Research Article

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Polyphenol-rich beverages: insights from sensory and consumer science

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Abstract

BACKGROUND: Reaching a go/no-go decision on a product concept early in the innovation cycle can save companies significant resources. The current research is situated within this context. Using polyphenol-rich beverages that were at an early stage in the formulation/optimisation cycle, a number of insights were sought: (1) how acceptable to consumers were these early-stage formulations; (2) what sensory attributes contributed to consumer liking/disliking; and (3) could the disliked sensory attribute(s) be sufficiently masked within the chosen product format?

RESULTS: Beverages were formulated according to a 2 × 4 factorial design where one factor varied the polyphenol source and the other sweetness. While consumer acceptability and purchase probability increased with sucrose concentration, the beverages were of below-average sensory quality. Bitterness was identified as a key sensory attribute to focus on in future optimisation efforts.

CONCLUSION: A number of approaches exist for masking bitterness and there appeared to be little reason why at least some of the beverages could not be improved to achieve high levels of sensory quality and consumer acceptance. Further, it is suggested that disclosing information about health properties of these polyphenol-rich beverages during consumer testing may further enhance their appeal to consumers.
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Keywords: berry fruit; cocoa; descriptive sensory analysis; acceptability; purchase probability; health claims

INTRODUCTION

From a sensory product quality perspective, developing functional foods and beverages can be a challenging task. The critical importance of flavour in consumer choice of foods is broadly recognised.[1–4] In this regard, functional foods are no different from any other product type. There are several reports in the extant literature[5,6] documenting how consumers are not willing to compromise on sensory quality when it comes to functional foods. They want proven health benefits and good taste. Unfortunately, functional ingredients can lack palatability. Polyphenols are a case in point. Their health benefits are well documented, particularly in relation to antioxidant activity.[7–14] However, one of their defining sensory characteristics is bitterness, which is an attribute that is typically associated with diminished acceptability.[15,16]

Against this backdrop, it seems sensible that when new functional foods are developed, insight is gained early on in the formulation/optimisation cycle of whether the focal product concept is a realistic achievement. In other words, for the chosen combination of functional ingredient(s) and product format (e.g., simple beverage, structured beverage, solid food) is it going to be possible to develop a product with high sensory quality and consumer appeal? Reaching a go/no-go decision on a focal concept early on in the innovation cycle can save companies significant human and financial resources that can be directed to more fruitful endeavours. The current research is situated within this context. Using products that were at an early stage in the formulation/optimisation cycle, a number of insights were sought: (1) how acceptable to consumers were these early-stage formulations; (2) what sensory attributes contributed to consumer liking/disliking the formulations; and (3) could the disliked sensory attribute(s) be sufficiently masked within the chosen product format? Taken together, it was expected that this research would provide the insight required to reach a go/no-go decision on the focal product concept (a polyphenol-rich beverage). If such a decision could be made, it would support the notion that consumer-led research in the early stages of the product formulation/optimisation cycle is worthwhile.

Having provided the conceptual background for this research, we move to considering the specifics of the study and the polyphenol-rich beverages that were tested. The polyphenol source of interest was berry fruit, for which there is a growing body of evidence of antioxidant activity and protective human health benefits.[17–25] Formulations containing a combination of berry fruit and cocoa extracts were also tested. Cocoa is also known to be a rich source of polyphenol.[17,26–31] Since chocolate and berries are a popular combination in a range of confectionary, baked goods, and breakfast cereal products, to name a few, it

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was considered a possibility that beverages containing both these flavours may have consumer appeal. A second strategy used to enhance consumer appeal was the use of a sweetening agent.

To achieve the stated aims of the research, descriptive sensory analysis and consumer evaluation was performed.

EXPERIMENTAL

Samples

Eight beverages were formulated according to a 2 × 4 factorial design. One factor varied the polyphenol source: beverages containing berry fruit extracts, and beverages containing berry fruit and cocoa extracts. The total polyphenol concentration was unchanged across the two levels of this factor (500 mg/80 mL). The second factor varied the level of added sweetener. Through pilot testing, four levels of added sucrose were determined: 0%, 3.5%, 7.0% and 10.5%. Here, 0% added sucrose represented a control sample. The addition of 10.5% sucrose was considered to be indicative of the highest level of sweetness that would be added to a commercial beverage of this type.

Samples were prepared by weighing the dry ingredients (i.e., polyphenol extracts and sucrose) into PE bottles. Berry fruit extract was obtained from a commercial New Zealand supplier. Cocoa extract (Acticoa fat-reduced cocoa powder) was obtained from Brendsdorp (Barry Callebaut, Belgium), and sucrose (white table sugar; New Zealand Sugar Company, Auckland, New Zealand) was obtained from a local supermarket. One hour prior to testing, purified and micro filtered water (40 °C) was added and each bottle was shaken vigorously until all dry ingredients were dissolved. The beverages were intensely coloured, with hues of dark crimson and dark purple. Samples were served at ambient temperature and bottles were agitated several times directly prior to pouring into serving cups.

Descriptive sensory analysis

The sensory panel consisted of 12 female participants, ranging from 35 to 53 years of age (mean = 48; SD = 5.31). All participants were experienced in sensory evaluation. They were non-smokers and refrained from wearing perfume and drinking or consuming foods that could affect performance in the hour before a panel session.

In accordance with standard practice, a sensory vocabulary was developed over 6 days in sessions lasting 1–1.5 h. During the first 2 days of training, panelists tasted all eight beverages, recording odour, taste, flavour and mouthfeel attributes for each sample. These were subsequently discussed and a preliminary vocabulary formed. Through informal round-table rating of samples and subsequent discussions, the vocabulary was finalised on days 3 and 4 when reference standards for each attribute were also developed (Table 1). The final two sessions were spent on further evaluations of the beverages, seeking to obtain consistency in evaluations within and across panelists.

The eight samples were assessed in triplicate over three consecutive days. Samples were presented monadically and perceived sensory intensities were recorded on a 150 mm unstructured line scale (0 = absent; 150 = extreme). Reference standard intensities were marked on each attribute line scale and panelists were required to re-familiarise themselves with the reference standards at the beginning of each data collection session. Samples were presented as 10-mL serves in 35-mL transparent plastic cups. Panelists evaluated odour first (berry, dark chocolate/cocoa, honey/spicy and tobacco). They were then instructed to take 5 mL of the sample into their mouths, swirl it around the mouth cavity for 10 s, then swallow and rate the four flavour and taste descriptors (berry, dark chocolate/cocoa, bitterness and sweetness). The second 5 mL was used to rate two mouthfeel descriptors (astringency and chalkiness). This sampling method was chosen as the sensation of astringency in the mouth can take up to 10–15 s to be perceived.[32] Panelists were required to cleanse their palate between each sample with water and water crackers (Arnott's Original; Arnott's Biscuits Limited, NSW, Australia) followed by an essential rinse with a 0.1% pectin solution to minimise the build-up of bitterness and astringency in the oral cavity.[33] A 2 min break was also enforced between samples to further mitigate sensory fatigue associated with bitterness and astringency.[34]

Data were collected through the Compusense software package v 5.0 in individual booths in the sensory science facility at the Plant & Food Research Mount Albert Research Centre. Samples were presented using three-digit random codes. Red lighting was used to mask any colour differences between samples. The temperature in the booth area was held at 20 °C and a positive airflow was maintained to prevent odour build-up.

Consumer evaluation

A consumer testing protocol was developed to obtain measures of acceptability, preference and purchase probability. By obtaining multiple consumer measures, comparisons across samples could be made enabling an assessment of internal validity of the results. The developed protocol was tailored to the testing environment (see below) and limited the number of samples to be evaluated by each participant to two. Participants were given their first sample and asked to rate it in terms of acceptability. The standard nine-point hedonic scale[35] was used: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely. Next, participants were asked whether or not they would buy this sample (yes, no, or not sure). The same two questions were asked for the second sample. Lastly, participants were asked which of the two samples they preferred, or if they had no preference. The allocation of samples to participants was in accordance with a random presentation of all possible pairs of two different samples. Samples were given in 15-mL serves (presented in 35-mL transparent plastic cups).

Data were collected from a convenience sample of university students (n = 392; 63% male). The median age was 19 years (mean = 21 years; SD = 3.2 years). Testing was conducted at the University of Auckland City Campus (Auckland, New Zealand). A testing stall was set up in an area on campus that experiences high student traffic. The test took 3–4 min to complete and as a token of appreciation each participant received a can of soft drink to the value of approx. NZ$3. The study was approved by the University of Auckland Human Participants Ethics Committee (ref: 2007/407).

Data analysis

The descriptive sensory analysis data was analysed using mixed effects models (Proc Mixed in SAS/STAT® software package, v 9.1). The two experimental factors (i.e., polyphenol source and sucrose concentration) were specified as fixed effects, while the effect pertaining to panelist was random. Type III sums of squares were used to construct the F statistics to carry out the overall tests of the fixed effects. To compensate for multiple testing, Tukey's HSD

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Table 1. Descriptive sensory vocabulary for beverages formulated with berry fruit and cocoa polyphenols and varying levels of sucrose

Attribute	Definition of attribute and reference standard	Intensity of reference standard[a]
Berry (odour)	The odour associated with mixed berry jam. Barker's Jam. Barker's, South Canterbury, New Zealand. One teaspoon per person.	130
Dark chocolate/cocoa (odour)	The odour associated with dark chocolate. Bittersweet dark chocolate, 70% cocoa mass. Green and Black's, London, UK. One square per person.	130
Tobacco (odour)	The odour associated with loose-leaf tobacco. Gallaher's Park Drive tobacco. Fine cut blue. British American Tobacco Company. 0.5 g per person.	140
Honey/spicy (odour)	The fruity and spicy odour associated with dried fruit and fruit products. Pomegranate paste. Kambiz Food Industries Co. Tehran, Iran. 5 mL per person.	130
Berry (flavour)	The flavour associated with mixed berry jam. Barker's Squeezed Fruit Juice Syrup. Barker's, South Canterbury, New Zealand. 50 mL syrup: 250 mL water. 10 mL per person.	120
Dark chocolate/cocoa (flavour)	The flavour associated with dark chocolate. Bittersweet dark chocolate, 70% cocoa mass. Green and Black's, London, UK. One square per person.	130
Bitter (taste)	The taste associated with caffeine in a water solution. 0.75 g L^{-1} caffeine in water. 10 mL per person.	90
Sweet (taste)	The taste associated with sucrose in a water solution. 40 g L^{-1} sucrose in water. 10 mL per person.	100
Astringent (mouth feel)	The drying and puckering in the mouth associated with alum in a water solution. 0.7 g L^{-1} alum in water. 10 mL per person.	100
Chalky (mouth feel)	The feeling of fine particulate matter coating the mouth. Cocoa powder. Cadbury, Bournville® Cocoa, Victoria, Australia. One teaspoon per person.	120

[a] Sensory intensity was measured on a scale from 0 = absent to 150 = extreme.

was used to adjust the significance level of pair-wise comparisons. Mean values for sensory attributes, averaged across replicates and assessors, were input to a principal components analysis (PCA) of the covariance matrix. Using an approach based on the study by Husson *et al.*,[36] confidence ellipses (at the 95% level) were derived to obtain an indication of variability in sample positions within the PCA space.

The consumer acceptability scores were also analysed in SAS Proc Mixed. The two experimental factors were specified as fixed effects, while the consumer effect was random. Tukey's HSD was used for pairwise comparisons. The consumer participants were asked, for each beverage they evaluated, whether or not they would buy this product. To predict probability of purchase of the focal beverages, mixed-effects logistic regression was performed using SAS Proc NLMixed. Two different regressions were performed; the first compared the 'yes' responses with the pooled 'not sure' responses and 'no' responses, and the second combined the 'not sure' answers with the 'yes' answers. For easier interpretation, probabilities of choice for each of the eight beverages were calculated. Having evaluated two beverages, participants were asked which of these they preferred. These data were analysed using a conditional logit model[37] in SAS Proc MDC. The conditional logit is a multinomial extension of the standard logit and enables inclusion of the 'no preference' data in the model, as opposed to eliminating such responses from the analysis as is sometimes done.[38]

RESULTS

Descriptive sensory analysis

Analysis of variance

Across participants and replicates, analysis of variance showed highly significant differences between samples for nine of the ten sensory attributes. The exception was for tobacco odour ($P = 0.20$) and this attribute was excluded from further analysis. Next, analysis of variance was performed using the experimental factors as independent variables. For all attributes, the interaction between polyphenol source (i.e., berry fruit only or berry fruit and cocoa) and sucrose concentration was non-significant ($P > 0.10$). As detailed below and shown in Table 2, significant main effects were established.

A significant effect of polyphenol source was found for all nine attributes. The berry fruit formulations were significantly higher in levels of honey/spicy odour, berry odour and berry flavour. Conversely, the berry fruit and cocoa formulations were significantly higher in levels of dark chocolate/cocoa odour, dark chocolate/cocoa flavour, and chalkiness. On average, the berry fruit formulations were lower in bitterness and higher in sweetness.

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Table 2. Mean values for sensory attributes across beverages formulated with berry fruit and cocoa polyphenols and varying levels of sucrose

Polyphenol source	Sucrose level (%)	Berry odour[a,b]	Dark chocolate/cocoa odour[a,b]	Honey/spicy odour[a,b]	Berry flavour[a,b]	Dark chocolate/cocoa flavour[a,b]	Bitterness[a,b]	Sweetness[a,b]	Astringency[a,b]	Chalkiness[a,b]
Berry fruit	0	80.1^{a}	19.0^{b}	46.4^{a}	73.6^{b}	14.9^{b}	62.0^{ab}	9.4^{d}	110.8^{a}	19.1^{b}
Berry fruit	3.5	83.7^{a}	22.2^{b}	41.0^{a}	92.6^{a}	17.7^{b}	44.5^{c}	38.0^{c}	103.3^{ab}	14.1^{b}
Berry fruit	7	84.4^{a}	19.3^{b}	39.0^{a}	100.8^{a}	19.4^{b}	30.5^{de}	78.5^{a}	94.9^{bc}	16.1^{b}
Berry fruit	10.5	81.2^{a}	17.4^{b}	41.5^{a}	100.9^{a}	18.9^{b}	24.5^{e}	90.6^{a}	92.8^{bc}	13.6^{b}
Berry fruit and cocoa	0	23.8^{b}	100.1^{a}	17.4^{b}	20.9^{e}	107.6^{a}	74.6^{a}	9.2^{d}	94.4^{bc}	73.1^{a}
Berry fruit and cocoa	3.5	25.2^{b}	102.9^{a}	15.8^{b}	29.4^{de}	105.2^{a}	50.0^{bc}	30.7^{c}	84.4^{cd}	67.8^{a}
Berry fruit and cocoa	7	30.0^{b}	104.1^{a}	17.2^{b}	42.9^{cd}	103.6^{a}	39.7^{cd}	62.0^{b}	76.6^{d}	59.3^{a}
Berry fruit and cocoa	10.5	30.3^{b}	102.0^{a}	15.1^{b}	48.5^{c}	105.2^{a}	30.5^{de}	82.6^{a}	76.4d	61.4^{a}
Main effect of polyphenol source		$F_{1,269} = 387.3$ $P \leq 0.001$	$F_{1,269} = 1041.6$ $P \leq 0.001$	$F_{1,269} = 128.3$ $P \leq 0.001$	$F_{1,269} = 533.2$ $P \leq 0.001$	$F_{1,269} = 1245.3$ $P \leq 0.001$	$F_{1,269} = 14.8$ $P \leq 0.001$	$F_{1,269} = 11.0$ $P = 0.001$	$F_{1,269} = 76.9$ $P \leq 0.001$	$F_{1,269} = 406.2$ $P \leq 0.001$
Main effect of sugar		$F_{3,269} = 0.6$ $P = 0.60$	$F_{3,269} = 0.3$ $P = 0.81$	$F_{3,269} = 0.6$ $P = 0.59$	$F_{3,269} = 25.9$ $P \leq 0.001$	$F_{3,269} = 0.02$ $P = 0.99$	$F_{3,269} = 67.5$ $P \leq 0.001$	$F_{3,269} = 209$ $P \leq 0.001$	$F_{3,269} = 17.6$ $P \leq 0.001$	$F_{3,269} = 2.6$ $P = 0.05$
Interaction effect of polyphenol source and sugar		$F_{3,269} = 0.3$ $P = 0.80$	$F_{3,269} = 0.2$ $P = 0.91$	$F_{3,269} = 0.4$ $P = 0.74$	$F_{3,269} = 1.1$ $P = 0.36$	$F_{3,269} = 0.5$ $P = 0.66$	$F_{3,269} = 0.6$ $P = 0.62$	$F_{3,269} = 1.9$ $P = 0.13$	$F_{3,269} = 0.1$ $P = 0.96$	$F_{3,269} = 1.1$ $P = 0.36$

[a] Anchor of line scale used to generate values per attribute was 0–150 (0 = absent, 150 = extreme).
[b] Within columns, means that share a common letter are not significantly different ($\alpha < 0.001$).

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However, the magnitude of these differences was smaller than those for the flavour and odour attributes. While, on average, astringency was higher for berry fruit beverages, all samples were perceived as being astringent. Chalkiness was, on average, lower in berry fruit than berry fruit and cocoa beverages.

A highly significant effect of sucrose concentration existed for four attributes: sweetness, bitterness, berry flavour, and astringency. Among these, the magnitudes of differences between the levels of added sucrose were largest for sweetness and bitterness. Perceived sweetness increased with increasing sucrose concentration, and all sucrose concentrations were perceived as significantly different from each other. Perceived bitterness decreased with increasing sucrose concentration. However, there was no perceived bitterness difference between beverages with 7% added sucrose and 10.5% added sucrose. The pattern for astringency was identical. Perceived berry flavour increased with an increase in sucrose concentration. Similarly to bitterness and astringency, there was no perceived difference in berry flavour between beverages with 7% and 10.5% added sucrose.

Principal components analysis

Principal components analysis (PCA) resulted in a two-dimensional solution accounting for 99.5% of the total variation in the data, of which 82.4% was explained by the first dimension. The first principal component accounted for variation in odour, flavour and mouthfeel attributes (Fig. 1a). Berry flavour, berry odour and to a lesser extent, honey/spicy odour loaded negatively on this dimension. Dark chocolate/cocoa odour, dark chocolate/cocoa flavour and chalkiness had high positive loadings on PC1. Correspondingly, beverages were separated along the first principal component with respect to polyphenol source (Fig. 1b). The second principal component was driven by the taste and mouthfeel attributes. Sweetness had a high positive loading, while bitterness and astringency had negative loadings on this dimension. Beverages were separated on this dimension based on sucrose concentration. As anticipated, beverages with sucrose concentrations of 7% and 10.5% were associated with higher levels of sweetness. Beverages with sucrose concentrations of 0% and 3.5% were associated with higher levels of bitterness.

The confidence ellipses around samples (Fig. 1b) revealed that beverages formulated with berry fruit extract were very different from those formulated with berry fruit and cocoa extract. In terms of added sucrose concentration, within beverage type, samples with 0% added sucrose and 3.5% added sucrose were different from one another and from samples containing higher levels of added sucrose. However, samples containing 7.0% added sucrose and 10.5% added sucrose were not distinctly different in terms of their sensory profiles, as evidenced by the partial overlap of their confidence ellipses.

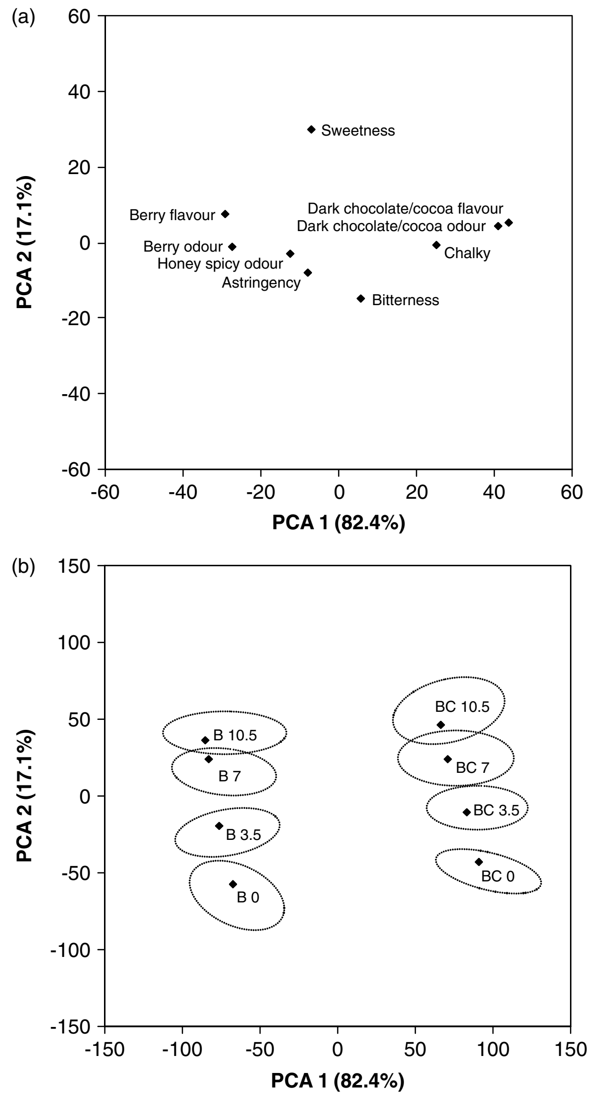

Figure 1. Principal components analysis of sensory profiling data for beverages formulated with berry fruit and cocoa polyphenols and varying levels of sucrose. (a) Plot of the first two principal component loadings; and (b) plot of the first two principal components scores showing product confidence ellipses. In panel b, berry fruit samples are identified as B; berry fruit and cocoa samples as BC. The level of added sugar is indicated numerically. For example, legend BC3.5 represents the sample formulated with berry fruit and cocoa extract, containing 3.5% added sugar.

Consumer evaluation

Acceptability

Across the eight samples, analysis of variance revealed significant differences in consumer acceptability (Table 3). Given that the beverages were at the early stage of the formulation/optimisation cycle, it was not unexpected that none of the formulations rated very highly in terms of consumer acceptability. The most liked beverage formulation (berry fruit polyphenol with 10.5% added sucrose) averaged a rating of 5.1, corresponding to the hedonic scale's verbal anchor 'neither like nor dislike.' The least liked beverage formulation (containing berry fruit and cocoa polyphenols and no added sucrose) scored, on average, a rating of 2.3 which is between the anchors 'dislike very much' and 'dislike moderately'.

Significant differences in levels of acceptability existed in relation to polyphenol source ($F_{1,390} = 12.9$; $P = 0.0004$) and the level of added sucrose ($F_{3,390} = 8.1$; $P = 0.0001$). On average, beverages formulated with berry fruit polyphenol were more liked (mean = 4.2) than beverages containing berry fruit and cocoa polyphenols (mean = 3.8). Mean liking for beverages increased with increasing sucrose concentration (0% sucrose = 2.5, 3.5% sucrose = 3.9, 7% sucrose = 4.7, and 10.5% sucrose = 5.0). However, Tukey's HSD post-hoc test revealed that, on average, mean acceptability of beverages containing the two highest sucrose concentrations did not differ significantly.

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Table 3. Consumer evaluation (mean [SD]) of beverages formulated with berry fruit and cocoa polyphenols and varying levels of sucrose

Polyphenol source	Sucrose level (%)	Acceptability[a,b]	Probability of buying (%), (most conservative)	Probability of buying (%), (least conservative)	Preference
Berry fruit	0	2.7 [1.5][a]	1.4	5.9	1.7
Berry fruit	3.5	4.3 [1.9][c]	6.8	30.4	8.1
Berry fruit	7	4.9 [2.0][cd]	14.5	45.6	16.7
Berry fruit	10.5	5.1 [1.8][d]	18.3	50.3	25.8
Berry fruit and cocoa	0	2.4 [1.5][a]	1.3	5.2	1.0
Berry fruit and cocoa	3.5	3.5 [1.9][b]	2.1	13.2	2.7
Berry fruit and cocoa	7	4.5 [1.9][cd]	9.1	29.4	10.7
Berry fruit and cocoa	10.5	4.9 [2.0][cd]	10.7	40.9	17.2

[a] Acceptability was rated on a nine-point scale from 1 = dislike extremely, to 9 = like extremely.
[b] Means that share a common letter are not significantly different ($\alpha < 0.001$).

The sensory attributes driving (dis)liking for these beverage formulations were explored through correlation analysis. The mean sensory ratings for sweetness were positively correlated with mean acceptability ($r = 0.95$; $P = 0.0002$). Conversely, the mean sensory ratings for bitterness were negatively correlated with mean acceptability ($r = -0.98$; $P < 0.0001$). The only other sensory attribute for which correlation analysis reached near significance was berry flavour ($r = 0.56$; $P = 0.15$) suggesting that the berry notes may have contributed to acceptability. This is in agreement with the main effect of polyphenol source for acceptability.

Finally, regression analysis was performed using the two experimental factors as independent variables. The best-fit model included the two main effects and a quadratic term for sucrose concentration. Although the model was significant ($F_{3,778} = 64.4$; $P < 0.0001$) the model fit was poor ($R^2 = 0.20$), indicating that polyphenol source and sucrose concentration only partially explained the variability in the acceptance scores. It is therefore possible that other characteristics of the beverages exerted significant influences on acceptability.

Purchase probability

In the first logistic regression analysis in which 'yes' responses were analysed against the pooled 'no' and 'not sure' responses, there were significant differences in purchase probabilities amongst the eight beverages ($-2LL = 526.2$; $df = 7$; $P < 0.0001$). Less conservative estimates were sought in the second analysis which pooled 'yes' and 'not sure' responses and analysed these against the 'no' responses ($-2LL = 850.1$; $df = 7$; $P < 0.0001$). Regardless of the analysis strategy adopted, the results from these regressions were similar to the analysis of the acceptability ratings in that choice probabilities increased with increasing concentration of added sucrose and were, on average, higher for formulations containing only berry fruit extract, as opposed to berry fruit and cocoa extracts.

The highest purchase probability was for berry fruit with 10.5% sucrose (Table 3). The 'most conservative' and 'least conservative' estimates of purchase probabilities differed considerably, in particular for formulations containing 7% and 10.5% added sucrose. This reflected the large number of responses falling in the 'not sure' answer category for these samples. Considering that the tested beverage formulations were in the early stage of the formulation/optimisation cycle it was encouraging that the predicted purchase probabilities of 50% were obtained. It pointed to the scope for further developing these formulations into commercially viable products.

Preference

The preference data was analysed using a conditional logit model and probabilities of each sample being preferred to all other samples were calculated. For ease of interpretation the data shown in Table 3 scales these probabilities against the sample containing berry fruit and cocoa extracts and no added sugar. Such a scaling provides an indication of the magnitude of differences in preferences for the different samples. Across the different consumer response measures, reported in Table 3 there is consistency in the finding that the formulation containing berry fruit and cocoa extracts and no added sucrose was the least acceptable of the eight tested beverages, and this sample was chosen as the references point (note that another sample could equally well have been chosen as the reference point). The magnitude of differences in the degree of liking of the samples is clearly seen in relation to the sample containing berry fruit extract and 10.5% added sucrose. The value of 25.8 means that this sample was ~25 times more likely to be chosen as the preferred sample than the berry fruit and cocoa formulation with no added sucrose. Significance testing at the 95% level revealed that three samples were equally likely to be the least preferred samples: berry fruit and cocoa with no added sucrose, berry fruit with no added sucrose, and berry fruit and cocoa with 3.5% added sucrose.

DISCUSSION

Value of sensory and consumer research with products in the early stage of the formulation/optimisation cycle

The consumer participants rated none of the beverages as highly acceptable, and acceptability ratings and estimates of purchase probability were below what would be required for commercial launch. From a perspective of reaching a go/no-go decision on the underlying product concept, this was not considered problematic. Rather, it was promising that purchase probability for the best formulations reached 50%. The joint analysis of the sensory and consumer data identified bitterness as a key attribute driving consumer dislike and if it was decided to progress the product concept to the next stage of development, efforts would need to be directed at masking bitterness further. The use of sucrose only

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achieved partial masking of bitterness, and the results suggested that further improvements in consumer acceptance would not be achieved through the use of higher concentrations of added sucrose. Recall that, on average, the formulations containing 10.5% added sucrose were not rated as more acceptable than those containing 7% added sucrose.

Rather, in the quest to improve consumer acceptability, it is suggested that the addition of sucrose be combined with other approaches to masking bitterness. It is beyond the scope of the present paper to go into details about such additional strategies, and we only briefly consider complexation, as it is thought to be a strategy that fits well with the current beverage concept. Complexation of a flavour compound using a food additive such as a cyclodextrin, lipid, protein, gum or polymer can be used to decrease the perception of bitterness.[39–42]

It was proposed that the combination of berry and cocoa/chocolate would be positively received by consumers. This proposition was not supported by the results. Recall that, on average, formulations containing both berry fruit and cocoa extracts were less positively evaluated then those containing only berry fruit extract. Although it is not possible from the current set of results to fully identify the sensory attributes associated with this difference in acceptability, suggestions can be put forward. On average, the berry fruit and cocoa formulations were more bitter than those containing only berry fruit extract, and this difference may have been the primary culprit. It is also possible that the berry flavour in these formulations was overpowered by the dark chocolate/cocoa flavour. The association between berry flavour and mean acceptability approached significance, suggesting that for the dual polyphenol-ingredient beverages, a re-adjustment of the relative concentrations of berry fruit extract and cocoa extract may have a positive effect on consumer acceptance.

It is also a possibility that the mouthfeel attribute 'chalkiness' contributed negatively to consumer acceptability in the berry fruit and cocoa formulations. It was a characteristic that a number of participants in the consumer test commented on, hereby signalling that it needed to be given at least some consideration in subsequent stages of product optimisation. Suggestions for how to do so are not easily forthcoming as there appears to be no directly relevant work in the extant literature to draw upon.

Taken together the insights obtained from the current research make it possible to reach a go/no-go decision as to the potential commercial viability of the tested polyphenol-rich beverages. At least for the berry fruit formulations there appears to be no reason why these beverages cannot be optimised to achieve a high level of sensory quality and consumer acceptance. For the berry fruit and cocoa formulations it is not possible to reach a similar 'go' decision. At least the issue of how to mask chalkiness appears to require further consideration.

Having argued that sensory and consumer research conducted with products at the early stage of the formulation/optimisation cycle can provide significant insights, it is worthwhile briefly considering the resources required to conduct such work. In this study, the consumer test was performed using a convenience sample of university students. It was conducted on a university campus and participants received a can of soft drink in return. There were very few costs associated with recruitment and reimbursement of consumer participants. While the use of a convenience sample generally means that results cannot be generalised beyond the current set of participants, it is, in view of the below average sensory quality of the products tested considered unlikely that other consumer samples would have provided acceptability scores significantly different from those obtained here. The sensory data were collected using descriptive sensory analysis and due to the vocabulary development required, this is quite an expensive process. It is suggested that other less rigorous approaches to obtaining descriptive sensory data be considered, for example, flash profiling.[43,44]

Consumer acceptance testing with health benefits disclosed

In the context of the tested polyphenol-rich beverages it is relevant to consider potential implications of disclosing information about the beverages' health benefits to consumers prior to tasting the products. In the current study, information of the healthful properties attributed to polyphenols was not disclosed to participants. The decision to execute the consumer test in this manner is in accordance with standard practice and enabled an unbiased assessment of consumer acceptability. It also permitted the joint analysis of sensory profiling and consumer data to uncover sensory attributes that were significantly associated with (dis)like. However, in the market place, it is likely that products such as these will be sold with accompanying health claims and it is therefore also of interest to understand if knowledge of the health benefits of these beverages would moderate consumers' evaluations.

The provision of health benefit information can contribute to more positive evaluation of some products, particularly in relation to purchase probability.[45,46] It seems important to ensure that consumers can see a direct personal health outcome and that they understand what the functional benefit means for them.[5,45] More broadly, willingness to buy functional foods is dependent on many factors, including: the taste of the product, consumers' knowledge and trust in health-related information, their motivation to engage in health preservation behaviours, how healthy the product is perceived to be, how it is priced and the particular demographics of the consumer.[5] Verbeke reported that belief in the health benefits from functional foods was the strongest determinant of willingness to compromise on taste.[6] However, he also highlighted the fast decreasing willingness to compromise on taste. Krystallis *et al.* concur; if functional foods do not taste palatable, consumers will not buy them.[5] In the context of the current beverages, it seems plausible that the disclosure of health benefit information will exert a positive influence on consumers. However, it is probably naive to expect that doing so would be sufficient to ensure commercial viability.

CONCLUSION

The health benefits of polyphenols are well documented, enabling polyphenol-rich foods/beverages to compete with other functional foods in the market place. However, to be successful, polyphenol-rich foods/beverages must not only have documented health benefits, their sensory quality must also be high. This research performed sensory analysis and consumer testing on a set of beverages in the early stage of formulation/optimisation, with the aim of establishing whether the focal product concept (a beverage made with berry fruit or berry fruit and cocoa polyphenol-rich extracts) could be developed into a commercially viable concept. The results were encouraging, and identified bitterness as a key sensory attribute to focus optimisation efforts on. On average, the cocoa and berry fruit formulations were less liked by consumers and chalkiness was an additional sensory attribute that required optimisation. It was suggested that the disclosure of the beverage's health benefit to consumers may further enhance their appeal to consumers.

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