Student Article: The Formulation and Sensory Evaluation of a Whey Permeate-Based Hydration Beverage

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Keywords: hydration, sensory evaluation, dairy, whey permeate

ABSTRACT

Whey permeate, a byproduct of cheese and Greek yogurt manufacturing, boasts a hydration-promoting nutrient profile, suggesting value as an ingredient for functional beverages. However, there are currently no whey permeate-based beverages on the market. Functional ingredients often contribute sensory characteristics that require masking or modification for product success. The objectives of this research were to formulate a whey permeate-based hydration beverage and assess its overall acceptability (9-Point Likert Scale) and sensory attributes (Just About Right Scale (JAR) for formulation guidance. Healthy adults (n=58; mean age between 31-35 years, 56% female) were recruited from a university campus. Participants provided basic demographic information and completed a questionnaire to assess habitual beverage intake. Participants evaluated four experimental beverage formulas in a randomly assigned order in comparison with a control hydration beverage (lemon-lime Gatorade®). Experimental variables included two flavors (lemon lavender, lemon punch) and sugar content (3%, 5% by weight). Overall, acceptability of experimental beverages was significantly lower to neutral ($x = 4.5 – 4.9$; $p < 0.05$) compared to the control beverage (6.7, "slightly" to "moderately" liked). Just About Right data combined with overall acceptability scores suggested how attributes influenced acceptability. Formulation adjustments are needed before the market potential of a whey permeate-based hydration beverage can be assessed.

INTRODUCTION

Maintaining adequate hydration is critical for optimal body functioning.[1] Dehydration is associated with mental fatigue, lack of alertness, and confusion.[2] Though water is essential for replenishing body fluid losses following exercise, the addition of electrolytes, particularly sodium and potassium, can increase the amount of fluid retained.[3] Sports drinks and milk are common fluid replacements since they contain electrolytes (i.e. potassium, sodium, etc.) and carbohydrates such as sucrose and/or lactose.[3,4] Sports drinks and non-fat milk have been recommended as rehydration beverages due to the nutrient contents that assist in the absorption and retention of fluids.[5] Carbohydrates in rehydration beverages provide fast-acting energy and can increase fluid retention following exercise.[5-7] The protein in non-fat milk, which is not found in current sports drinks promotes muscle building and may also contribute to rehydration as it decreases the loss of body fluid while maintaining plasma osmolality.[6]

Whey permeate is a powder that is created as a co-product with whey protein concentration and whey protein isolate from the liquid whey byproduct that is expressed during processing of Greek yogurt and many cheeses.[10] Whey permeate is rich in electrolytes, lactose, and whey proteins, including branched-chain amino acids, which can increase hydration.[5] Beverages containing these nutrients, such as non-fat milk, are considered high on the beverage hydration index (BHI).[4] In addition, the micronutrients within whey permeate beverages provide other health benefits which may further enhance the value of this product.[9] However, whey permeate often contributes off-flavor, -odor, and -texture characteristics in food and beverage products, limiting its application. Therefore, the goal of this project was to formulate a whey permeate-based beverage for use in a hydration study. The first objective of this investigation was to formulate whey permeate-based beverages to promote hydration. The second objective was to evaluate the formulated products using validated sensory analysis methods for potential use in a clinical trial.

METHODS

Sample Preparation

A base beverage formulation was developed using 84% (by weight) water (Kroger Brand, Cincinnati, OH), 12.6% whey permeate powder (Agri-Mark Inc., Methuen, MA), 3.4% powdered whey isolate (Heat Stable; (Agri-Mark Inc., Methuen, MA), and 0.15% stabilizer (Ticaloid Pro 192 AGD High Viscosity, TIC GUM, Belcamp, MD). Whey isolate was used to increase the protein content of the beverage to more closely mimic that of non-fat milk. Ingredients were mixed together, heated to 80°C to activate the stabilizer with stirring, and then cooled to ambient temperature (21°C).

Four formulations were designed, targeting sweetness (2 levels of sucrose: 3%, 5% by weight) and flavoring (2 lemon-based flavors) for masking the whey protein and high salt tastes in the whey perme-

ate product. Whey masking agent (0.5% by weight; Gold Coast Ingredients Inc., Commerce, CA) and citric acid (0.33% by weight) were also added to help minimize the salt and whey protein influence on flavor. The two flavors were lemon punch (LP) and lemon lavender (LL) (Gold Coast Ingredients Inc., Commerce, CA), added at 0.5% by weight. These flavors were selected from a variety of flavor options that the research team believed might provide complementary or masking benefit to the whey permeate and those which might be similar to commercially available sports drinks. Samples for sensory testing included the whey permeate-based beverages (LL3%; LL5%; LP3%; LP5%) and a commercial sports drink (Lemon-Lime Gatorade®, PepsiCo, Purchase, NY). Aliquots of each solution (1 oz., 15 g) were poured into disposable plastic cups (2 oz.; Monogram Company, Columbia, MD) coded with 3-digit identification numbers and sealed with a plastic cap. Samples were stored at a refrigerated temperature (4 °C) until sensory testing.

Study Protocol

This investigation consisted of one study session which included completion of a demographic questionnaire, a beverage intake questionnaire, and a sensory panel. The protocol was approved by the Institutional Review Board (IRB) of Virginia Tech, and all participants were requested to review the written consent form and provide consent prior to enrollment. Individuals aged 18-65 years, with activity levels ranging from sedentary to active, were recruited from a university campus using email listservs and social media advertisements. The population was selected to assess beverage acceptability in a general adult sample. Individuals who were lactose intolerant or allergic to milk proteins were excluded from participation.

The demographic questionnaire captured information on gender, age, ethnicity/race, socioeconomic status, and activity level. Usual beverage intake habits were determined using the 15 category Beverage Intake Questionnaire (BEVQ-15). This validated questionnaire consists of 15 beverage categories and was developed to quantitatively assess habitual beverage consumption over the past 30 days.[7]

Sensory Protocols

Participants completed testing at the Virginia Tech Sensory Evaluation Laboratory in the Department of Food Science and Technology. Participants were seated in individual sensory evaluation booths; each booth was equipped with a sliding hatch to receive and return beverage samples. Participants were given printed forms (scorecards: acceptability, Just about Right (JAR) scale) to complete for each sample (n=5) they tasted. Product acceptability was assessed using a 9-point Likert-type scale (1=dislike extremely; 5= neither like nor dislike; 9=like extremely) as well as the JAR scale[8] and given to participants in a randomly assigned order. The JAR scale (1 = "too thin/too light/too little", 3= "just about right", 5 = "too thick/too dark/too much") was used to evaluate levels of a specific attribute of the product against participant's self-perception of the ideal.[8] Attributes evaluated on the JAR scale included appearance, smell, taste, mouthfeel, and aftertaste.

Table 1. Demographic Characteristics

Participant Characteristic	Value (n, %)
Sex	
Male	25 (43.1)
Female	32 (55.2)
Age Range, yrs	
18-30	33 (56.9)
31-50	13 (22.4)
51 +	11 (19.0)
Ethnicity	
American Indian/Alaskan Native	2 (3.4)
Black/African American	3 (5.2)
White	36 (62.1)
Asian	15 (25.9)
Other Race	1 (1.7)
Activity Level	
Sedentary or Inactive	0 (0)
Recreationally Active	19 (32.8)
Moderately Active	33 (56.9)
Extremely Active	5 (8.6)

Mineral Analysis

Sodium, magnesium, inorganic phosphorus, sulfur, chlorine, potassium, and calcium concentrations of each whey permeate-based beverage as well as the commercial sports drink were measured by emission spectroscopy using Inductively Coupled Plasma (ICP) technique (Thermo Electronic Corporation, X-Series ICP-MS, Waltham, MA).[9] Each whey permeate-based beverage and the commercial sports drink were centrifuged at 18500 ×g for 15 minutes to reduce viscosity and remove debris. Sample digestion was modified from the previous studies by diluting each sample at 1:10 (v/v) with 4% nitric acid and mixed well by vortex in order to decompose the sample for the release of minerals and accurate analysis.[9,10]

Statistical Analysis

Descriptive statistics were used to characterize study participant demographics and to describe acceptability data (mean ± SD). One participant was excluded from analysis due to incomplete demographic questionnaire data and JAR data. Independent sample t-test was used to evaluate gender differences. Paired, two-sample t-tests (one-tail) were completed between each formulation and each formulation to the commercial control beverage; alpha was preset at 5%. Independent sample t-test was used to evaluate differences in major electrolyte composition. Statistical analyses were performed using Microsoft Excel 2010 and IBM SPSS Statistics statistical analysis software (Version 24). Analysis of JAR data, in combination with acceptability scores for overall acceptability, was completed using XLSTAT Sensory (Microsoft Excel).[11] Penalty analysis and mean drop were calculated to determine guidance for potential improvements that might positively affect acceptability scores.

RESULTS

Participants' ages ranged from 18-65 years of age (n=58; 55.2% female) (Table 1). The majority (93%) of the participants considered themselves healthy (subjective yes/no response), and most (79%) reported that they were moderately active and incorporated hydration strategies into their daily life. Daily hydration strategies included selecting water (44%), milk or other dairy products (28%), sports drinks (12%), energy drinks (4%), pop/soda (7%), and/or other beverages (12%). "Other" beverages included: tea, coffee, lemonade, and seltzer water.

Five participants did not provide complete data for the BEVQ-15 and thus were

excluded from BEVQ analysis (n=53). Mean total daily beverage intake was 62.3 ± 32.2 fl oz. and 328 ± 586 kcal/day (from beverages). Most participants reported consuming water (81%) and milk (89%) in varying quantities. Mean water and milk intake were 33.2 ± 18.3 fl oz. and 5.6 ± 7.4 fl oz., respectively. Female participants consumed 34.27 ± 19.07 fl oz. water and 5.75 ± 8.68 fl oz. milk per day, and male participants consumed 31.8 ± 17.55 fl oz. water and 5.55 ± 5.72 fl oz. milk per day with no significant differences by gender ($p > 0.05$). However, male participants consumed significantly ($p < 0.005$) more energy/sports drinks than female participants (males 1.58 ± 3.72 fl oz.; females 0.30 ± 0.77 fl oz.). Only16% of participants reported consuming these beverages; thus mean consumption levels were low for this beverage category.

Acceptability of the four formulated whey permeate beverages approached the neutral score (5=neither like nor dislike) (Figure 1). The commercial sports drink (control) had a mean of 6.7, corresponding to "slightly" to "moderately" acceptable. There was a significant difference ($p < 0.0001$) between each test beverage compared to the commercial beverage but no differences among mean acceptability scores for experimental beverages. For the tested population, responses did not follow a normal distribution, and histograms illustrate the distribution was typically bi-modal for the experimental beverages. The experimental LL formulation with 5% sucrose (LL5%) had 58% of respondents selecting 'neutral' or higher on the acceptability scale.

Just About Right (JAR) scores were used to further clarify how respondents compared the prototype formulations to their 'ideal' hydration beverage concept (Figure 2). For each attribute, we identified significant differences ($p<0.05$) in JAR values between the means of each experimental formulation and the commercial beverage. No beverage, including the commercial beverage, received the ideal JAR score for all attributes.

The distribution of JAR responses for each attribute within each formulation helps assess the impact of the non-JAR ratings (JAR=3.0 value) on overall acceptability of the product. A large change in mean value (mean drop) and a large percentage of the population indicates a potential for formulation modification to improve acceptability (Figure 3). The commercial beverage and two experimental formulations (LP3%, LL5%) had no attributes that significantly influenced the overall mean acceptability score. Significant differences ($p<0.05$) between the too light/too dark (non-JAR) proportions of the population were noted for appearance (LL3%, LP5%) with the 'too dark' response creating a positive influence (>1.3) on acceptability score. Mouthfeel (too thick) was detrimental to acceptability score for LL3% ($p<0.05$). In Figure 3, note that mouthfeel (in the lower right quadrant LL3%) depresses the acceptability score for a large proportion (33%) of the population. Mean drop values near 0 (-1 to 1) and/or with small proportion of the population (<20%) indicate small penalties and are not actionable (LL5%).

The formulated beverage delivered a combination of nutrients valuable for hydration, including whey proteins, carbohydrates (lactose, sucrose), minerals, and electrolytes common in milk (Table 2). For major electrolytes (sodium, magnesium, inorganic phosphorus, potassium, and calcium), the whey permeate beverage was found to have significantly higher ($p \leq 0.05$) electrolyte composition than the commercially available hydration beverage.

DISCUSSION

To our knowledge, this is the first investigation to formulate a whey permeate-based beverage for the general adult population with the intention to promote hydration. The beverage formulations did not meet the targeted mean acceptability score goal of 6 or higher. Typically, product developers strive for a mean acceptability score close to the market leader, which typically is at or above the 'like moderately' category (mean of 7 or higher on a 9-point scale) to suggest a potential for commercial success[17]; this indicates that additional formulation modifications are needed to improve acceptability for potential commercial success. If targeted for a clinical trial, formulation improvement would promote participant compliance. JAR data provides some guidance for improving the formulation.

Figure 1. *Histograms of acceptability ratings (Mean ± SD; n=58; 1 = Dislike Extremely, 5=neither like nor dislike, 9= Like Extremely) of experimental and control beverages. LL = Lemon Lavender; LP = Lemon Punch; 3%, 5%: sucrose by weight; Commercial sports drink (Lemon-Lime Gatorade, PepsiCo™, Chicago, IL).*

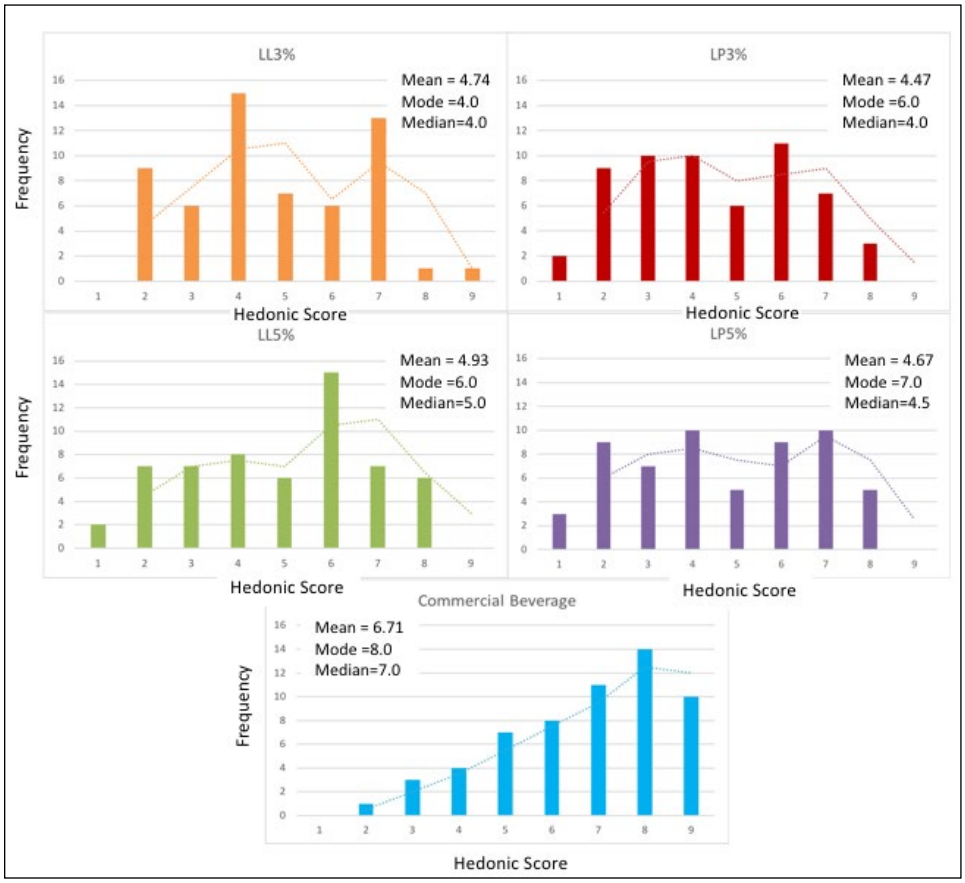


Figure 2. *Just About Right (JAR) (Mean ± SD; n=58) ratings for experimental and commercial beverages. LL = Lemon Lavender; LP = Lemon Punch; 3%, 5%: sucrose by weight; commercial sports drink (Lemon-Lime Gatorade, PepsiCo™, Chicago, IL). JAR scale for attributes included Appearance: 1=too light, 5=too dark; Mouthfeel: 1=too thin, 5=too thick; Smell, Taste, Aftertaste: 1=too little, 5=too much; 3=Just about Right for all attributes.*

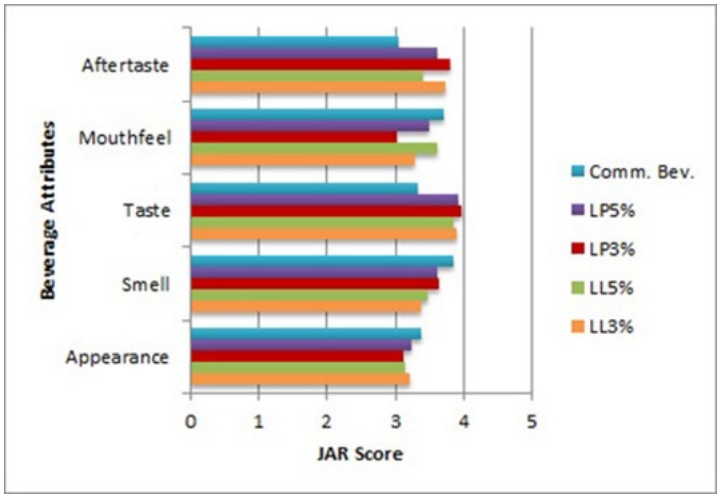
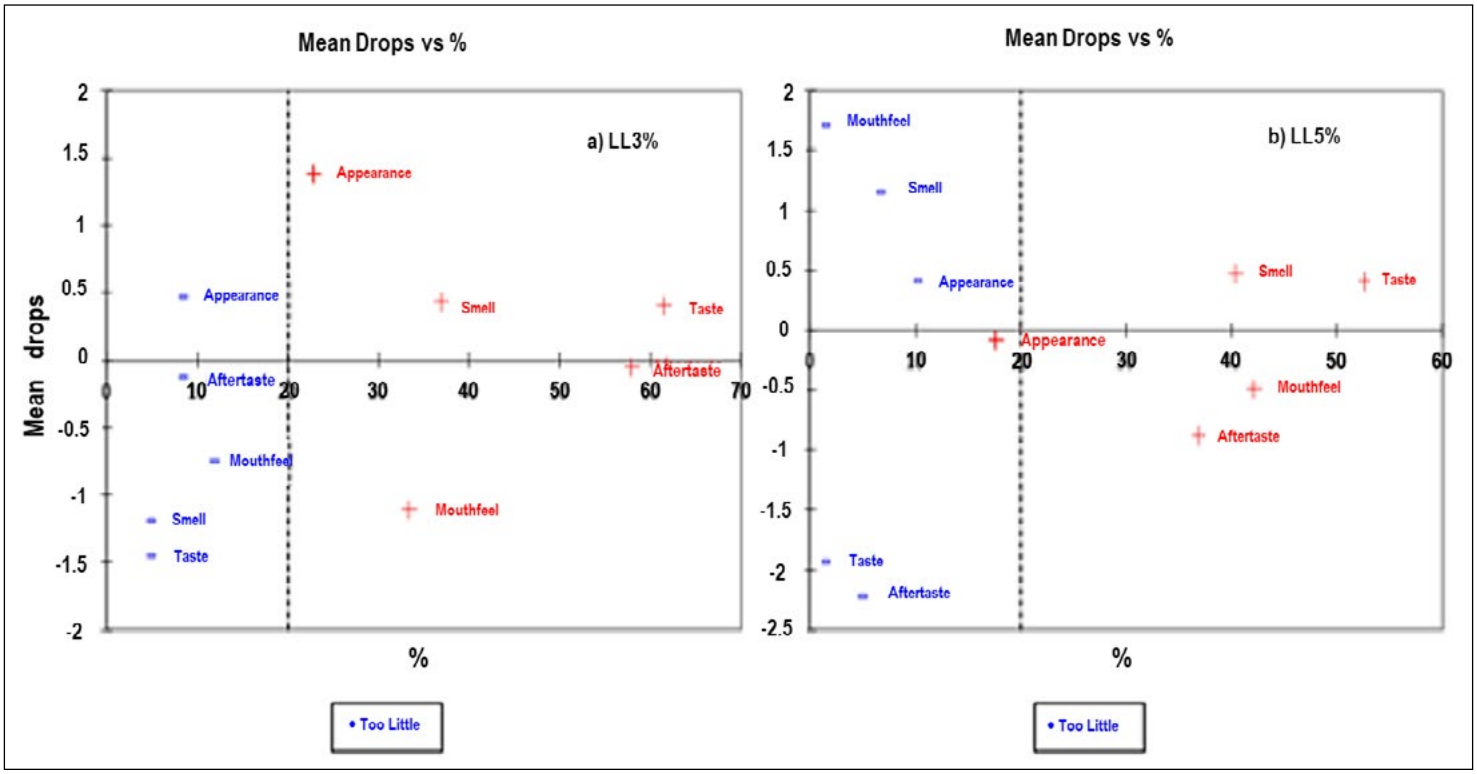


Figure 3. *Illustration of penalty analysis and mean drop for lemon lavender (LL) whey-based hydration beverage at two sucrose levels (3% sucrose, 5% sucrose).*



It is difficult to interpret the exact influence on JAR responses which may be attributed to flavors in the whey permeate or isolate, amount of flavoring added, the lavender or punch influence on the flavoring, or the combination. In general, of the whey permeate formulations tested, the LL5% had the best potential for further development.

In order to efficiently retain and replenish the fluids lost through exercise, beverages that contain electrolytes, such as sports drinks and dairy products, are recommended.[12-14] The inclusion of electrolytes in this study's whey permeate beverage is consistent with a high BHI because it contains greater amounts of macro- and micronutrients than non-fat milk. In comparison to sports drinks, the whey permeate beverage contains branched-chain amino acids necessary for muscle rebuilding and thought to promote hydration by maintaining plasma osmolality.[4,6] Therefore, this formulation may be useful for increasing hydration status more than the current rehydration beverages that are on the market. Spe-

Table 2. *Comparison of hydration components in nonfat milk (USDA ARS 2017) and experimental hydration beverage formula.*

Component	Whey Permeate Beverage (Per 8 Fl Oz, 238.72 g)	Nonfat Milk (Per 8 Fl Oz, 244.8 g)
ENERGY	133.52 kcal	83.00 kcal
WATER	198.95 g	222.38 g
PROTEIN	7.81 g	8.25 g
LIPID (TOTAL)	0.40 g	0.20 g
CARBOHYDRATE (BY DIFFERENCE)*	25.48 g	12.14 g
CALCIUM	181 mg	299 mg
MAGNESIUM	40 mg	27 mg
PHOSPHORUS	296 mg	247 mg
POTASSIUM	693 mg	382 mg
SODIUM	211 mg	103 mg

* By difference is included to address the sum of the nutritionally available carbohydrate from the total carbohydrate. For the whey permeate beverages, this was based upon the 3% sucrose formulation.

cifically, sodium intake increases plasma volume, promotes voluntary thirst, and increases glucose absorption in the small intestine.[14,15] However, due to the high content of salt in whey permeate, Beucler et al.[18] found that lower concentrations of the by-product, incorporated into a commercial beverage for their experimental study, were more acceptable.[16] Together with our findings, this suggests that the amount of whey permeate and whey isolate should be reduced or masked with a higher concentration of sugar, flavoring, or an effective masking ingredient.

This study had several strengths. First, the use of whey permeate as a hydration beverage ingredient is novel due to the use of an undervalued by-product of dairy processing. Second, the study population consisted of individuals who were aware of the importance of consuming beverages for hydration purposes and who regularly consumed water and milk making them ideal participants for testing the whey-based formulas. The study utilized validated food sensory evaluation methodologies commonly used in commercial development of food products. We acknowledge the limitation of a small sample size (n=58) that did not represent the general population at large.

Future efforts should evaluate further modifications to the formulation before market potential can be assessed. The flavor selection could better complement the beverage as a dairy product, such as vanilla or caramel to improve coloration (appearance). Particular attention should be focused upon factors that affect mouthfeel, especially as integrated with taste and aftertaste. This could be accomplished by reducing the concentration of whey permeate or isolate to slightly reduce the mineral, protein, and lactose (carbohydrate) composition.

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