UPCYCLING COTTAGE CHEESE ACID WHEY INTO A VALUE DRIVEN FUNCTIONAL SPORTS BEVERAGE

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Abstract

The goal of this project was to determine if upcycled cottage cheese whey could serve as a base for a value driven sports beverage. Cottage cheese whey was chosen for its richness in electrolytes and neutral flavor, and filtration was utilized to remove impurities and dairy nodes. The resulting filtered base was further formulated with enzymes, carbohydrates, amino acids, and non-nutritive sweeteners to optimize glycogen replenishment, maximize digestibility, and prevent the breakdown of muscle tissue following strenuous bouts of exercise. Finally, an acceptance sensory test was conducted on the three different flavors to determine the overall liking of the product as well as potential avenues for improvement. The results of the sensory study reveal a promising potential in transforming cottage cheese acid whey into a sports drink, serving as a viable approach to repurposing this residual dairy industry waste.

Introduction

As the field of food science and technology continues to develop, our ability to extract resources, automate processing, and cater to the demands of the market, has allowed food producers to generate a nearly infinite portfolio of consumer goods. But even with all the technological and logistical advancements of our modernized world, nearly one-third of the food produced in the world becomes food waste (Quinton 2023). Not only is food waste an area of concern due to nutrition loss in a world where 9.8% of the world population is affected by hunger, but it is also concerning that the disposal of these nutritious compounds can become breeding grounds for bacterial contamination and a pipeline for environmental pollution ("World Hunger" 2022; Ravidran and Jaiswal 2016). In this context, food waste refers to the disposal of food, that is considered fit for human consumption in its current form but gets "consciously discarded at the retail or consumption phases" ("Food Waste" 2022). Due to the substantial costs associated with eliminating waste, there is a major push in the food industry to better utilize existing resources. Additionally, food waste is not the only source of valuable nutrients that become a costly burden of disposal, as many of our food manufacturing processes produce massive quantities of by-products that are also characterized by high volumes and elimination costs (Mateos-Aparicio and Matias 2019). With recent technological advancements in the food industry, scientists now have a unique opportunity to convert these production byproducts into valuable resources or products, which would otherwise go to waste, as they often contain valuable nutrients.

The dairy industry presents a significant opportunity to better utilize production byproducts that are both burdensome and wasteful. Dairy is a key player within the food supply due to its rich nutritional profile, which consists of all three macronutrients, a complete source of protein, important fat-soluble vitamins, and a broad spectrum of electrolytes (Górska-Warsewicz et al.

2019). Additionally, according to an article published within the National Library of Medicine, dairy products alone provide 10% of the total caloric content within the U.S. food supply (Mozaffarian 2019). But with an increased ability to process raw milk into a variety of products, food product manufacturers have started developing products that isolate key ingredients within milk while leaving behind large quantities of byproducts. According to a recent article in the International Journal of Dairy Technology, approximately 80-90% of the milk that enters cheese manufacturing plants becomes whey, which is a problematic liquid byproduct that remains after milk has been curdled and strained (Buchanan et al. 2023). Despite the nutritious components found in whey, its high levels of organic matter and low pH levels create a significant barrier to efficiently utilizing the massive quantities that is produced each year (Zandona et al. 2021).

To date, the most significant co-product that is generated by the US dairy industry, by volume, is the acidic whey that is generated from the production of fermented products such as Greek-style yogurts and cottage cheese. Unlike sweet whey, a byproduct of rennet cheese manufacturing, the acid whey that is produced from acid coagulated dairy products is much more difficult to repurpose (Menchik et al. 2019). A few methods of repurposing acid whey have been suggested, such as fertilization, cattle feed, or biogas energy production, but these methods have seen limited success due to high processing costs and technical difficulties that limit their commercial feasibility. While high levels of lactic acid in acid whey creates additional challenges for processing techniques such as evaporation or drying, lactic acid can also act as a natural food preservative, since the pH of acid whey typically falls within a range that inhibits unfavorable microbial growth (Chandrapala et al. 2016). Furthermore, acid whey contains a broad spectrum of electrolytes and a significant quantity of lactose, both of which are currently being wasted. Acid whey has an optimal pH for shelf-stable beverages and a similar electrolyte composition to popular sports drinks already in the

market. As a result, there is promising potential for converting acid whey into a value-added sports beverage.

For the purpose of this report, we are going to focus specifically on cottage cheese whey, which was selected as a favorable base for a sports beverage due to its mild flavors, decreased microbial load, and relative abundance within the food industry. Recent advancements in membrane technology have allowed cottage cheese producers to maximize the concentration of protein retentates, leaving behind a salty and acidic whey that has been shown to be quite stable under refrigerated conditions for up to 6 weeks (Nguyen et al. 2003). To produce just 15 pounds of cottage cheese requires approximately 100 pounds of milk. Considering that the United States alone produces more than 31 million pounds of cottage cheese each month, the surplus of cottage cheese whey not only presents a substantial financial challenge for producers, but also represents a significant potential opportunity for food science entrepreneurs (Gaille 2018). While other entrepreneurs have utilized yogurt acid whey to develop functional beverages such as “Good Sport” and “Super Frau!”, it appears that this project would serve as the first proof of concept for upcycling cottage cheese whey into a value driven sports beverage. The sports beverage that was developed in this project was titled “Post-Workout Fuel” and will be referred to as PWF throughout the document.

Situational Analysis

The global sports drink market size is projected to grow at a compound annual growth rate (CAGR) of 4.2% in the 2021-2028 period (“Sports Drink Market” 2023). It is worthwhile to note that the “electrolyte drink market size” is expected to grow at an increased CAGR of 6.33% as compared to the growth rate of the entire sports drink market (“Electrolyte Drinks” 2022). It is

evident that traditional sports drinks, those which deliver energy through sugar and electrolytes, have the widest consumer base with significant growth potential.

Functional Competitive Analysis

Table 1

Functional Comp. Analysis mg / 16 fl. oz		CCW-PWF	Gatorlyte	Bio Steel	Pedialyte Sport	BodyArmour	FitAID Recovery	Biolyte	GoodSport
Electrolytes	Variety #	5	5	5	5	3	4	3	6
	Sodium	151	392	140	650	40	0	700	227
	Magnesium	43	84	5	55	70	33	0	28
	Potassium	681	280	33	600	700	67	400	530
	Calcium	469	96	18	0	0	27	0	156
	Chloride	unknown	780	unknown	920	0	0	1100	483
	Phosphorus/ Phosphate	277	0	unknown	190	0	unknown	unknown	166
Amino Acids	Leucine	3g		1.2g			Blend		
Carbohydrates	Galactose								
	Glucose								
	Fructose								

low | neither low nor good | good | excellent

Table 1: The table above compares PWF to leading brands of the functional sports drink category, and specifically those that are focused on electrolytes and recovery. Additionally, GoodSport was included in this competitive analysis, as this upcycled whey product is most similar in nature to PWF. The electrolyte breakdown that is shown above for PWF represents the electrolyte composition of cottage cheese whey without any additional formulation. This represents a clear opportunity for improvement that will be touched on in the "Formulation" section of this report. From the table above, we can see that CCW is an excellent source of calcium and phosphorus, and a good source of potassium. Although the chloride content of PWF remains unclear, formulating the beverage with NaCl would allow PWF to have comparable amounts of sodium to the leading brands while representing all six key electrolytes. PWF's unique formulation allows for a competitive advantage over GoodSport, as the inclusion of fructose increases the rate of sugar metabolism following strenuous bouts of exercise.

Product Development

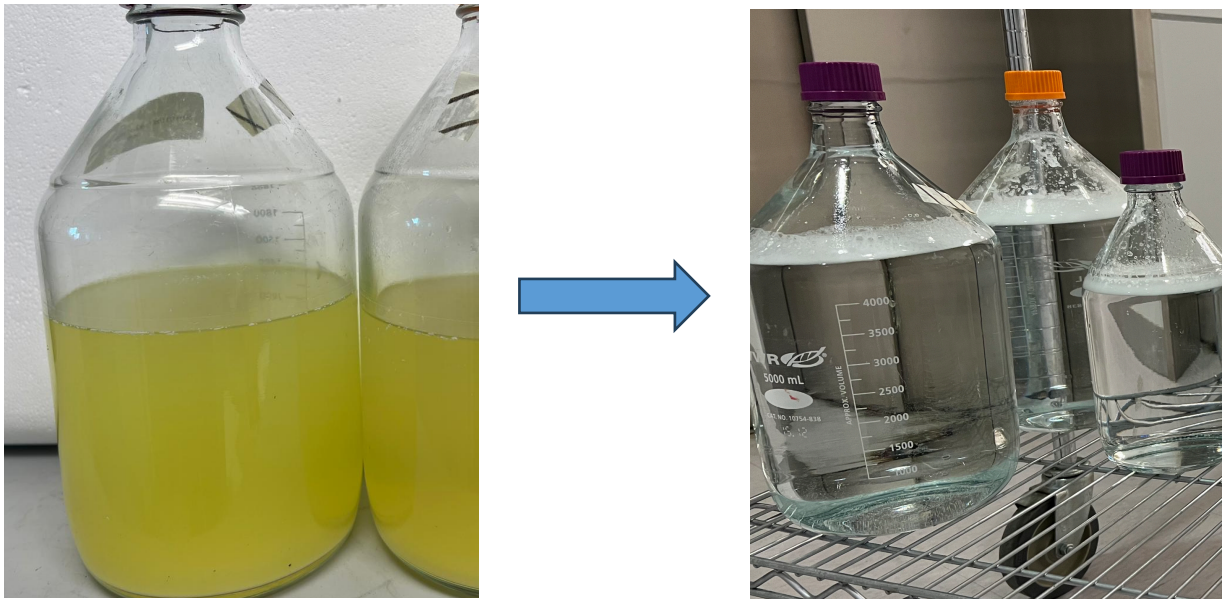
Developing a Neutral Base

Lactose Hydrolysis

Cottage cheese whey (CCW) was obtained from a local processor and taken directly from the processing line and stored in 5-gallon buckets. DSM's Maxilact A4 was added to the CCW at a concentration of 120 acid lactase units (ALU) per gram of lactose. A lactose concentration of 3.1% for the CCW was used as a reference point from Eurofins data collected on 9/21/2022 from the same local processor. The CCW with 120 ALU/g lactose was stored at 40 degrees Fahrenheit to reach complete lactose hydrolysis after 10 days of incubation.

Filtration

During the first three days of incubation, the CCW underwent a filtration process. It started with three rounds of wine filters (Buon Vino Filters), each one stronger than the previous, followed by a final filtration using activated carbon (PROC 3 ACN, from Core Filtration LLC). The CCW passed through first a 5.0-micron filter, then a 1.8-micron filter, and finally a .5-micron filter before receiving treatment of carbon filtration.



Formulation

Lactose Hydrolysis

According to the U.S. Department of Health, approximately 68% of the world's population has "lactose malabsorption" (Fisher 2018). Although dairy byproducts such as acid whey are loaded with essential vitamins and minerals, a high concentration of lactose creates a barrier for efficient valorization for human consumption. To overcome this hurdle, lactase enzyme can be added during any stage of the processing, as long as it has 10 days at 40F to reach a near complete lactose hydrolysis. PWF utilizes lactase enzyme to deliver both glucose and galactose from CCW's significant lactose concentration, as well as fructose from the addition of fruit juice concentrates.

The combination of glucose, galactose, and fructose creates Post-Workout-Fuel's first value proposition, the maximization of glycogen replenishment following strenuous bouts of exercise. The combination of glucose and fructose have long been used in the fitness industry to maximize the utilization of exogenous carbohydrate sources (Gonzalez et al. 2017). This is because glucose and fructose utilize different intestinal transporters. Glucose is absorbed via the intestinal transporter "SGLT1" at a maximum rate of approximately 60g/hr, while fructose is absorbed via intestinal transporter "GLUT5" at an estimated maximum rate of 30g/hr. Because glucose and fructose do not compete for intestinal absorption, greater rates of carbohydrate oxidation can be achieved (Jeukendrup 2020). Finally, the inclusion of galactose in the sports drink can help to dampen the spike of blood sugar levels, helping to prevent a crash in energy, as galactose is a low glycemic sugar that is particularly efficient at replenishing liver glycogen stores (Stahel et al. 2017).

Leucine Enrichment

The sports drink was fortified with 3g of leucine per 16 fl/oz to create PWF's second value proposition: prevention of muscle protein degradation and the stimulation of muscle protein synthesis following strenuous bouts of exercise (Garlick 2005). Although the efficacy of supplemental leucine is still debated within the scientific community, multiple leading brands of the whey protein market segment have started to display their leucine content per serving on their principal display panel to appeal to their target consumer. For example, Dymatize, a key player within the whey protein industry, boasts of 2.6g added leucine per serving in their most popular whey protein isolate product, "ISO100". Following this trend, supplemental leucine was added to PWF at a dosage of 3g per 16 fl/oz serving, adding value to our target consumer who is looking to gain a competitive advantage on their sports performance through nutrient optimization. The cost of leucine fortification (3g per serving) was approximately $0.13 per serving. Further market research is necessary to determine the utility of leucine fortification to our target consumer.

Electrolyte Optimization

Cottage cheese whey is naturally a great source of highly bioavailable electrolytes. As shown in *Table 1* of the competitive analysis, CCW is rich in potassium, magnesium, calcium, sodium, and phosphorus. According to a report by Menchik et al. in the Journal of Dairy Science, CCW contains negligible amounts of chloride, but it is uncertain whether this value would be representative of the CCW used in this project for producing PWF (Menchik et al. 2019). To overcome this hurdle, PWF could easily be formulated with NaCl or MgCl to provide the full spectrum of electrolytes while optimizing desirable amounts of sodium and magnesium. One of the objectives of this project was to enrich the product during formulation to have an "ideal"

electrolyte profile. However, over the course of this project, it became clear that the idea of an "ideal" electrolyte profile was highly situational and required further exploration to develop a proprietary blend. As a result, the final electrolyte profile of PWF comes directly from the CCW utilization. Further exploration of optimizing electrolyte content will be discussed in the "Future Work and Opportunities for Improvement" section of the report.

Ingredient Functionality

Ingredient	Function
Cottage Cheese Whey (CCW)	Main upcycled ingredient, source of electrolyte and sugars.
Lactase enzyme	Hydrolyzes lactose into easier digested monomers; glucose and galactose.
Leucine	Functional benefit.
Fruit juice concentrates	Flavor, source of fructose, sweetener.
Monk Fruit, Allulose, Stevia	Sweetener.
Natural flavors	Flavoring.

Final Flavor Recipes ~ 100 mL

Ginger Peach

Ingredient	Quantity
Acid whey (mL)	90 mL
Natural Peach Flavor (uL)	470 uL
Natural Ginger Extract (uL)	150 uL
Ginger Juice (mL)	5 mL
Peach Juice Concentrate (mL)	7.5 mL
Monk Fruit Extract Powder (g)	0.065 g
Allulose (g)	5.0 g
Stevia (g)	0.015 g
Leucine (g)	0.64 g

Mixed Berry

Ingredient	Quantity
Acid whey (mL)	90 mL
Natural Strawberry Flavor (uL)	980 uL
Natural Blue Raspberry Flavor (uL)	300 uL
Strawberry Juice Concentrate (mL)	5 mL
Monk Fruit Extract Powder (g)	0.067 g
Allulose (g)	5.0 g
Leucine (g)	0.64 g

Blood Orange

Ingredient	Quantity
Acid whey (mL)	90 mL
Natural Blood Orange Flavor (uL)	550 uL
Blood Orange Juice Concentrate (mL)	4 mL
Monk Fruit Extract Powder (g)	0.065 g
Allulose (g)	4.5 g
Leucine (g)	0.64 g

Sensory Analysis

Overview

A sensory test was conducted at the Cornell Sensory Evaluation Center on Wednesday, April 5th, 2023. Panelists were recruited from Cornell's sensory panelist database, as well as by word of mouth and on campus flyers. The final number of participants was 108. The type of sensory test that was designed and implemented was an "Acceptability Test", which looks to determine the overall liking, purchase intent, and hedonics of specific attributes. By utilizing a "Just About Right" (JAR) scale for specific attributes and recording the overall liking of the samples, we were able to conduct a penalty analysis to gain valuable insight regarding product shortcomings and areas of improvements for the formulation.

Demographics:

n = **Total number of participants:** 108

Age: **Average age:** 30.9 **Percentage of participants 30 years or older:** 40.7%

Gender: **Percentage Female:** 61.1% **Percentage male:** 38% **Nonconforming:** 0.9%

Figure 1 – Activity Level:

Rate your activity level:	
Count	**77**
Athlete (2x a day)	**1%**
Heavy exercise (6-7x a week)	**18%**
Moderate exercise (3-5x a week)	**55%**
Light exercise (1-2x a week)	**25%**
Sedentary (Office Job)	**5%**
Mean	**2.86**

Figure 1: This figure shows that the average activity level of our participants was somewhere between light exercise (1-2x per week) and moderate exercise (3-5x per week).

Figure 2 – Familiarity with Sports Drink Product Category:

Familiarity with Sports Drink Product Category	
Count	**108**
Very familiar	**22%**
Moderately familiar	**38%**
Familiar	**60%**
Somewhat familiar	**28%**
Not Familiar	**12%**
Not too familiar	**11%**
Not at all familiar	**1%**
Mean	**3.69**

Figure 2: This figure shows that 60% of our participants were either very familiar or moderately familiar with the sports drink product category.

Flavor Ranking:

Figure 3 – Flavor Ranking:

	Blood Orange	Ginger Peach	Mixed Berry
Count	108	108	108
Rank 1	18%	53%	30%
Rank 2	43%	23%	34%
Rank 3	40%	24%	36%
Rank Sum	**240**	**185**	**223**
Post Hoc	**B**	**A**	**B**

Figure 3: In this figure, we can see that ginger peach was the highest rated flavor, and that there was no statistically significant difference between the mixed berry and blood orange flavors in 2nd/3rd place. The statistical significance of the differences was determined through the application of Friedman's Test, conducted using Redjade software, which resulted in a p-value of 0.001.

Acceptance Test:

Overall Liking:

Figure 4 – Overall Liking:

Prompt: OVERALL, taking everything about this SPORTS DRINK into consideration (its aroma, flavor, and texture), would you say you...? (Please select one response)

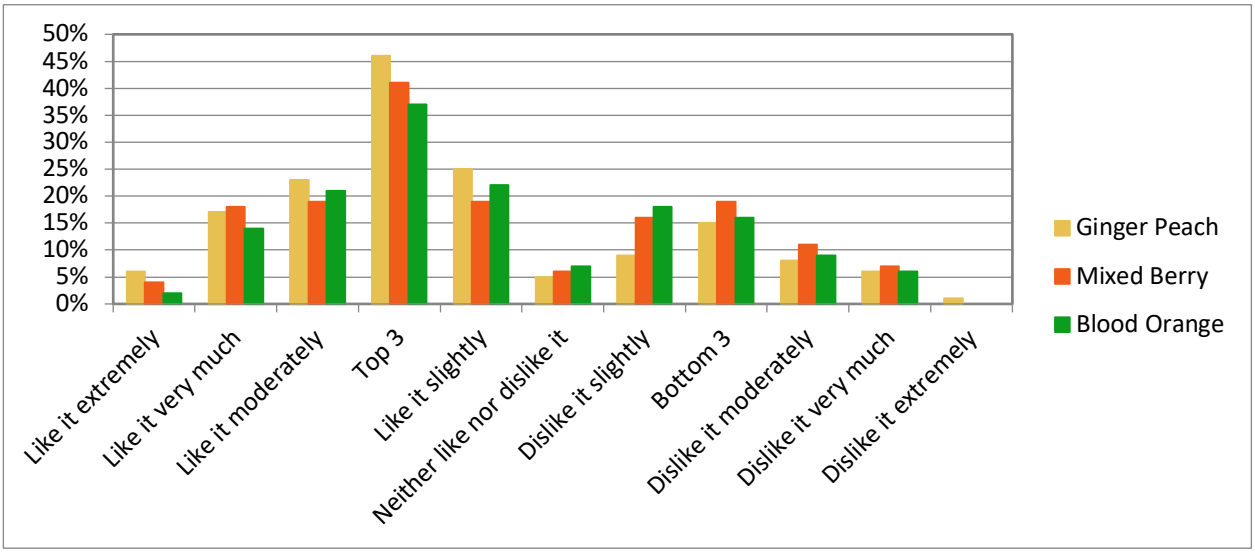


Figure 4: In this figure, we can see that ginger peach had the greatest number of people who "Liked it extremely", but also, had the greatest number of people who "Disliked it extremely". Respondents were least likely to find the blood orange flavor to be liked or disliked, as it had the greatest number of middle scores. Dataset for ***Figure 4*** *is shown below:*

Overall Liking			
	Ginger Peach	**Mixed Berry**	**Blood Orange**
Like it extremely	**6%**	**4%**	**2%**
Like it very much	**17%**	**18%**	**14%**
Like it moderately	**23%**	**19%**	**21%**
Top 3	**46%**	**41%**	**37%**
Like it slightly	**25%**	**19%**	**22%**
Neither like nor dislike it	**5%**	**6%**	**7%**
Dislike it slightly	**9%**	**16%**	**18%**
Bottom 3	**15%**	**19%**	**16%**
Dislike it moderately	**8%**	**11%**	**9%**
Dislike it very much	**6%**	**7%**	**6%**
Dislike it extremely	**1%**	**0%**	**0%**
Mean Score	**6.01**	**5.66**	**5.58**

Figure 5 – Overall Flavor Liking:

Prompt: Thinking about the OVERALL FLAVOR of this SPORTS DRINK, would you say you...? (Please select one response)

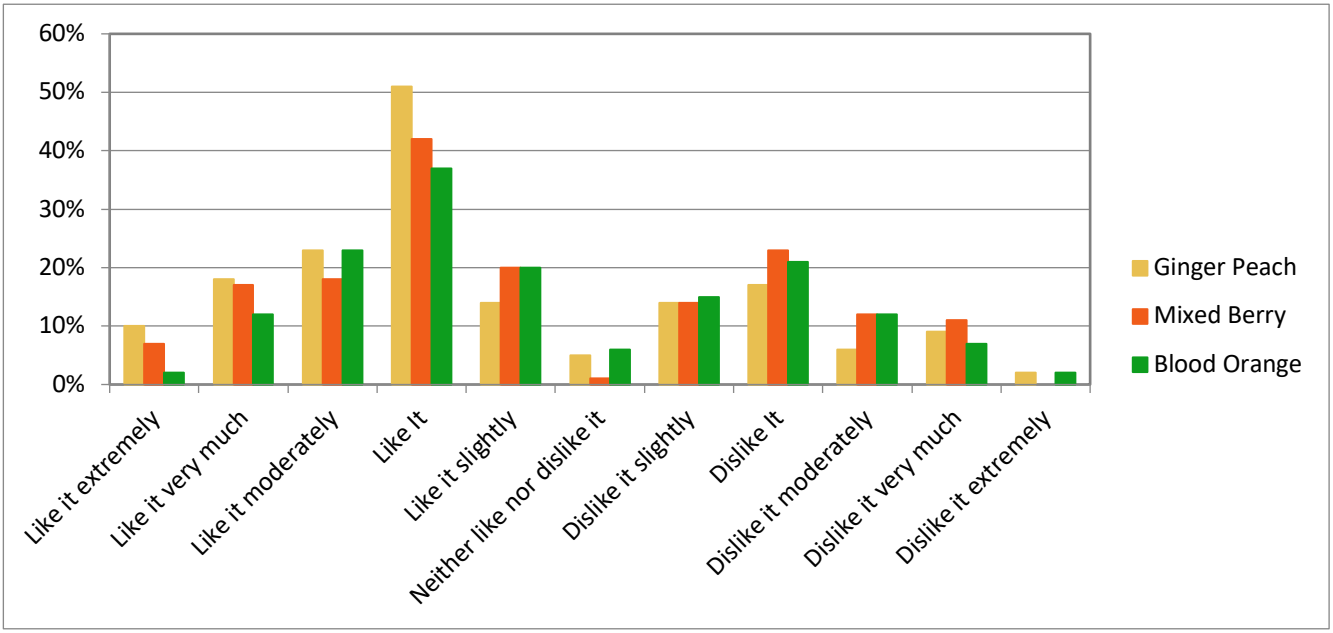


Figure 5: In this figure, we can see that the "overall flavor liking" scores were slightly lower than the "overall liking scores" in Figure 4, but that overall, the data is similar. Dataset for ***Figure 5*** *is shown below:*

Overall Flavor Liking			
	Ginger Peach	**Mixed Berry**	**Blood Orange**
Like it extremely	**10%**	**7%**	**2%**
Like it very much	**18%**	**17%**	**12%**
Like it moderately	**23%**	**18%**	**23%**
Like It	**51%**	**42%**	**37%**
Like it slightly	**14%**	**20%**	**20%**
Neither like nor dislike it	**5%**	**1%**	**6%**
Dislike it slightly	**14%**	**14%**	**15%**
Dislike It	**17%**	**23%**	**21%**
Dislike it moderately	**6%**	**12%**	**12%**
Dislike it very much	**9%**	**11%**	**7%**
Dislike it extremely	**2%**	**0%**	**2%**
Mean Score	**5.94**	**5.64**	**5.42**

Figure 6 – Overall Consistency Liking

Prompt: Thinking about the OVERALL CONSITENCY of this SPORTS DRINK, would you say you...? (Please select one response)

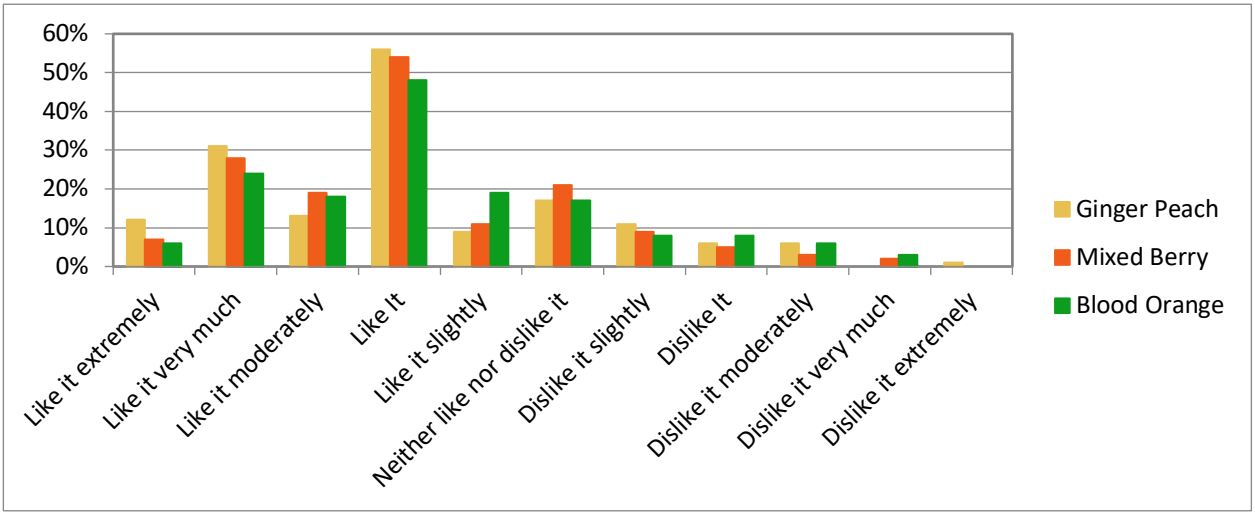


Figure 6: In this figure, we can see that the overall liking scores for consistency were similar to the overall liking scores in Figure 4. Ginger peach had the greatest number of respondents who liked the consistency. Dataset for ***Figure 6*** *is shown below:*

Texture Liking	Ginger Peach	Mixed Berry	Blood Orange
Like it extremely	12%	7%	6%
Like it very much	31%	28%	24%
Like it moderately	13%	19%	18%
Like It	**56%**	**54%**	**48%**
Like it slightly	9%	11%	19%
Neither like nor dislike it	17%	21%	17%
Dislike it slightly	11%	9%	8%
Dislike It	**6%**	**5%**	**8%**
Dislike it moderately	6%	3%	6%
Dislike it very much	0%	2%	3%
Dislike it extremely	1%	0%	0%
Mean Score	**6.52**	**6.41**	**6.24**

Figure 7 – Consistency 5-Point JAR Scale:

Prompt: How would you rate this test sample's CONSISTENCY? (Please select one response)

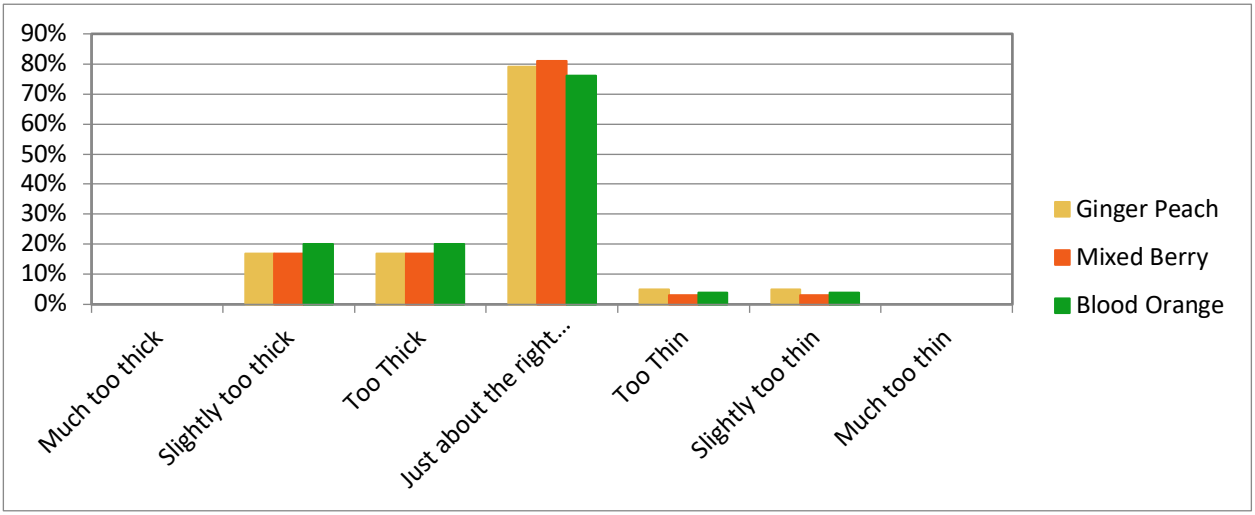


Figure 7: In this figure, we can see that most respondents found the consistency of the sports drink to be just about the right level of thickness. More respondents found that the drink was too thick rather than thin, and it appears that blood orange had the most perceived thickness in consistency. Note that the "Too Thick" and "Too Thin" categories were not an option and are the sum of the top 2 or bottom 2 scores. Dataset from ***Figure*** *7 is shown below:*

Consistency JAR

	Ginger Peach	Mixed Berry	Blood Orange
Much too thick	0%	0%	0%
Slightly too thick	17%	17%	20%
Too Thick	17%	17%	20%
Just about the right CONSISTENCY	79%	81%	76%
Too Thin	5%	3%	4%
Slightly too thin	5%	3%	4%
Much too thin	0%	0%	0%
Mean Score	3.12	3.14	3.17

Aftertaste:

Figure 8 – Aftertaste Detected?:

Aftertaste detected?					
Stat Method: Cochran's Q	**Ginger Peach**	**Mixed Berry**	**Blood Orange**	**P Value**	**Confidence**
Count	**108**	**108**	**108**		
Yes	46%	44%	47%	.864	14%
	A	A	A		
No	54%	56%	53%	.864	14%
	A	A	A		

Figure 8: In the figure above, we can see that no significant differences were observed between the flavors when it comes to detecting an aftertaste.

Figure 9 – Aftertaste Acceptable?:

aftertaste acceptable?					
Stat Method:	**Ginger Peach**	**Mixed Berry**	**Blood Orange**	**P Value**	**Confidence**
Count	**50**	**48**	**51**		
No	30%	31%	35%		
Yes	70%	69%	65%		

Figure 8: In the figure above, we can see that blood orange had the highest number of respondents who reported that the aftertaste was unacceptable. This will be further discussed in the "Future Work and Opportunities for Improvement" section of the report.

Open Ended Word Clouds for Overall Liking/Disliking:

Ginger Peach:

Figure 10 – Ginger Peach "Liking" Word Cloud:

Prompt: What, if anything, do you particularly LIKE about this product?

Figure 11 – Ginger Peach "Disliking" Word Cloud:

Prompt: What, if anything, do you particularly DISLIKE about this product?

Blood Orange:

Figure 12 – Blood Orange "Liking" Word Cloud:

Prompt: What, if anything, do you particularly LIKE about this product?

Figure 13 – Blood Orange "Disliking" Word Cloud:

Prompt: What, if anything, do you particularly DISLIKE about this product?

Mixed Berry:

Figure 14 – Mixed Berry "Liking" Word Cloud:

Prompt: What, if anything, do you particularly LIKE about this product?

Figure 15 – Mixed Berry "Disliking" Word Cloud:

Prompt: What, if anything, do you particularly DISLIKE about this product?

Flavor JAR Scales:

Ginger Peach Flavor JAR:

Figure 16 – Ginger Flavor Intensity JAR

Prompt: Thinking about the intensity of GINGER flavor in this sample, would you say it was...? (Please select one response)

Ginger JAR	
	Ginger Peach
Much too strong ginger flavor	**8%**
Somewhat too strong	**32%**
Too Strong	**41%**
Just about the right level of ginger flavor	**50%**
Too Weak	**9%**
Somewhat too weak	**9%**
Much too weak ginger flavor	**0%**
Mean Score	**3.40**

Figure 16: Im the chart above, we can see that the ginger flavor was most likely" strong enough", but potentially even too strong. Penalty analysis was conducted and will be discussed in following sections of the report to determine whether the intensity of ginger flavor was causing the overall liking score to decrease significantly. Only 9% of respondents found the ginger flavor to be too weak.

Figure 17 – Peach Flavor Intensity JAR

Prompt: Thinking about the intensity of PEACH flavor in this sample, would you say it was...? (please select one response)

Peach JAR	
	Ginger Peach
Much too strong peach flavor	**0%**
Somewhat too strong	**2%**
Too Strong	**2%**
Just about the right level of peach flavor	**19%**
Too Weak	**80%**
Somewhat too weak	**56%**
Much too weak peach flavor	**24%**
Mean Score	**1.98**

Figure 17: In the table above, we can see that most of the respondents found the peach flavor to be too weak. Penalty analysis will be conducted in subsequent sections of the report to validate whether a "weakness" in peach flavor was causing a drop in the overall liking score. Only 2% of respondents found the peach flavor to be too strong.

Blood Orange Flavor JAR:

Figure 18 – Orange Flavor Intensity JAR

Prompt: Thinking about the intensity of ORANGE flavor in this sample, would you say it was...? (Please select one response)

Orange JAR	
	Blood Orange
Much too strong orange flavor	**2%**
Somewhat too strong orange flavor	**15%**
Too Strong Orange Flavor	**17%**
Just about the right level of orange flavor	**44%**
Too Weak Orange Flavor	**40%**
Somewhat too weak orange flavor	**26%**
Much too weak orange flavor	**14%**
Mean Score	**2.65**

Figure 18: In the table above, we can see that the dataset is skewed towards "too weak" of an orange flavor, but that the majority found the intensity of orange flavoring to be just about right. Penalty analysis will be conducted in subsequent sections of the report to determine if the orange flavor intensity impacted the overall liking scores.

Mixed Berry Flavor JAR:

Figure 19 – Berry Flavor Intensity JAR

Prompt: Thinking about the intensity of BERRY flavor in this sample, would you say it was...? (Please select one response)

Berry JAR	
	Mixed Berry
Much too strong berry flavor	**4%**
Somewhat too strong berry flavor	**24%**
Too Strong Berry Flavor	**28%**
Just about the right level of berry flavor	**57%**
Too Weak Berry Flavor	**15%**
Somewhat too weak berry flavor	**14%**
Much too weak berry flavor	**1%**
Mean Score	**3.16**

Figure 19: In the table above, we can see that most panelists found the berry flavor intensity to be just about right, with a greater number of participants viewing the flavor to be too intense rather than too weak.

Sweetness JAR:

Figure 20 – Sweetness JAR

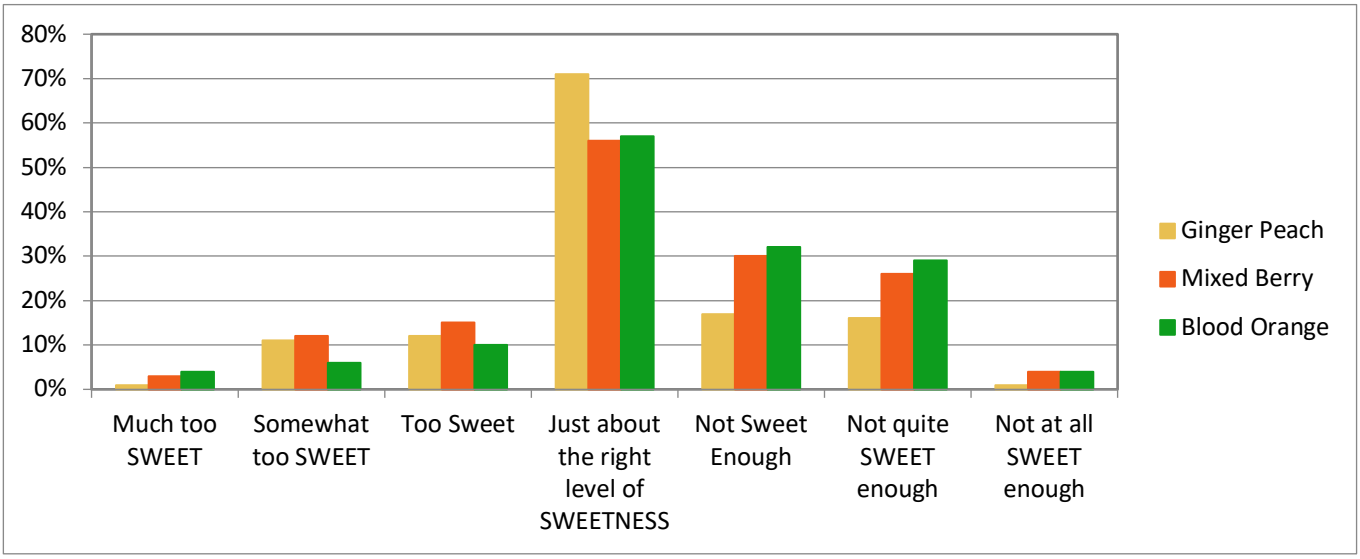


Figure 20: In the bar graph above, we can see that ginger peach had the most balanced level of sweetness among the three flavors. Penalty assessments will be conducted in subsequent sections of the report to determine whether or not a lack of sweetness in the other two sample flavors caused a decrease in overall liking.

Sourness JAR:

Figure 21 – Sourness JAR

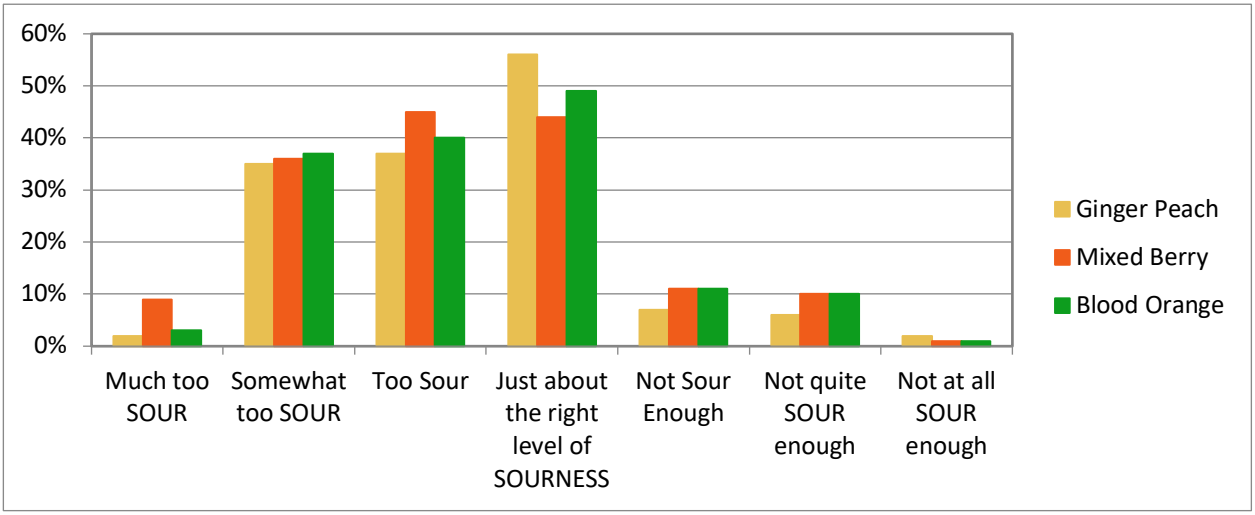


Figure 21: In the bar graph above, we can see that even though many of the panelists found the ginger peach to have just about the right level of sweetness, it was often found to be too sour. Additionally, we can see that many panelists found the mixed berry flavor to be too sour. A penalty analysis will be conducted in later portions of the report to determine whether sourness levels had a negative impact on the overall liking scores.

Saltiness JAR:

Figure 22 – Saltiness JAR

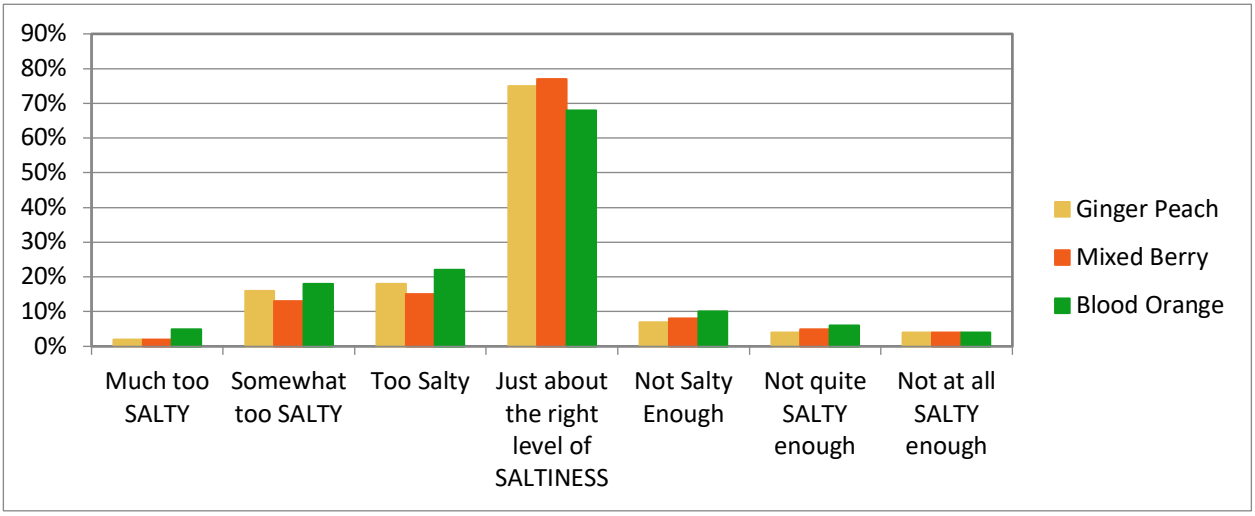


Figure 22: In the bar graph above, we can see that most panelists found the saltiness to be just about right. As a result, we are less likely to see the saltiness levels impact the penalty analysis.

Penalty Analysis:

Ginger Peach:

Figure 23 – Ginger Peach Weighted Penalty Analysis:

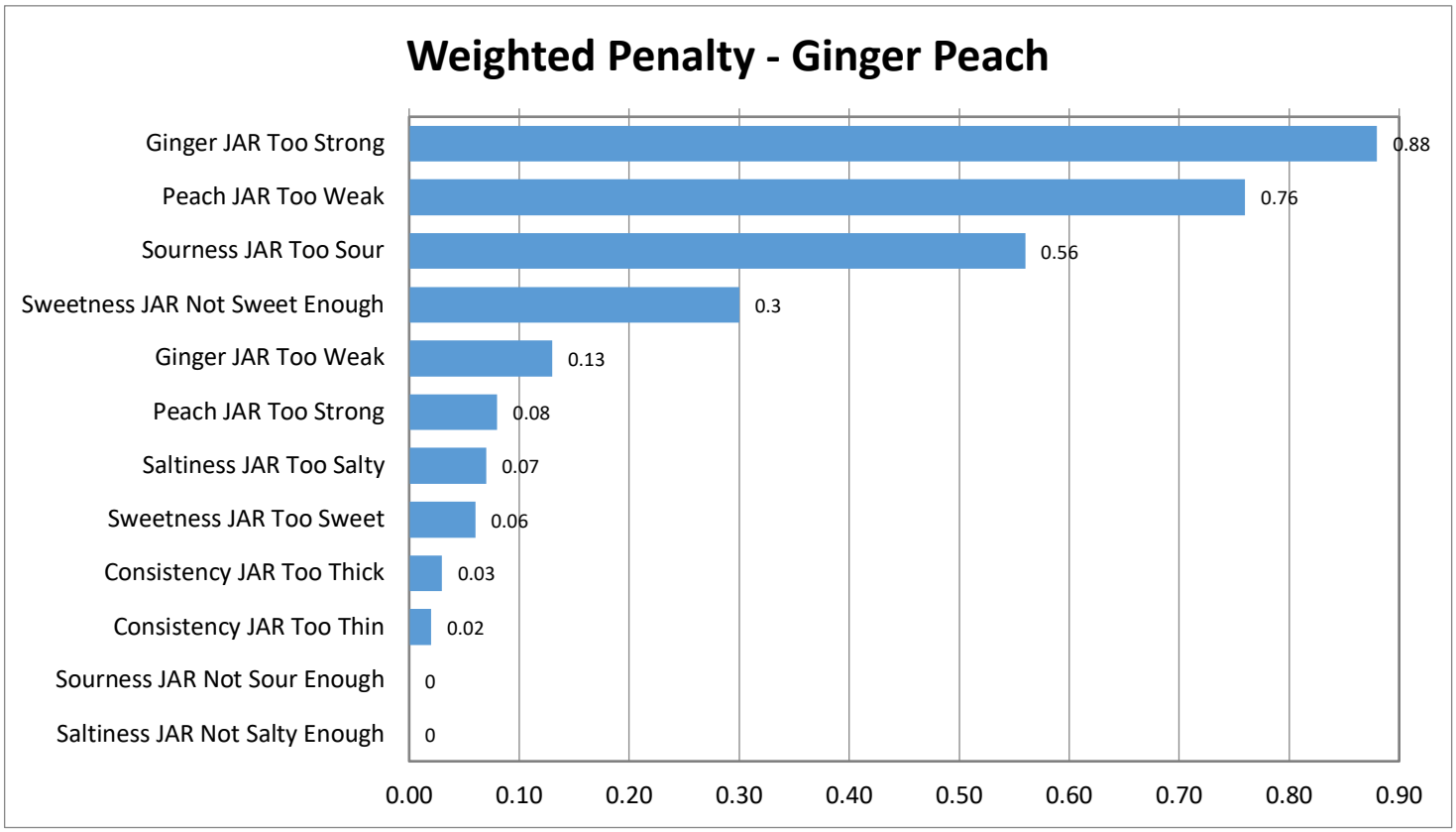


Figure 23: From the bar chart above, we can see that the main areas of improvement for the ginger peach sample would be to decrease the intensity of ginger flavor, increase the intensity of peach flavor, and to make the beverage sweeter.

Blood Orange:

Figure 24 – Blood Orange Weighted Penalty Analysis:

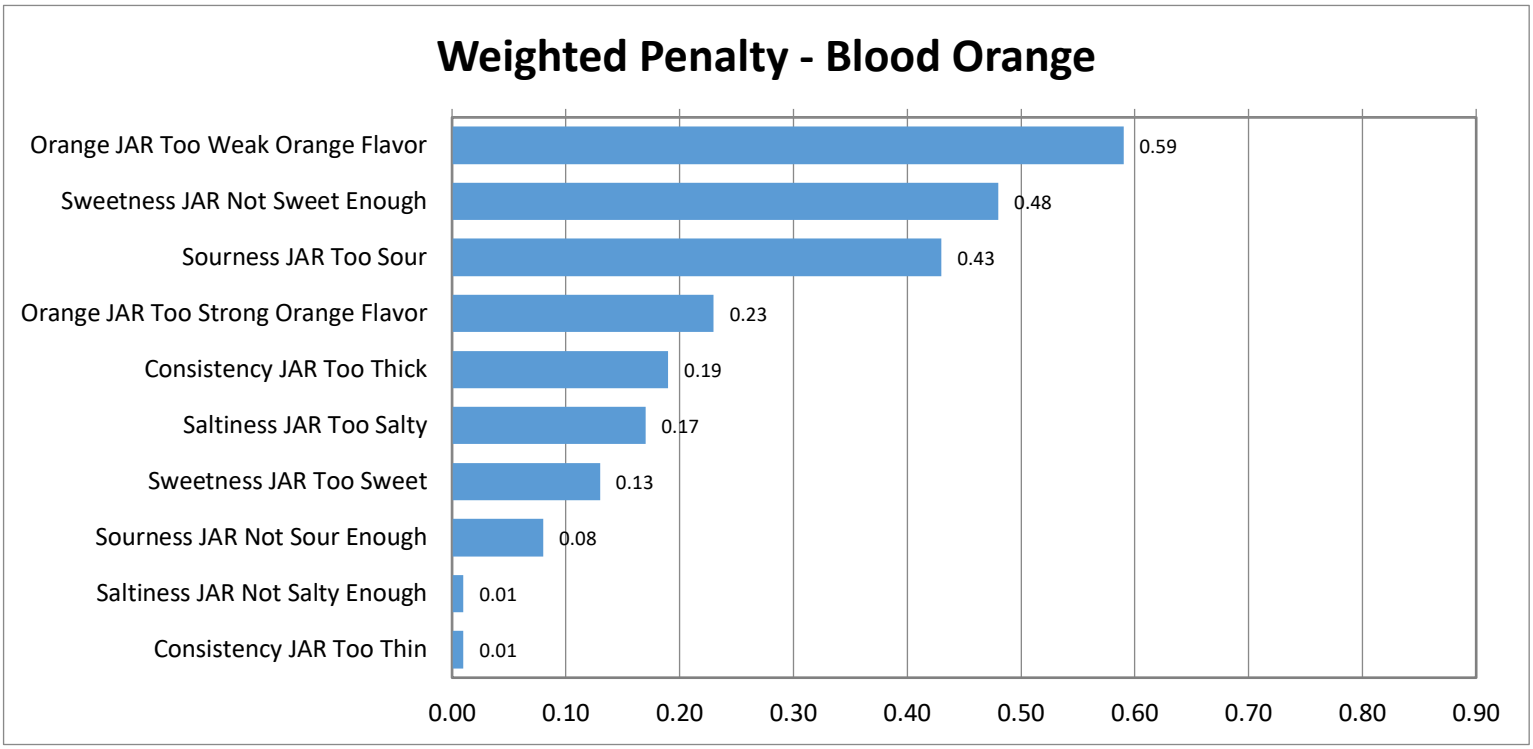


Figure 24: In the bar graph above, we can see that the top three scores of the penalty analysis for the blood orange flavor were: too weak of an orange flavor, lack of sweetness, and too sour. However, it is unclear whether we should increase the orange flavor intensity considering that the 4th highest penalty score comes from too strong of an orange flavor. As a result, it would make the most sense to increase the sweetness while decreasing sourness to improve the overall liking of this flavor.

Mixed Berry:

Figure 25 – Mixed Berry Weighted Penalty Analysis:

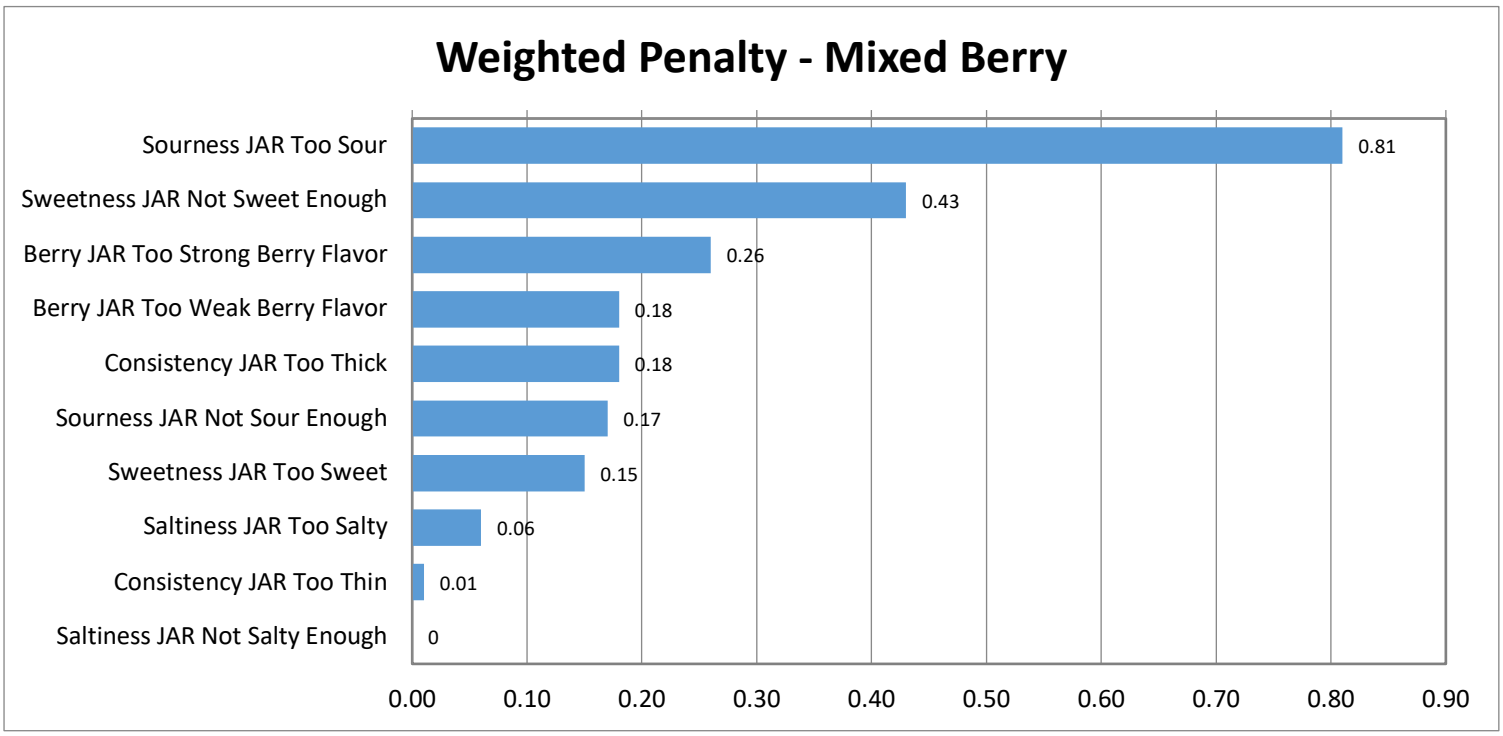


Figure 25: In the bar chart above, we can see that the main attribute causing a decrease in the overall liking score for the mixed berry flavor was that the drink was too sour and not sweet enough. As a result, the best course of improving the mixed berry flavor would be to increase the overall sweetness of the drink.

Purchase Intent:

Uninformed Purchase Intent:

Figure 26 – Uninformed Purchase Intent

Prompt: If this SPORTS DRINK was available to you in a store where you usually shop, at a price that you typically pay, and from the brand that you typically buy, would you say you would...? (Select one response)

Purchase intent

P-Value: 0.018 Confidence: 98.2% Stat Method: GLM	Ginger Peach	Mixed Berry	Blood Orange
Count	108	108	108
Definitely would purchase	17%	4%	5%
Probably would purchase	20%	26%	24%
Top 2	**37%**	**30%**	**29%**
May or may not purchase	33%	26%	22%
Bottom 2	**30%**	**44%**	**49%**
Probably would not purchase	18%	31%	36%
Definitely would not purchase	12%	13%	13%
Mean Score	3.12	2.76	2.71
Post Hoc	A	B	B

Figure 26: In this figure, we can see that the ginger peach flavoring had the greatest purchase intent, and that the results were statistically significant. As the best performer, the uninformed purchase intent of ginger peach was approximately 37%. There was no statistically significant difference observed between the purchase intent scores for mixed berry and blood orange. Statistical significance of differences was determined through the application of a general linear model, conducted using Redjade software, which resulted in a p-value of 0.018.

Informed Purchase Intent:

Panelists were first presented with the following information:

"Please read the following description of the product you have just tried.

The beverages that you have just tried are made from cottage cheese whey, an underutilized co-product from cottage cheese production. This product aims to upcycle the cottage cheese whey and create a more sustainable processing option, ensuring the resources used to make cottage cheese are not wasted while also making value driven sports beverages.

Cottage cheese whey contains all 6 key electrolytes for hydration and a variety of B vitamins.

Our unique formulation includes a variety of carbohydrates, comprised of both high and low glycemic sugars, to maximize the replenishment of glycogen stores after a workout while avoiding subsequent crashes in energy. We added lactase enzyme to ensure that the lactose is broken down into its easily digested components and added fruit juice concentrates (containing fructose) to utilize an additional metabolic pathway for sugar absorption.

In addition to this, we have fortified this sports drink with 3.5g of Leucine per serving, one of the 9 essential amino acids that specifically helps to prevent the breakdown of muscle tissue, increase the bodies insulin response, stimulate muscle protein synthesis, and accelerate recovery."

Figure 27 – Informed Purchase Intent

Prompt: Given the above description, if this product were available to you in a store where you usually shop, at a price that you typically pay, and from the brand that you typically buy, would you say you would...? (Select one response)

Informed Purchase Intent	
Count	**108**
Definitely would purchase	**28%**
Probably would purchase	**42%**
Would Purchase	**69%**
May or may not purchase	**18%**
Would Not Purchase	**13%**
Probably would not purchase	**11%**
Definitely would not purchase	**2%**
Mean	**3.82**

Figure 27: In this figure we can see that the purchase intent greatly increased to 69.7% when participants were informed of the sustainability/functionality of the sports drink. This dataset shows just how critical consumer education would be for success in today's market.

Limitations of Informed Purchase Intent:

Figure 28 – Familiarity with Electrolytes

Prompt: Thinking about electrolytes within the context of hydration, would you say you are...? (Please select one response)

Familiarity With Electrolytes	
Count	**108**
Very familiar	**19%**
Moderately familiar	**37%**
Familiar	**56%**
Somewhat familiar	**36%**
Not Familiar	**7%**
Not too familiar	**6%**
Not at all familiar	**1%**
Mean	**3.68**

Figure 28: In the figure above, we can see that only 56% of our participants were familiar with electrolytes within the context of hydration. This is critical information because our product is targeted towards the highly informed athletic population that is looking to gain a competitive advantage in nutrition.

Figure 29 – Familiarity with Glycogen

Prompt: Thinking about the phrase "Glycogen Replenishment" within the context of sports nutrition, would you say you are...? (Please select one response)

Familiarity with Glycogen	
Count	**108**
Very familiar	**6%**
Moderately familiar	**26%**
Familiar	**32%**
Somewhat familiar	**19%**
Not Familiar	**49%**
Not too familiar	**37%**
Not at all familiar	**12%**
Mean	**2.78**

Figure 29: In the figure above, we can see that even less of our participants were familiar with glycogen replenishment within the context of sports nutrition. Because PWF is formulated to maximize glycogen replenishment, it is important to note that only 32% of the participants of the sensory study would recognize this competitive advantage.

Figure 30 – Familiarity with Leucine

Prompt: Thinking about Leucine as a dietary supplement, would you say you are...? (Please select one response)

Familiarity with Leucine	
Count	**108**
Very familiar	**6%**
Moderately familiar	**15%**
Familiar	**20%**
Somewhat familiar	**23%**
Not Familiar	**56%**
Not too familiar	**31%**
Not at all familiar	**25%**
Mean	**2.44**

Figure 30: In the figure above, we can see that the least number of participants were familiar with leucine when compared to electrolytes or glycogen replenishment. This is important to consider, because our product has been formulated with leucine to drive another value proposition. Considering that this is one of our differentiating competitive advantages in the market, it is important to consider that demographics of our panelist population might not accurately represent the target consumer.

Future Work and Opportunities for Improvement

Based on the results of the sensory study, it seems clear that the ginger peach flavor combination would have the highest probability of success in today's market despite ginger being a very polarizing flavor component. If I were to continue this project, my focus would be on creating additional flavor combinations that capture the same distinctiveness as ginger peach, while simultaneously developing a marketing/branding strategy that highlights bold flavor pairings. At the beginning of my research process, I assumed that strawberry would be the "best" flavor to formulate with dairy effluents, as strawberry milk and yogurt perform very well in today's market, however, strawberry ended up being a major challenge to work with. Strawberry did not taste appealing as a standalone flavor or when mixed with lemon to create a "strawberry lemonade" type flavor. To overcome this hurdle, blue raspberry flavoring was added to create the "mixed berry" flavor. An interesting takeaway that I observed during this experiment was that when formulating CCW with citrus juice concentrates, a very undesirable off flavor and aftertaste would develop during storage. Although this off flavor was not strongly observed during the sensory study, this could have been due to the freshness of the samples used, as they were freshly made just one week prior to the date of the study. However, blood orange still did receive the highest number of respondents who detected an aftertaste and reported it as unacceptable (as seen in figure 9), though the differences between other flavors were small.

Looking to the future, one of the main aspects of the project that remains incomplete is the electrolyte optimization. If I were to continue this project, it would be important to formulate the beverage in such a way that the electrolyte composition drives yet another key value proposition. Because this product was developed as a "Post Workout Fuel", this sports drink should serve to replenish the electrolytes that are lost during exercise. One way to determine the ratio of

electrolytes lost during exercise would be to collect sweat samples from athletes sitting in a sauna, as the sauna would produce consistent levels of perspiration. As a result, one could formulate PWF to have a proprietary and "optimized" electrolyte profile for recovery that is new to the industry. Additionally, as previously mentioned in this report, the addition of NaCl not only enhances the sodium content to levels comparable to those of leading sports brands in the industry but also facilitates the incorporation of chloride ions. This grants PWF yet another competitive edge by offering all six essential electrolytes which leading sports drink brands cannot claim. Finally, at the beginning of the project, I made the mistake of assuming that fruit juice concentrates would not be considered as "added sugars". The FDA recently declared that "sugars from concentrated fruit or vegetable juices that are in excess of what would be expected from the same volume of 100 percent fruit or vegetable juice of the same type" must be declared as added sugars ("Nutrition and Supplement…" n.d.). As a result, PWF can look to incorporate glucose to increase the sweetness and add additional functionality to the beverage, as lack of sweetness was the greatest opportunity for improvement observed from the penalty analyses.

In conclusion, it is clear that cottage cheese whey has the potential to serve as a favorable base for a functional sports drink. In this experiment, the final formulations included anywhere from 90-95% cottage cheese whey, and the significant electrolyte content came directly from the whey. One might assume that a formulation with 50-60% cottage cheese whey could increase the overall liking scores while continuing to utilize an impactful amount of CCW. Although this report serves as a proof of concept for reducing the economic burden of acid whey, life cycle analyses are required to validate the feasibility of this approach.

Thank you Dr. Alcaine for building the foundation for inspiring and impactful research. I am forever grateful to have been a part of the Alcaine Research Group. Thank you, Cornell University, for bringing inspiring individuals together into one beautiful place.

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