoa powder with both high acceptability and bioactivity, paving the way for future *in vivo* studies.

Regarding fat content, consumers preferred not-fat reduced cocoa, suggesting that cocoa fat content influences consumer acceptability of cocoa beverages. In contrast, a study on 70 % dark chocolate showed that cocoa fat content does not affect the chocolate liking; however, cocoa fat significantly decreases the perceived bitterness and dry mouthfeel, while increases the perceived intensity of sweetness (Brown et al., 2023), making it more palatable, although it should be mentioned that the matrices were not the same as in ~~our~~ the current study. In this sense, a major attribute significantly affecting the liking was when the samples were in general *"not sweet enough",* with 66 % and 50 % of the consumers considering the flavor of the beverage and the aroma of the powder, respectively, *to be "not sweet enough".* The bitterness of the samples was also a concern, with 37 % considering the cocoa-based beverage to be *"too bitter"* and 27 % *"not bitter enough"*. There could be an opposing influence between sweetness and bitterness in the cocoa-based beverage samples, indicating an interaction between sweet and bitter flavors on the palate. Sweetness may mitigate the perception of bitterness, and vice versa (Brown et al., 2023). Hence, ~~it is plausible that~~ sweeter samples might be perceived as less bitter, while less sweet samples could be perceived as more bitter.

In terms of color, samples that underwent alkalization received the highest liking scores. The alkalization process made the cocoa darker and this quality appears favorable in cocoa beverages. Only *"too much color"* for the cocoa powder generated a significant liking different from JAR, indicating that the consumers preferred a darker color (Figure 3). Even though the alkalization process increases the color (Li et al., 2014), only 28 % of the consumers significantly liked the cocoa powders less when found *"not enough color",* and the decrease was only 0.6 in the liking scale, therefore the impact of this color increase on liking appeared limited. In fact, in another study on cocoa beverages, where the alkalized sample was also darker, no increase in color liking was observed (Juvinal et al., 2023). This could also suggest a role for beverage temperature, as the cocoa beverages were hot in the present study and cold in the other.

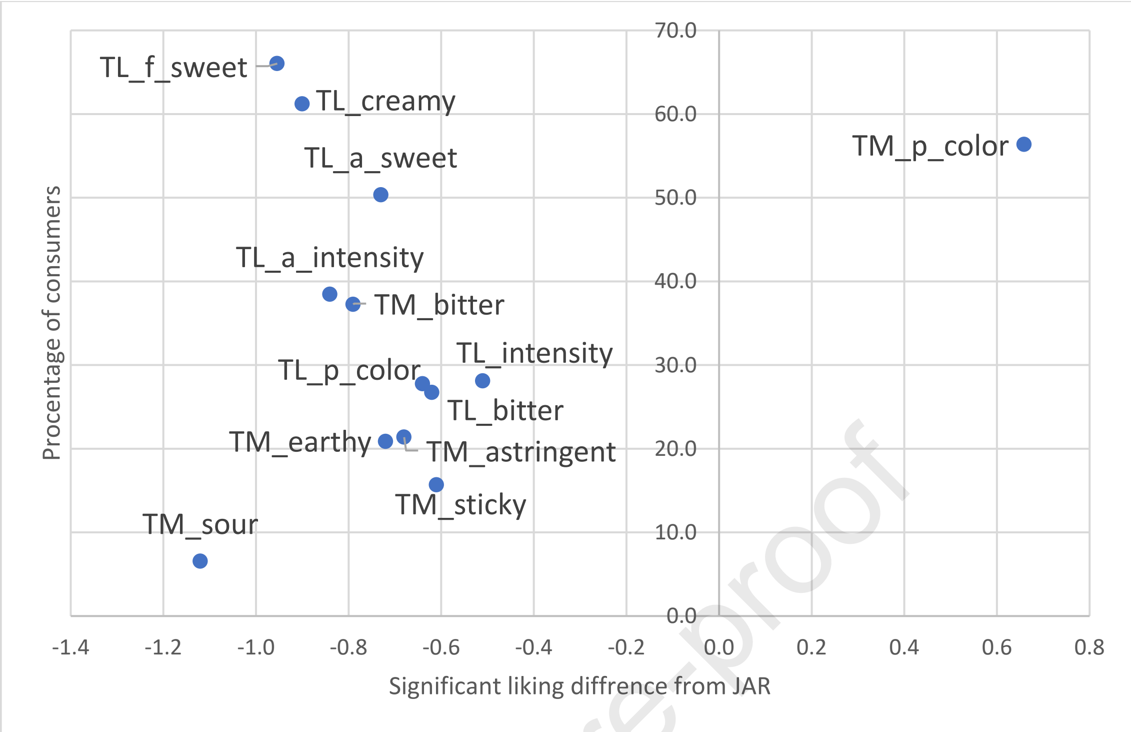

Figure 3: Penalty analysis between mean liking differences between JAR category (*just about right,* and *not enough/too much*), and the percentage of consumers (N=116) voting for each JAR category (*too much* and *not enough*). Only significant ($p < 0.05$) different from JAR attribute are shown. TM: too much and TL: too little. a: aroma, p: cocoa powder, f: flavor; if nothing is stated: it is the cocoa-based beverage.

Concerning smell, Samples 5 and 2 were the least liked. In the case of Sample 5, this could be due to a distinctive “spicy” smell characteristic of some cocoa varieties from Peru (Valle-Epquín et al., 2020) that may have been unexpected or unfamiliar to consumers. In the case of Sample 2, ~~this might be attributed to the fact that~~ a significant percentage of participants considered the smell intensity to be *“not enough”.* Sample 4 had the lowest percentage of consumers considering the aroma “not enough”, and it is worth noting that both samples (2 and 4) were alkalized. In this sense, in the case of sample 4, the results ~~are~~ were in line with the findings from previous studies such as the one from Huang and Barringer (2010) which reported that alkalization results in a more intense aroma profile. Meanwhile, in the case of sample 2, the results ~~are~~ were in agreement with the study conducted by Sioriki et al. (2021) in which a reduction in the concentration of most volatile compounds after alkalization ~~was~~ is reported. This could be due to highly volatile aromatic compounds formed during roasting ~~which are~~ might be prone to evaporate during the alkalization process but also it could can be attributed to the depletion of precursors consumed during the previous roasting stage, leading to the absence of additional aroma formation during alkalization (Sioriki et al., 2021). These discrepancies between studies with respect to aroma effects induced by alkalization could be explained based on the processing stage at which alkalization is applied (before or after roasting). Huang and Barringer (2010) reports that alkalization produced a more intense aroma when applied before roasting, while in the study conducted by Sioriki et al. (2021) the alkalization process was applied after roasting.

The attribute *"too earthy"* was significantly different from *"JAR"* in general, however, as this only was significantly different from *"JAR"* in Sample 3, it is suggested focusing on other attributes. The same trend was observed in the attribute *"too astringent",* where only Sample 4 was found to be *"too astringent"*. Finally, the attributes *"too sour"* and *"too sticky"* also caused a significant drop in liking, but this was only experienced by very few consumers (7 % and 16 %, respectively).

Moving on to the effect of the phenolic content of cocoa on beverage preference, concentrations above 30 g GAE/kg d.w. decreased the preference, but it did not mean that the lower the content the higher liking. Phenolic compounds contribute to a distinctive bitter taste, unfamiliar to consumers used to commonly consumed cocoa products in Spain, such as chocolate bars and soluble cocoa (Mercasa, 2023). These products typically include ingredients like milk and sugar, enhancing their sweetness and masking the inherent bitter taste of cocoa. Additionally, as expected, the alkalized samples exhibited lower total phenolic content, lower content of flavanols, catechin and epicatechin, and proanthocyanidins., along with lower antioxidant capacity analyzed by the DPPH, ABTS and FRAP assays.

Concerning the effect of methylxanthine content on beverage preference, the most liked samples (3 and 4) exhibited low levels of caffeine and high levels of theobromine, resulting in the highest T/C ratios. Therefore, the results indicated that a higher T/C ratio may correspond to greater preference. Caffeine and theobromine are known to influence the sensory characteristic of cocoa powder, contributing to a bitter taste. Hence, lower caffeine content in samples could enhance the palatability of cocoa powder (Sioriki et al., 2021).

Regarding overall liking and WTB, both cocoa fat content and alkalization demonstrated comparable impacts on preference, with fat content having a slightly more pronounced influence. Furthermore, the results of the present study revealed how each attribute affected the consumer liking for each sample and in general.

Some limitations should also be acknowledged. As the participants ~~dissolved~~ dispersed the cocoa powder in the milk themselves, the mixture might not be completely uniform among the participants; however, solubility was one of the attributes to assess. Further, the order of presentation was not randomized. While this is unlikely to affect the main conclusions given the specifics of this study due to the low number of samples evaluated and their homogeneity in terms of flavor complexity and hedonic value (Schifferstein, 1995; Mazur, Drabek & Goldmann, 2018), possible positional biases cannot be ruled out. Additionally, the results apply within the conditions tested and some other methodological choices may have influences the outcome: for example, the serving temperature of the milk (around 52 °C) for all participants which could have influenced the liking, as some people may prefer the milk warmer and others colder. Therefore, interaction effects between these factors and serving temperature as well as other factors (e.g., sample origin) should be considered in future studies.

5 Conclusion

Consumers preferred samples classified as cocoa powder, rather than fat reduced cocoa. Alkalization had an independent effect on liking, suggesting that it could improve consumer preferences for fat reduced cocoa. Alkalization reduces the phenolic content of cocoa, and the samples with higher phenolic content were less liked by participants. Thus, the combination of cocoa powder and alkalized was the most preferred, while the combination of fat reduced and non-alkalized ~~(the healthiest)~~ was the less liked. Since there was a greater difference in liking between fat reduced cocoa and cocoa powder than between alkalyzed and non alkalyzed cocoa, the results suggest that the reduction in fat has a greater impact on the smell liking than the alkalization process. In contrast, it was observed that the effect of alkalization is larger on color than the effect of fat removal. It should not be forgotten that apart from alkalization and fat content, the origin could also impact in cocoa´s composition and further studies designed considering this variable should be carried out. In short, comprehensive insights on the effect of the fat reduction and alkalization process on the physicochemical and sensory properties of cocoa are provided, adding to the complex interplay of various factors influencing the acceptability of cocoa products.

Author Contributions

Conceptualization, M.P.-M. and C.R.-P.; methodology, M.P.-M. and C.J.B.-R; validation, C.R.-P. and D.G. ; formal analysis, C.J.B.-R. and D.G.; investigation, M.P.-M.; resources, C.R.-P. and E.C.-O.; data curation, C.J.B.-R. and D.G.; writing—original draft preparation, M.P.-M. and C.J.B.-R. writing—review and editing, M.P.-M., C.J.B.-R, E.C.-O., D.G. and C.R.-P.; visualization, E.C.-O., D.G. and C.R.-P.; supervision, D.G. and C.R.-P.; project administration, C.R.-P. and E.C.-O. All authors have read and agreed to the published version of the manuscript.

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Highlights

- Alkalization enhanced cocoa beverage acceptability
- Alkalization decreased phenolic compound content
- Fat content strongly influenced cocoa beverage liking
- Phenolic composition affected consumer liking

Declaration of interest statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.