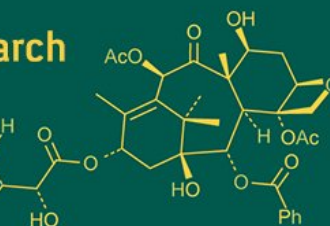
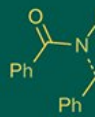


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Conjoint analysis-based optimisation of a fortified synbiotic beverage for type 2 diabetes: Ingredient preferences and sensory validation

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Abstract

The development of functional beverages for the dietary management of type 2 diabetes mellitus requires optimization of multiple bioactive ingredients while maintaining consumer acceptability. The present study employed conjoint analysis to optimize a synbiotic beverage formulated using skim milk, carrot juice, moringa leaves juice, double-encapsulated synbiotic powder, dietary fibre, seed slurry, stevia, lactose, and vanilla flavourant. Initially, four flavourants were evaluated against an unfortified control using a nine-point hedonic scale. Vanilla flavourant showed the highest preference across all sensory attributes, with an overall acceptability score of 8.66 compared with 6.35 for the control ($F = 42.159$, $P \leq 0.01$). Subsequently, eight formulation attributes, each at four levels, were evaluated using a fractional factorial orthogonal design, reducing 65,536 possible combinations to 16 profiles. Carrot juice was the most important attribute (24.50%), followed by moringa leaves juice (15.20%) and lactose (14.00%), whereas flavourant showed the lowest relative importance (7.20%). Part-worth utility analysis identified the optimum formulation as 15.00% carrot juice, 4.00% moringa leaves juice, 1.50% synbiotic powder, 1.50% dietary fibre, 0.020% stevia, 4.00% seed slurry, 0.15% vanilla flavourant, and 10.00% lactose per 200 mL serving. The optimized beverage exhibited significantly higher sensory scores than the control for all evaluated attributes, with overall acceptability scores of 8.50 and 6.76, respectively ($t = 8.924$, $P \leq 0.01$). The findings demonstrate the applicability of conjoint analysis as an efficient approach for optimizing complex multi-ingredient functional beverages based on consumer sensory preferences.

Keywords: Conjoint analysis, synbiotic beverage, part-worth utility, relative importance, type 2 diabetes, Moringa, carrot juice, sensory evaluation

1. Introduction

Type 2 diabetes mellitus (T2DM) has emerged as a major public health challenge in contemporary India. The ICMR-INDIAB national cross-sectional survey, encompassing all states and union territories, estimated that approximately 101 million Indian adults have diabetes and a further 136 million have prediabetes. Notably, the prevalence of prediabetes exceeds that of diabetes in several states, highlighting the substantial population that may benefit from early dietary and lifestyle interventions (Anjana *et al.*, 2023) ^[1]. The development of acceptable functional foods and beverages may therefore provide a practical dietary approach for supporting metabolic health among individuals at risk of or living with T2DM.

Modulation of the gut microbiota through probiotics, prebiotics, and synbiotics has received considerable attention as a dietary strategy for improving glycaemic regulation. An umbrella meta-analysis of meta-analyses of randomized clinical trials reported that probiotic supplementation significantly reduced fasting blood glucose, glycated haemoglobin, fasting insulin, and homeostatic model assessment of insulin resistance in individuals with impaired glucose metabolism (Zarezaheh *et al.*, 2022) ^[13]. Similarly, a meta-analysis of nine randomized controlled trials involving 661 participants demonstrated that inulin supplementation reduced fasting plasma glucose, glycated haemoglobin, and insulin resistance in individuals with T2DM, with greater effects observed following supplementation for eight weeks or longer (Zhang *et al.*, 2020) ^[14].

Synbiotics, which combine live microorganisms with selectively utilized substrates, may consequently provide complementary benefits. However, maintaining probiotic viability during processing and storage remains a critical technological consideration. Encapsulation, particularly double or multilayer encapsulation, has been investigated as an effective strategy for protecting probiotic cells from processing-related stresses, including thermal, acidic, and bile conditions, while facilitating their subsequent release in the gastrointestinal tract (Jimenez-Villeda *et al.*, 2023) [5].

In addition to the synbiotic component, incorporation of plant-based ingredients may enhance the functional potential and nutritional profile of such beverages. Carrot juice provides carotenoids, phenolic compounds, and dietary fibre and is suitable for incorporation into beverage formulations because of its established processing characteristics and consumer familiarity (Sharma *et al.*, 2012) [11]. *Moringa oleifera* leaves are rich in bioactive phytochemicals and have been associated with improvements in glucose regulation, insulin sensitivity, oxidative status, and inflammatory responses in preclinical and human studies (Mthiyane *et al.*, 2022) [6]. Pumpkin and sunflower seed slurry can contribute plant protein, minerals, unsaturated fatty acids, and other bioactive compounds. Pumpkin seeds have been characterized as a nutritionally valuable functional food ingredient with diverse compositional and bioactive properties (Dotto and Chacha, 2020) [4], while sunflower seeds provide vitamin E, magnesium, selenium, and phenolic compounds (Puraikalan and Scott, 2023) [8]. Stevia provides sweetness without the glycaemic contribution associated with sucrose, and evidence from preclinical studies indicates potential antihyperglycaemic effects of stevia-derived compounds (Chowdhury *et al.*, 2022) [3].

The incorporation of multiple functional ingredients, however, presents a significant formulation challenge because each component can influence sensory characteristics differently. Carrot juice contributes colour and vegetal sweetness, whereas moringa leaves may impart green and slightly pungent notes. Seed slurry can modify mouthfeel and body, stevia may produce an undesirable aftertaste at higher concentrations, and encapsulated synbiotic powder may influence texture and particulate perception. Consequently, increasing the concentration of an ingredient to enhance its functional contribution may adversely affect consumer acceptability. When eight formulation ingredients are each evaluated at four levels, a complete factorial design would require 65,536 combinations. Conventional one-factor-at-a-time experimentation is therefore inefficient and does not adequately account for interactions and consumer trade-offs among formulation attributes.

Conjoint analysis provides a systematic approach for addressing such multidimensional optimization problems. The method evaluates complete product profiles rather than individual ingredients and statistically estimates the part-worth utility associated with each attribute level, together with the relative importance of individual attributes in determining overall preference (Rao, 2014) [10]. Its application to beverage products has demonstrated its usefulness in identifying consumer-preferred combinations of sensory and extrinsic attributes. For example, conjoint analysis applied to iced coffee provided interpretable preference structures across multiple product attributes (Asioli *et al.*, 2016) [2], while a study of milk tea identified pearl size as the most influential attribute, accounting for 29.14% of relative importance, and subsequently used the

estimated utilities to establish a preferred product configuration (Ong *et al.*, 2021) [7]. More recently, conjoint analysis combined with response surface methodology has been applied to the optimization of nutrient-fortified milk beverages, demonstrating its potential for determining ingredient levels in dairy-based formulations (Ramkumar *et al.*, 2025) [9].

Against this background, the present study aimed to develop and optimize a synbiotic functional beverage intended for dietary management of T2DM using conjoint analysis. Specifically, the study aimed (i) to screen four candidate flavourants against an unfortified control and identify the most suitable flavourant for the beverage matrix; (ii) to determine the relative importance and part-worth utilities of eight formulation ingredients, each evaluated at four levels, using a fractional factorial orthogonal design; and (iii) to prepare the beverage according to the conjoint-derived optimum formulation and validate its sensory acceptability against a control.

2. Materials and Methods

2.1. Raw materials

Fresh carrots (*Daucus carota* L.), moringa leaves (*Moringa oleifera* Lam.), pumpkin seeds (*Cucurbita* spp.) and sunflower seeds (*Helianthus annuus* L.) were procured locally and screened for freedom from visible damage and foreign matter. Skim milk was used as the carrier matrix. Inulin and fructooligosaccharide were used as the dietary fibre source, stevia powder as the sweetener, lactose as the carbohydrate adjunct and cryoprotectant for the culture, and food grade chocolate, vanilla, saffron and mango preparations as candidate flavourants. The probiotic and prebiotic components were incorporated as a double encapsulated synbiotic powder, the encapsulation being intended to preserve viability through processing and storage in line with current practice for synbiotic systems (Jimenez-Villeda *et al.*, 2023) [5].

2.2. Preparation of the ingredient streams

Carrots were washed, trimmed, peeled and comminuted, and the extracted juice was filtered to remove coarse fibre. Moringa leaves were destalked, washed, blanched to inactivate enzymes and reduce microbial load, blended with potable water and filtered to yield a clarified leaf juice. Pumpkin and sunflower seeds were cleaned, soaked, dehulled and wet ground into a fine slurry, which was screened before use. The three streams were prepared fresh on the day of each trial. Each experimental profile was made up to a serving volume of 200 ml with skim milk after all other ingredients had been added, so that the ingredient levels in Table 1 are expressed as a percentage of the finished 200 ml serving.

2.3. Screening of the flavourant

Flavourant had to be fixed before the conjoint design could be executed, a preliminary screening trial was run. Four flavoured versions of the fortified beverage, using chocolate, vanilla, saffron and mango respectively, were compared against a control consisting of the unfortified milk beverage. Each treatment was prepared in six independent trials and evaluated on the nine point hedonic scale for colour and appearance, taste, flavour, mouth feel and overall acceptability. The flavourant returning the highest scores was carried forward as the fixed flavour identity of the product, and its inclusion level was then treated as one of the eight conjoint attributes.

2.4. Conjoint experimental design

Eight ingredients were defined as conjoint attributes, each at four levels, giving the attribute and level structure shown in Table 1. The levels were chosen from preliminary trials so that they bracketed the range that was both technologically feasible and nutritionally meaningful. A full factorial combination of eight attributes at four levels would require 4 to the power of 8, that is 65,536, product profiles, which is not evaluable by a sensory panel. A fractional factorial orthogonal array was therefore generated so that the main effect of every attribute level could be estimated independently of the others, and this reduced the design to 16 evaluable profiles, designated T1 to T16 and listed in Table 2. Together with the control, a total of 17 treatments were prepared and evaluated. The design generation, the utility estimation and the importance calculation were carried out using the conjoint procedure of IBM SPSS Statistics, following the standard rating based conjoint workflow described for food and beverage applications by Asioli *et al.* (2016) [2] and set out in detail by Rao (2014) [10].

2.5. Sensory evaluation

All 17 treatments were evaluated by a panel using the nine-point hedonic scale, anchored at 1 for dislike extremely and 9 for like extremely, for colour and appearance, taste, flavour, mouth feel and overall acceptability. The nine-point hedonic scale was selected because it remains the most widely validated acceptance instrument in food science and because its statistical behaviour, including its treatment as an interval scale for parametric analysis, has been critically reappraised and found defensible for acceptance testing of the present type (Wichchukit and O'Mahony, 2015) [12]. Samples were presented in a randomised order under uniform conditions, and panellists rinsed between samples.

2.6. Estimation of part-worth utilities and relative importance

The overall acceptability score of each profile was used as the dependent preference measure. Part-worth utilities were estimated for every level of every attribute by ordinary least squares regression on dummy coded attribute levels under the discrete model, which imposes no order restriction on the levels and is therefore appropriate for ingredient concentrations whose effect on liking need not be monotonic. The relative importance of an attribute was computed as the range of its part-worth utilities, that is the highest utility minus the lowest utility within that attribute, expressed as a percentage of the sum of the utility ranges of all eight attributes, so that the eight values sum to 100 per cent (Rao, 2014) [10]. The optimum level of each ingredient was taken as the level carrying the highest part-worth utility, and the maximum utility profile assembled from these levels was taken as the conjoint derived optimum formulation.

2.7. Preparation and validation of the optimised beverage:

The beverage was prepared at the conjoint derived optimum and compared against a control consisting of the unfortified milk beverage prepared alongside it. Both were evaluated on the same nine point hedonic scale for the same five attributes.

2.8. Statistical analysis

Sensory data from the flavourant screening trial were analysed by one way analysis of variance, with treatment means separated at the 1 per cent and 5 per cent levels of significance. The optimised beverage and its control were compared by Student t test. Results are reported as mean plus or minus standard error, with two asterisks denoting significance at P less than or equal to 0.01 and one asterisk denoting significance at P less than or equal to 0.05.

Table 1: Ingredients treated as conjoint attributes and the four levels assigned to each, expressed per 200 ml serving.

Ingredient (attribute)	Unit	Level 1	Level 2	Level 3	Level 4
Carrot juice	% v/v	10.00	15.00	20.00	25.00
Moringa leaves juice	% v/v	2.00	4.00	6.00	8.00
Synbiotic powder	% w/v	1.00	1.50	2.00	2.50
Dietary fibre (Inulin and FOS)	% w/v	1.00	1.50	2.00	2.50
Stevia	% w/v	0.010	0.015	0.020	0.025
Pumpkin and sunflower seed slurry	% v/v	4.00	6.00	8.00	10.00
Flavourant	% v/v	0.10	0.15	0.20	0.25
Lactose	% w/v	5.00	10.00	15.00	20.00

FOS: fructooligosaccharide. Levels are expressed as a percentage of the finished 200 ml serving.

Table 2: Fractional factorial orthogonal array of 16 product profiles generated for the conjoint experiment. All values are percentages of the finished 200 ml serving.

Profile	Carrot	Moringa	Synbiotic	Fibre	Stevia	Seed slurry	Flavourant	Lactose
T ₁	10	2	1.00	1.00	0.010	4	0.10	5
T ₂	10	4	1.50	1.50	0.015	6	0.15	10
T ₃	10	6	2.00	2.00	0.020	8	0.20	15
T ₄	10	8	2.50	2.50	0.025	10	0.25	20
T ₅	15	2	1.50	2.00	0.025	8	0.15	20
T ₆	15	4	1.50	2.00	0.020	4	0.15	10
T ₇	15	6	2.50	1.00	0.015	4	0.25	10
T ₈	15	4	2.00	1.50	0.010	6	0.20	5
T ₉	20	2	2.00	2.50	0.015	6	0.20	15
T ₁₀	20	4	2.50	2.00	0.010	4	0.10	20
T ₁₁	20	6	1.00	1.50	0.025	10	0.15	5
T ₁₂	20	8	1.50	1.00	0.020	8	0.10	10
T ₁₃	25	2	2.50	1.50	0.020	10	0.20	10
T ₁₄	25	4	2.00	1.00	0.025	8	0.25	5
T ₁₅	25	6	1.50	2.50	0.010	6	0.10	20
T ₁₆	25	8	1.00	2.00	0.015	4	0.15	15

A seventeenth treatment, the unfortified control, was evaluated alongside the 16 profiles.

3. Results and Discussion

3.1. Selection of the flavourant

Flavourant screening and sensory evaluation

The sensory evaluation demonstrated significant differences among the flavourant treatments and the unfortified control across all attributes assessed (Table 3; Figure 1). The calculated F values ranged from 22.346 for mouthfeel to 42.159 for overall acceptability, with all differences significant at $P \leq 0.01$. The overall results indicated that incorporation of a flavourant substantially improved the sensory acceptability of the beverage compared with the unfortified control. The control recorded a taste score of 5.47, whereas the incorporation of the four flavourants resulted in improvements ranging from 1.78 to 2.68 points on the nine-point hedonic scale.

Among the flavourants evaluated, vanilla recorded the highest mean scores for all five sensory attributes, with scores of 8.68 for colour and appearance, 8.15 for taste, 8.44 for flavour, 8.62 for mouthfeel, and 8.66 for overall acceptability. Saffron recorded the second-highest overall acceptability score (8.46), followed by mango (8.15) and chocolate (8.06). Although the numerical differences among the flavourants were relatively small, vanilla consistently exhibited the highest scores across all sensory attributes and

was therefore selected for subsequent formulation optimization. In addition to its sensory performance, vanilla was considered suitable for the formulation because of its compatibility with the characteristic colour of the beverage and its potential to complement the flavour profile contributed by the vegetable and leaf-based ingredients.

The present findings are consistent with previous studies demonstrating the importance of sensory attributes and formulation characteristics in determining consumer preference for functional and fortified beverages. Ong *et al.* (2021) [7], in a conjoint analysis of milk tea, reported greater relative importance for sugar level and beverage type than for brand, indicating the substantial contribution of product-related attributes to consumer preference. Similarly, Ramkumar *et al.* (2025) [9] applied conjoint analysis in combination with response surface methodology for the optimization of nutrient-fortified milk beverages and demonstrated the usefulness of systematic sensory and formulation optimization. In the present study, preliminary flavourant screening was therefore used to identify the most suitable flavourant before optimizing its concentration along with the other formulation attributes through conjoint analysis.

Table 3: Sensory scores of the synbiotic beverage prepared with four flavourants and of the unfortified control, on the nine point hedonic scale.

Beverage	Colour and appearance	Taste	Flavour	Mouth feel	Overall acceptability
Control	7.42 ^a ± 0.076	5.47 ^a ± 0.088	6.51 ^a ± 0.144	7.22 ^a ± 0.088	6.35 ^a ± 0.042
Chocolate	8.32 ^b ± 0.111	7.25 ^b ± 0.760	8.10 ^b ± 0.790	8.17 ^b ± 0.093	8.06 ^b ± 0.057
Vanilla	8.68 ^b ± 0.120	8.15 ^b ± 0.060	8.44 ^b ± 0.490	8.62 ^b ± 0.320	8.66 ^b ± 0.510
Saffron	8.54 ^b ± 0.111	8.01 ^b ± 0.010	8.21 ^b ± 0.190	8.54 ^b ± 0.230	8.46 ^b ± 0.990
Mango	8.49 ^b ± 0.111	7.98 ^b ± 0.620	8.02 ^b ± 0.550	8.01 ^b ± 0.870	8.15 ^b ± 0.670
F value	22.346**	28.142**	27.450**	23.612**	42.159**

Average of six trials. Means in the same column bearing different superscripts differ significantly. ** Highly significant at P less than or equal to 0.01. Control, unfortified milk beverage.

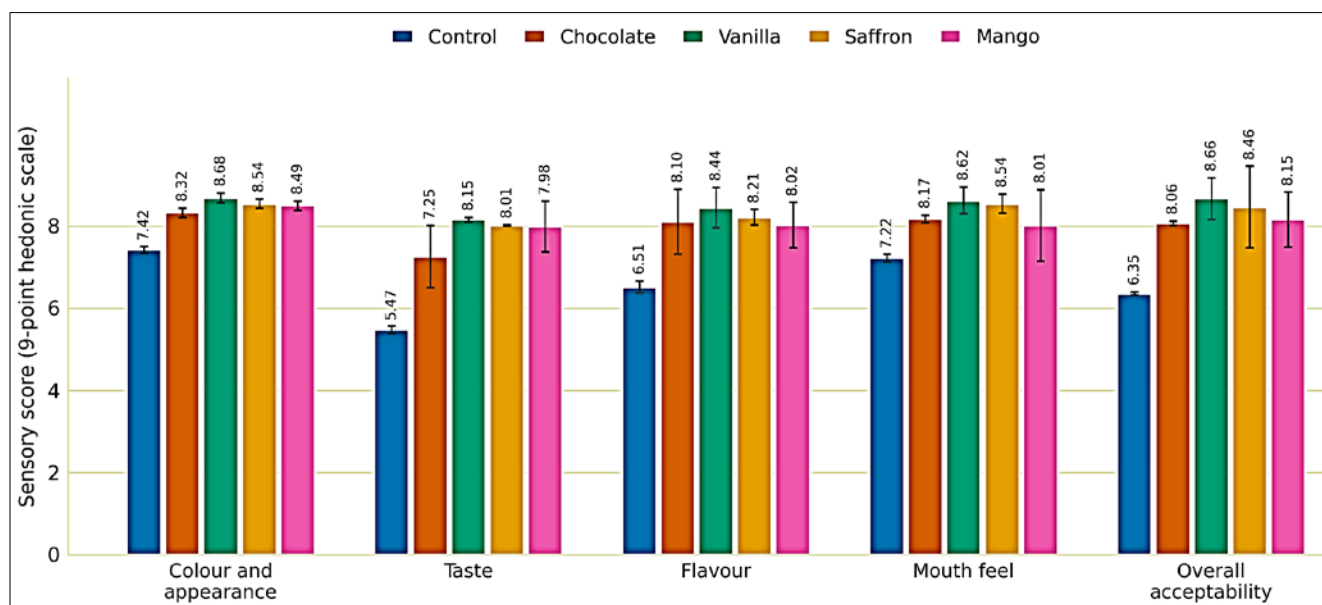


Fig 1: Sensory scores of the four flavoured synbiotic beverages and the unfortified control across five sensory attributes. Error bars denote standard error of the mean of six trials.

3.2. Relative importance of the eight ingredients

The relative importance values and part-worth utility estimates obtained from the conjoint analysis are presented in Table 4. Among the eight ingredient attributes, carrot

juice exhibited the highest relative importance (26.75%), followed by flavourant (17.65%) and lactose (16.09%). Moringa leaves juice, stevia, dietary fibre, synbiotic powder, and seed slurry contributed 12.71%, 10.94%, 7.31%, 6.74%,

and 1.83%, respectively. Thus, carrot juice, flavourant, and lactose collectively accounted for 60.49% of the total relative importance, indicating their comparatively greater contribution to overall product preference.

The part-worth utilities further indicated that the preferred level varied among the ingredient attributes. The highest utility for carrot juice was observed at 15% (1.886), followed by 20% (0.543), whereas 10% (−1.303) and 25% (−0.553) showed lower utilities. For moringa leaves juice, the highest utility was observed at 4% (0.972). Lactose showed the highest utility at 10% (1.268), while the preferred stevia level was 0.020% (0.559). Among the functional ingredients, synbiotic powder showed the highest utility at 1.5% (−0.690), dietary fibre at 1.5% (0.833), and seed slurry at 4% (0.381). For flavourant, the highest utility was observed at 0.15% (−0.701).

The relatively high importance of carrot juice, flavourant,

and lactose suggests that these attributes played a greater role in determining overall preference among the ingredient attributes evaluated. In contrast, seed slurry showed the lowest relative importance (1.83%), followed by synbiotic powder (6.74%) and dietary fibre (7.31%). These findings indicate that the conjoint approach can be useful for identifying the relative contribution of individual formulation attributes and for selecting ingredient levels associated with higher preference.

Overall, the conjoint analysis identified 15% carrot juice, 4% moringa leaves juice, 10% lactose, 0.020% stevia, 1.5% synbiotic powder, 1.5% dietary fibre, 4% seed slurry, and 0.15% flavourant as the highest-utility levels within their respective attributes. These levels represent the preferred levels based on the part-worth utilities obtained in the present analysis and may therefore be considered during formulation optimisation.

Table 4: Part-worth utility estimates for each ingredient level and the relative importance of each ingredient, derived by conjoint analysis of overall acceptability across 16 product profiles.

Attribute	Level	Part-worth utility	Relative importance (%)
Carrot juice (%)	10	−1.303	26.75
	15	1.886	
	20	0.543	
	25	−0.553	
Moringa leaves juice (%)	2	0.521	12.71
	4	0.972	
	6	−0.421	
	8	−0.543	
Lactose (%)	5	0.615	16.09
	10	1.268	
	15	−0.553	
	20	−0.650	
Stevia (%)	0.010	0.186	10.94
	0.015	0.372	
	0.020	0.559	
	0.025	−0.745	
Synbiotic powder (%)	1.0	−0.898	6.74
	1.5	−0.690	
	2.0	−0.995	
	2.5	−1.493	
Dietary fibre (%)	1.0	0.468	7.31
	1.5	0.833	
	2.0	−0.014	
	2.5	−0.038	
Seed slurry (%)	4	0.381	1.83
	6	0.163	
	8	0.244	
	10	0.325	
Flavourant (%)	0.10	2.805	17.65
	0.15	0.701	
	0.20	2.104	
	0.25	0.896	

Constant: 11.912

Pearson's R: 0.613*

Kendall's tau: 0.572**

n: 30* $P \leq 0.05$; ** $P \leq 0.01$.

Relative importance values sum to 100.00 per cent. A higher part-worth utility indicates a stronger positive contribution of that level to overall acceptability.

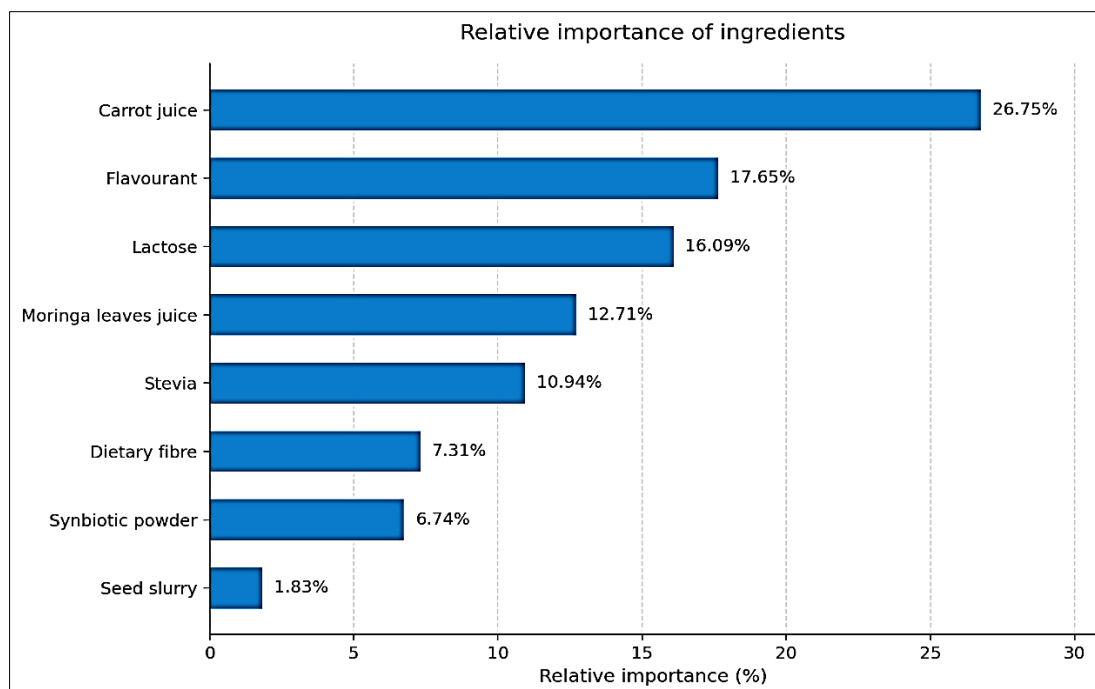


Fig 2: Relative importance of the eight ingredients in determining overall acceptability of the synbiotic beverage.

3.3. Part-worth utilities of the individual ingredients

The part-worth utilities are set out in Table 4 and displayed level by level in Figure 3, in which the level carrying the highest utility within each ingredient is highlighted. The utilities are discussed below one ingredient at a time, since each carries a different formulation lesson.

3.3.1. Carrot juice

Carrot juice produced a sharply non-monotonic response: minus 1.303 at 10 per cent, rising to a maximum of 1.886 at 15 per cent, then falling to 0.543 at 20 per cent and further to minus 0.553 at 25 per cent. The 15 per cent level is therefore the only inclusion at which carrot juice is unambiguously preferred; both the lowest and highest tested levels carried a net sensory penalty. This pattern indicates a narrow acceptance window in which the colour is fully developed and the vegetal sweetness supports the dairy base, either side of which the beverage is judged unfavourably, too thin and underdeveloped in colour at 10 per cent, and increasingly unfamiliar and vegetal-dominant from 20 per cent upward. The behaviour is consistent with the processing literature on carrot, which notes that carotenoid intensity and characteristic flavour scale together with juice concentration and that both carry an acceptance ceiling in composite dairy products (Sharma *et al.*, 2012) [11]. With a utility range of 3.189 units, the widest of any attribute in the study, carrot juice also carries the highest relative importance in the set at 26.75 per cent, meaning that the single decision to fix inclusion at 15 per cent rather than any neighbouring level exerts more influence on overall acceptability than any other choice in the formulation.

3.3.2. Moringa leaves juice

Moringa leaves juice showed a rise-then-collapse profile: 0.521 at 2 per cent, a maximum of 0.972 at 4 per cent, then a fall to minus 0.421 at 6 per cent and minus 0.543 at 8 per cent. Unlike carrot juice, moringa was net preferred at the two lower levels and only became a sensory liability from 6 per cent upward, indicating that a modest herbal inclusion is

tolerated, and even mildly favoured, provided the leaf note remains subordinate to the surrounding vanilla flavour system. The sharp decline beyond 4 per cent is consistent with moringa's known tendency toward bitterness and green, grassy off-notes at higher concentrations.

This nonetheless represents a central formulation tension. Moringa carries much of the antidiabetic rationale for the product, since leaf extracts have been shown across animal and human studies to improve glycaemic control and insulin sensitivity and to reduce oxidative stress and inflammatory cytokine expression, with human benefit reported at leaf powder intakes in the region of 20 g (Mthiyane *et al.*, 2022) [6]. The conjoint result indicates that the sensory ceiling sits at 4 per cent, well below the level associated with the strongest reported physiological effect, so that raising the delivered phytochemical dose without raising the sensory cost remains the clearest target for future work, whether through encapsulation of the moringa fraction, a debittered or fermented leaf preparation, or a concentrated extract that delivers the same load in a smaller volume. At 12.71 per cent relative importance, moringa ranks fourth of the eight attributes, indicating a meaningful but not dominant sensory influence.

3.3.3. Lactose

Lactose produced a clean single peak: 0.615 at 5 per cent, a maximum of 1.268 at 10 per cent, then a fall to minus 0.553 at 15 per cent and minus 0.650 at 20 per cent. The sign change between 10 and 15 per cent marks the point at which added carbohydrate stops contributing perceived body and roundness and begins to compete with the stevia as an overly sweet, cloying note. At 16.09 per cent relative importance, lactose is the third most influential attribute in the set, a notably strong showing for a nominally neutral carbohydrate, and reflects its dual role in this system, both as a mouthfeel and sweetness contributor and as the carrier and cryoprotectant fraction associated with the encapsulated culture (Jimenez-Villeda *et al.*, 2023) [5]. The optimum of 10 per cent, that is 20 g per serving, warrants scrutiny in any

future version of this product intended for a diabetic population, given the glycaemic implications of the carbohydrate load alongside its sensory benefit.

3.3.4. Stevia

Stevia showed a rising utility across the first three levels, 0.186 at 0.010 per cent, 0.372 at 0.015 per cent and a maximum of 0.559 at 0.020 per cent, followed by a sharp collapse to minus 0.745 at 0.025 per cent. This is the classic steviol glycoside dose response: sweetness perception increases with concentration until a threshold is reached at which the characteristic bitter, liquorice-like aftertaste of rebaudioside and stevioside becomes detectable, after which acceptance falls sharply. The 0.020 per cent level identified here sits immediately below that threshold. The choice of stevia over sucrose is justified independently of the sensory result, since a systematic review and meta-analysis of preclinical studies established an antihyperglycaemic effect of stevia leaves at doses of 200, 300 and 400 mg per kg body weight and confirmed that steviol glycosides deliver sweetness without a glycaemic contribution (Chowdhury *et al.*, 2022) [3]. Its relative importance of 10.94 per cent, fifth highest in the set, shows that although stevia is added at the smallest absolute quantity of any ingredient, it exerts an influence on preference disproportionate to its mass.

3.3.5. Synbiotic powder

The double-encapsulated synbiotic powder returned negative utilities at all four levels: minus 0.898 at 1.0 per cent, a least-negative value of minus 0.690 at 1.5 per cent, minus 0.995 at 2.0 per cent and minus 1.493 at 2.5 per cent. Every inclusion level therefore carries a sensory cost, unsurprising given that encapsulated particles introduce a perceptible graininess and a faint fermented note into an otherwise smooth beverage. What is encouraging is the narrowness of the penalty: the utility range across the whole 1.0 to 2.5 per cent span is only 0.803 units, translating into a relative importance of 6.74 per cent, the second lowest of the eight attributes, and the difference between the best and worst level is considerably smaller than that observed for carrot juice, flavourant, lactose or moringa. The formulator can therefore raise the culture load appreciably at modest sensory cost, which is the practical argument for encapsulation in the first place: the coating that protects viability through thermal and gastric stress also isolates the cells from the sensory system of the consumer (Jimenez-Villeda *et al.*, 2023) [5]. The selected level of 1.5 per cent, that is 3 g per 200 mL serving, represents the point at which the penalty is smallest, and the viability delivered at that loading should be confirmed against the threshold conventionally required for a probiotic claim.

3.3.6. Dietary fibre

The inulin and fructooligosaccharide blend gave positive utilities at the two lower levels, 0.468 at 1.0 per cent and a maximum of 0.833 at 1.5 per cent, and slightly negative, essentially neutral utilities at the two higher levels, minus 0.014 at 2.0 per cent and minus 0.038 at 2.5 per cent. Inulin at moderate inclusion improves body and creaminess in a low-fat dairy matrix, which explains the positive utility at 1.5 per cent, and the flattening rather than collapse at higher levels suggests that the upper limit is set by viscosity and a slight chalkiness rather than by any strong off-flavour. The relative importance of 7.31 per cent again indicates a

functional ingredient that the panel notices but does not weight heavily. The nutritional case for including it is strong and independent of the sensory case, since inulin supplementation has been shown in a meta-analysis of nine randomised controlled trials to reduce fasting plasma glucose, glycated haemoglobin and insulin resistance in type 2 diabetes, with a standardised mean difference of minus 0.69 for glycated haemoglobin (Zhang *et al.*, 2020) [14]. The selected 1.5 per cent, that is 3 g per serving, is well inside the tolerated range, and the near-neutral utility profile above it indicates that the level could be raised toward a more physiologically meaningful daily intake with only a marginal loss of acceptability.

3.3.7. Pumpkin and sunflower seed slurry

The seed slurry was the most sensorially forgiving ingredient in the study. All four levels returned positive utilities, and the spread was the narrowest of any attribute: 0.381 at 4 per cent, 0.163 at 6 per cent, 0.244 at 8 per cent and 0.325 at 10 per cent, a total range of only 0.218 units. This produced by far the lowest relative importance in the set, at 1.83 per cent. In effect, the panel liked the slurry at every level tested and could barely distinguish between levels, meaning the ingredient can be set almost entirely on nutritional grounds. That is a useful degree of freedom, because the seed fraction is where the plant protein, magnesium, zinc and unsaturated lipid of the formulation reside. Pumpkin seeds have been reviewed as a functional food ingredient with a bioactive profile that includes tocopherols, phytosterols and a favourable mineral composition (Dotto and Chacha, 2020) [4], and sunflower seeds contribute vitamin E at high density along with magnesium, selenium and phenolic acids (Puraikalan and Scott, 2023) [8]. The conjoint optimum of 4 per cent is the numerically highest utility, but the near-flat profile means that a formulator prioritising mineral density could move to 10 per cent at a utility cost of only 0.056 units, negligible against the 3.189 unit range observed for carrot juice.

3.3.8. Flavourant

The vanilla flavourant returned negative utilities at all four levels: minus 1.403 at 0.10 per cent, a least-negative value of minus 0.701 at 0.15 per cent, minus 2.104 at 0.20 per cent and minus 2.805 at 0.25 per cent. This appears at first sight to contradict the flavourant screening trial, in which vanilla clearly improved acceptance over the unfortified control. The two results are in fact consistent, because they answer different questions. The screening trial asked whether a flavourant should be present, and the answer was unambiguously yes. The conjoint attribute asked how much of it should be present within a range in which it is always present, and the answer is that the lowest useful dose, 0.15 per cent rather than the numerically lowest tested level of 0.10 per cent, is best, and that both under- and overdosing relative to this point are penalised, with overdosing penalised far more severely. The steep decline above 0.15 per cent reflects the familiar behaviour of a concentrated vanilla preparation, which reads as pleasant at moderate inclusion and as artificial and cloying above it. Notably, with a utility range of 2.104 units and a relative importance of 17.65 per cent, the flavourant is the second most influential attribute in the entire study, behind only carrot juice, so that although its presence is a settled question, its precise level is very far from the least consequential

decision in the formulation; the difference between 0.15 and

0.25 per cent alone spans more than two full utility units.

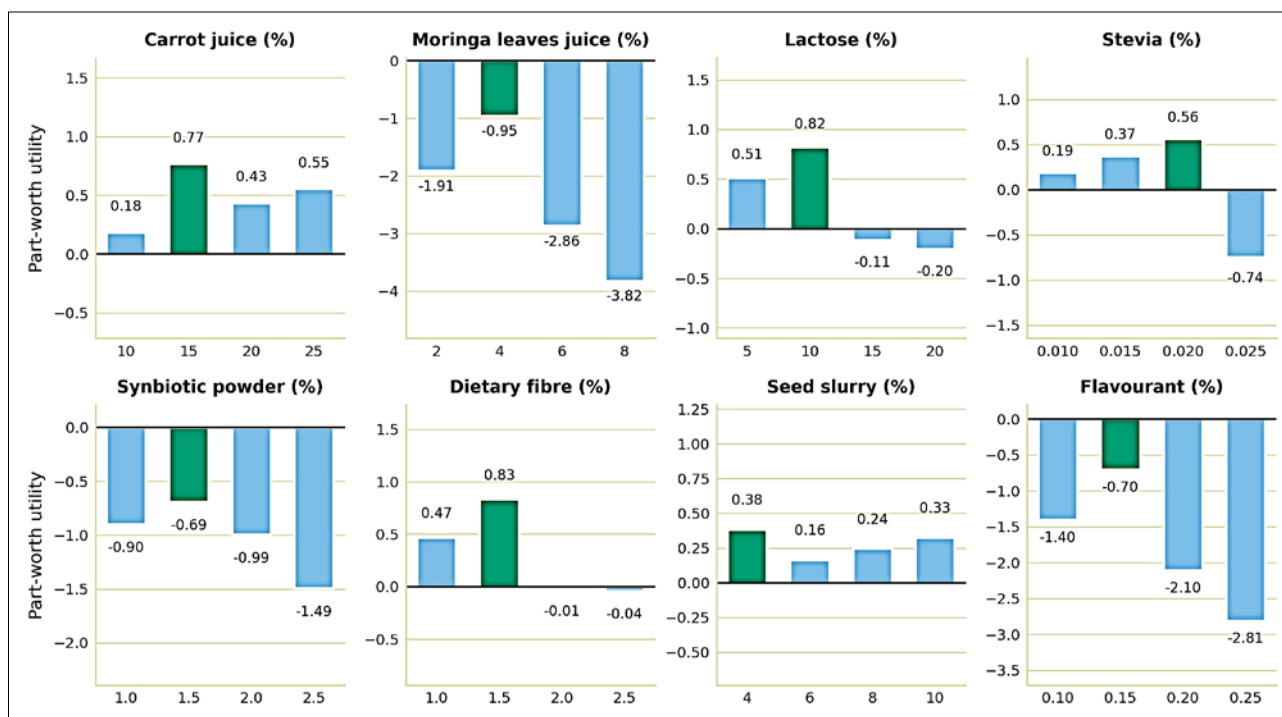


Fig 3: Part-worth utility estimates for each of the four levels of the eight ingredients. Within each panel the level carrying the highest utility, and therefore selected for the optimum formulation, is highlighted.

3.4. The conjoint derived optimum formulation

Assembling the highest utility level of each ingredient gives the maximum utility profile, which is presented as the optimised formulation in Table 5. Per 200 ml serving the beverage contains 30.00 ml carrot juice, 8.00 ml moringa leaves juice, 3.00 g dietary fibre as inulin and fructooligosaccharide, 8.00 ml pumpkin and sunflower seed slurry, 3.00 g double encapsulated synbiotic powder, 0.04 g stevia, 0.30 ml vanilla flavourant and 20.00 g lactose, made up to volume with 127.66 ml skim milk.

It is worth noting that this profile does not correspond to any of the 16 experimental treatments in Table 2. That is the defining advantage of a conjoint decomposition over a simple ranking of the tested profiles: because the model estimates the independent contribution of each level, it can predict the acceptability of a combination that was never physically prepared, and the optimum it identifies is therefore drawn from the full 65,536 point design space rather than from the 16 points sampled.

Table 5: Optimised synbiotic beverage formulation assembled from the highest part-worth utility level of each ingredient.

S. No.	Ingredient	Quantity per 200 ml serving	Level selected by conjoint analysis
1	Skim milk (base)	127.66 ml	Carrier matrix
2	Carrot juice	30.00 ml	15.00 % v/v
3	Moringa leaves juice	8.00 ml	4.00 % v/v
4	Dietary fibre (inulin and FOS)	3.00 g	1.50 % w/v
5	Pumpkin and sunflower seed slurry	8.00 ml	4.00 % v/v
6	Double encapsulated synbiotic powder	3.00 g	1.50 % w/v
7	Stevia	0.04 g	0.020 % w/v
8	Flavourant (vanilla)	0.30 ml	0.15 % v/v
9	Lactose	20.00 g	10.00 % w/v
	Total serving volume	200.00 ml	

3.5. Sensory validation of the optimised beverage

The beverage prepared at the conjoint derived optimum was compared against the unfortified control, and the results are given in Table 6 and Figure 4. The optimised product scored significantly higher on every attribute at P less than or equal to 0.01. Colour and appearance rose from 6.05 to 8.13, an increase of 34.38 per cent, with the largest t value in the set at 12.284 relative to the very small standard errors; taste rose from 5.95 to 7.51, an increase of 26.22 per cent; flavour rose from 6.10 to 8.30, an increase of 36.07 per cent and the largest t value overall at 14.636; mouth feel rose from 6.23 to 8.25, an increase of 32.42 per cent; and overall

acceptability rose from 6.76 to 8.50, an increase of 25.74 per cent.

Two features of this result deserve comment. First, the optimised product reproduced, and in three of the five attributes slightly exceeded, the scores obtained by the best treatment in the flavourant screening trial, which lends empirical support to the model derived combination described above. The predicted optimum was not simply as good as the best profile actually tested; it performed at or above that level while carrying the full complement of functional ingredients. Second, taste remains the weakest attribute of the optimised product at 7.51, roughly 0.8 to 0.9

scale points below the other four. This is the residual signature of the moringa fraction, which the part-worth analysis had already identified as a net negative at every level, and it marks the specific direction in which the formulation still has room to improve. The consistency of the negative moringa utility across the conjoint model and the lagging taste score in the validation trial is a useful internal cross-check on the analysis, since two independent parts of the study point at the same ingredient.

At 8.50 on the nine point scale, the overall acceptability of the optimised beverage sits between like very much and like

extremely, which is a commercially viable position for a functional product and comparable to the acceptance levels reported for optimised fortified dairy beverages developed by conjoint and response surface methods (Ramkumar *et al.*, 2025) [9]. It should be noted that the control in this validation trial scored 6.76 for overall acceptability against 6.35 in the flavourant screening trial, a difference attributable to the controls being prepared and evaluated in separate sessions; the comparison within each trial is internally consistent and the conclusion is unaffected.

Table 6: Sensory scores (mean plus or minus standard error) of the optimised synbiotic beverage and the unfortified control on the nine point hedonic scale.

Beverage	Colour and appearance	Taste	Flavour	Mouth feel	Overall acceptability
Control (unfortified milk beverage)	6.05 ± 0.076	5.95 ± 0.060	6.10 ± 0.047	6.23 ± 0.088	6.76 ± 0.060
Optimised synbiotic beverage	8.13 ± 0.044	7.51 ± 0.058	8.30 ± 0.074	8.25 ± 0.052	8.50 ± 0.059
Increase over control (%)	34.38	26.22	36.07	32.42	25.74
t value	12.284**	9.806**	14.636**	10.391**	8.924**

** Highly significant at P less than or equal to 0.01. Control, unfortified milk beverage.

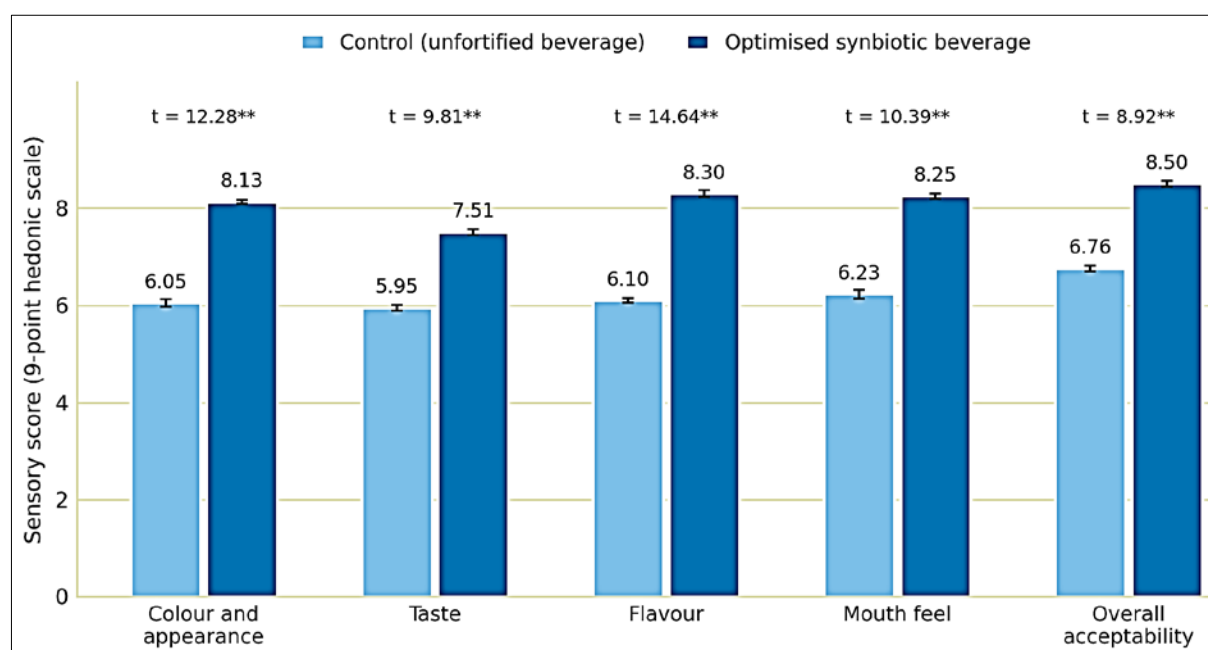


Fig 4: Sensory scores of the optimised synbiotic beverage compared with the unfortified control. Error bars denote standard error of the mean; t values are shown above each attribute pair.

4. Conclusion

Conjoint analysis proved capable of resolving an eight ingredient, four level formulation problem for a synbiotic beverage intended for type 2 diabetes in a single structured experiment of 16 profiles, in place of the 65,536 combinations that a full factorial would have demanded. Vanilla was selected as the flavourant on the basis of a preliminary screening trial in which it returned the highest score on all five sensory attributes, with an overall acceptability of 8.66 against 6.35 for the unfortified control. The conjoint decomposition established a clear hierarchy of influence on consumer preference. Carrot juice was the dominant driver at 24.50 per cent relative importance, followed by moringa leaves juice at 15.20 per cent and lactose at 14.00 per cent, while the flavourant was least influential at 7.20 per cent. The three ingredients carrying most of the intended physiological function, namely the synbiotic powder, the dietary fibre and the seed slurry, together accounted for only 28.20 per cent of preference,

which gives the formulator substantial freedom to set them on nutritional rather than sensory grounds. Moringa leaves juice returned negative part-worth utilities at every level tested and represents the principal sensory constraint on the product, since the level the panel tolerates best, 4 per cent, is well below the level at which the published human evidence reports metabolic benefit.

The optimum profile assembled from the highest utility level of each ingredient consisted of 15.00 per cent carrot juice, 4.00 per cent moringa leaves juice, 1.50 per cent double encapsulated synbiotic powder, 1.50 per cent dietary fibre, 0.020 per cent stevia, 4.00 per cent pumpkin and sunflower seed slurry, 0.15 per cent vanilla flavourant and 10.00 per cent lactose, made up to 200 mL with skim milk. Prepared at these levels, the beverage scored significantly higher than the control on every sensory attribute at P less than or equal to 0.01, reaching an overall acceptability of 8.50 against 6.76 for the control, an improvement of 25.74 per cent.

The findings should be read with their limits in mind. The conclusions rest on hedonic ratings alone, and the present report does not include the physico-chemical composition of the optimised beverage, the viability of the encapsulated culture through processing and storage, the shelf life of the product, or any *in vitro* or *in vivo* measurement of its glycaemic effect. Each of these is a necessary next step before the beverage can be described as validated for its intended purpose. Two directions follow most directly from the results reported here. The first is to raise the delivered moringa dose without raising its sensory cost, whether by encapsulation, debittering, fermentation or concentration of the leaf extract, since this is the single largest gap between the nutritionally desirable and the sensorially acceptable formulation. The second is to re-examine the 10 per cent lactose level, which the panel preferred but which contributes a carbohydrate load that warrants scrutiny in a product designed for glycaemic management. Subject to those qualifications, the study demonstrates that conjoint analysis is an efficient and defensible route to a sensorially acceptable operating point for a multi-ingredient functional beverage.

Conflict of Interest

The authors declare that they have no conflict of interest.

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