2008

Development and Quality Evaluation of Pre- and Post-Workout Sport Beverages

Maria Christine Pfister
Louisiana State University and Agricultural and Mechanical College

DEVELOPMENT AND QUALITY EVALUATION OF PRE- AND POST-WORKOUT SPORT BEVERAGES

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

In

The Department of Food Science

by
Maria Christine Pfister
B.S., Food Science, Louisiana State University, 2006
August 2008

ACKNOWLEDGEMENTS

I would like to express my immense gratitude to my major professor and advisor Dr. Witoon Prinyawiwatkul, who has been there to help me every step of the way. It has been an honor being his student. To learn from him and work with him has been a privilege. I would also like to thank Dr. Kayanush Aryana, a committee member, for helping me with several critical aspects of my research. To my other committee members, Dr. Joan King and Dr. Zhimin Xu, thank you for guiding me throughout this process. I would also like to thank Dairy Plant Manager Kamalesh Ashanta for all of his help during the past two years. I would not have been able to do this without him.

I would also like to thank my parents for supporting me throughout my education. Their love and encouragement have helped me along this arduous journey. To my mom Janelle Pfister, thank you for always having a smile on your face. Your generous smile and encouraging words have helped me get through many hard times. To my boyfriend and best friend Travis Godawa, thank you for your love and support throughout my college career.

I am also thankful for my fellow food science students. To Karen, Pamarin, and Rachel, thank you for all of the long hours and late nights, but most of all, thank you for being great friends.

I would also like to thank all other members of our department, especially Bonnie, Terri, and Laura for their help throughout the years.

Finally, I would like to thank Brad, Tamara, Tricia, and all other UREC employees for helping me with the consumer study process.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Athletes and gym goers are continuously searching for sports supplements that will set them apart from others. Resistance training is a popular form of exercise that enables one to increase in strength and power. Resistance or strength training, however, results in several degradation processes. A popular way of enhancing workouts and recovering after workouts is through the consumption of sports drinks.

In study one, a preliminary study, eight pre-workout and eight post-workout sports drinks were formulated that contained whey proteins, sugars, natural fruit flavors, and other vitamins and supplements. A consumer acceptance test was preliminarily conducted to evaluate consumer acceptability of several sensory attributes and purchase intent of the sports drinks. Overall, acceptance of appearance, aroma, color, consistency, mouthfeel, flavor, sweetness, and overall liking were not acceptable to consumers, and purchase intent was not adequate.

For the second study, improvements were made to the sports drinks formulated in the first study. A consumer acceptance test was conducted to test the acceptability of eight new pre-workout and eight new post-workout formulations. Based on the consumers' results, one pre-workout and one post-workout formulation were selected for further study. Selection was based on acceptance of specific sensory attributes, overall product acceptance, and purchase intent.

In the third study, the two most acceptable sports drinks from the second study were selected for validation of consumer acceptance and for the analysis of market potential. Two commercially available sports drinks were also selected. A consumer acceptance test (N=300) was conducted. The consumers evaluated the commercially available pre-workout beverage as having greater acceptance and purchase intent than the formulated beverage, but they evaluated the formulated post-workout sports drink as being more acceptable than the commercially

available drink. No statistical differences were found in the acceptability and purchase intent between the commercially available and formulated sports drinks. Therefore, the formulated beverages have the potential to be innovative products on store shelves.

Further analysis of the formulated beverages would be worthy of studying. Consumers' perception and acceptability of the two sports drinks if they were packaged together, and the shelf-life of the beverages are ideas worth researching.

CHAPTER 1. INTRODUCTION

Functional foods are foods, or parts of foods, consumed as part of the daily diet that are designed and processed to provide health benefits for consumers (Maughan 1998). Some of the most popular foods in the functional food spectrum are energy/sports drinks, probiotic dairy products, heart health spreads and ready-to-eat cereals (Westrate and others 2002). The rise in popularity of sports drinks is apparent when looking at sales trends. Sports drink sales increased by 19.1 percent, which is more than $1.5 billion, in the year 2005. The largest increase was seen in bottled sports drinks, at 21 percent for a total of $1.4 billion, in supermarkets, and in drug and merchandise outlets. In a much smaller segment, powdered sports drink mixes grew 15 percent for a total of $31.7 million in the measured channels (Beverage Industry 2006).

In general, sports drinks are formulated and consumed with the aim of achieving one or more of the following objectives: 1) to supply fuel for working muscles, usually in the form of glucose, which will spare the body’s limited energy reserves and, thus, improve performance; 2) to provide water to replace that lost in sweat, and thus to reduce the problems of dehydration; 3) to supply electrolytes to replace those lost in sweat (Maughan 1991). However, more recently, the field of interest has shifted from macronutrients and fluids to isolated nutritional or non-nutritional components such as caffeine, creatine, ribose, antioxidants, and certain amino acids (Brouns and others 2002).

Strength is defined as the ability of the muscle to exert force. Strength training is a popular type of training employed by bodybuilders, powerlifters, Olympic lifters, and athletes who strength train for conditioning, or anyone who works out with weights to stay in shape. In athletes, strength training depletes muscle glycogen, stimulates the acute inflammatory response, increases protein breakdown, and causes muscle damage (Ivy and Portman 2004). If the appropriate nutrients are consumed at the proper times prior to exercise and at the completion of exercise, the degradation that results from strength training can be minimized.

An important goal of the athlete's everyday diet is to provide the muscle with substrates to fuel the training program that will achieve optimal adaptation and performance enhancements. Body fat and carbohydrate stores provide the major sources of exercise fuel; whereas fat sources are relatively plentiful, and carbohydrate sources are limited. As a result, sports nutrition guidelines have focused on strategies to enhance body carbohydrate availability. Such practices include the intake of carbohydrate before and during a workout to provide fuel for that session, as well as intake of carbohydrate after the session and over the day in general to promote refueling and recovery (Burk and others 2004). High to moderately high glycemic carbohydrates are a common addition to most sports drinks on the market today, which include glucose, sucrose, and maltodextrins.

The importance of protein to athletes has long been recognized. From coaches of Olympians in ancient Greece to today's multi-millionaire athletes, protein has been considered a key nutritional component for athletic success (Tipton and Wolfe 2004). Research has shown that protein should be consumed within 2 hours of exercising, either before or after, to provide the most benefit. The emergence of whey protein as a functional ingredient and a good source of essential and branched chain amino acids has propelled whey protein into the spotlight (Beucler and others 2005). The high concentration of branched-chain amino acids leucine, isoleucine, and valine, helps to decrease protein degradation and increase protein synthesis (Biolo and others 1997).

Antioxidants are another key component that can be included in sports drinks. Muscular exercise promotes the production of radicals and other reactive oxygen species in the working muscle. Growing evidence indicates that reactive oxygen species are responsible for exercise-induced oxidation and contribute to muscle fatigue (Davison and Gleeson 2005). Exogenous dietary antioxidants interact with endogenous antioxidants to form a cooperative network of cellular antioxidants (Powers and others 2004). Such antioxidants that can be incorporated into a sports drink are vitamin E, vitamin C, glutathione, α-lipoic acid, carotenoids, flavonoids, and ubiquinones (Powers and others 2004).

Other ingredients that can be included in sports drinks are creatine, L-glutamine, and L-leucine. Scientific studies have consistently demonstrated the efficacy of creatine supplementation for increasing muscular strength and body mass as well as increasing the synthesis of muscle contractile proteins (Hoffman and others 2005). Glutamine, the most abundant amino acid in the body, has been shown to regulate protein balance in skeletal muscles based on findings in both experimental and clinical studies (Svanberg and others 2001). Leucine, a branched chain amino acid, has been shown to stimulate protein synthesis and is closely associated with the release of gluconeogenic precursors (Mero 1999).

Based on existing literature about specific ingredients that can help to enhance an athlete's workout, or help an athlete recover after intense exercise, novel pre- and post-workout sports beverages were developed. The sports beverages contained protein, carbohydrates, amino acids, antioxidant, electrolytes, and specific sport enhancing supplements. The objectives of this thesis work were to develop the aforementioned pre- and post-workout sport beverages that are acceptable to consumers, and to explore the market potential of these innovative new products.

This thesis is divided into six chapters. Chapter 1 represents an introduction to the sports drink market, and provides justifications about the importance of specific nutrients that should be included in a sports drink. Chapter 2 is a literature review with concepts associated with this thesis work. Chapter 3 discusses a preliminary study on the development of two novel sports drinks. Chapter 4 discusses the development and evaluation by consumers of sixteen pre- and post-workout sports drinks. Chapter 5 discusses the market potential of the newly developed sports drinks. Chapter 6 provides a brief summary of all findings of this research, and potential future work. Appendices including sample questionnaires, research consent forms, SAS codes, and other figures are also included. Finally, the VITA of the author concludes this thesis.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

Products that focus on boosting energy, increasing muscle mass, or improving muscle restoration populate shelves at gyms and even mainstream supermarkets (Ohr 2003). The trend towards increasingly hectic lifestyles, combined with greater consumer awareness of healthy and functional products, is driving new opportunities for increased sales from energy and sports drinks (Vending International 2006). Exercise training is performed with the goal of adaptation so that subsequent exercise capacity is improved, and optimal nutrition is an important aid needed to facilitate recovery from training (Millard-Stafford and others 2005). In athletes, strength training depletes muscle glycogen, stimulates the acute inflammatory response, increases protein breakdown, and causes muscle damage (Ivy and Portman 2004). If the appropriate nutrients are consumed at the proper times prior to exercise and at the completions of exercise, the degradation that results from strength training can be minimized. An ideal mode of supplying the body with the proper nutrients pre- and post-exercise is through the consumption of sports beverages.

2.2 Sports Drinks

Sports drinks are formulated to provide fluid to minimize dehydration and to supply carbohydrates and electrolytes for fluid absorption and retention (Seifert and others 2006). However, more recently, sports drinks are being marketed with benefits such as ‘more power’, ‘improved recovery’, and ‘reduction of body fat/increased muscle mass’ (Brouns and others 2002). The relative importance of individual objectives for strength training depends on the intensity and duration of the exercise, on the climatic conditions, and on the physiological characteristics of the individual. Such factors will, in turn, determine the optimum composition of drinks to be consumed. However, no one drink is appropriate for all individuals in all situations (Maughan 1991).

Specific estimates on the market size of nutritional sports products vary depending on definitions used and data included. An October 2005 report by Mintel Internationa1, "The Market for Sports Food and Drinks," placed category growth at 48% between 2000 and 2005 (Prepared Foods 2007). According to the 2008 Beverages Market Research Handbook, the consumptions of sports drinks are as follows: 775 million gallons in 2002, 883 million gallons in 2003, 990 million gallons in 2004, 1.21 billion gallons in 2005, and 1.35 billion gallons in 2006. Gatorade®, arguably the most commercially successful sports beverage, was first introduced in 1967, has more than 80% marketshare of the sports drink category. PowerAde®, a division of the Coca-Cola® Company, holds the number two market position in the segment with 13% marketshare.

The suffix "-ade" means both "action" and "product, especially a sweet drink," according to Webster's Dictionary (Zegler 2007). Influenced by both definitions, "-ade" has taken over the sports drink category as a powerful end to a name brand. Starting with Gatorade®, and followed by Coca-Cola's® PowerAde® and Accelerade® from Cadbury Shwepps, these beverages share the same suffix that defines them as sports drinks.

From its inception, Gatorade® has contained three essential ingredients for athletes: carbohydrates, minerals, and water. Over the years, sports beverage formulations have evolved (Prepared Foods 2007). Recently, energy drinks with stimulants and products with antioxidants, proteins and peptides, and more exotic ingredients like taurine, creatine, chromium and L-carnitine have entered the marketplace. Low sodium, low glycemic, and non-digestible carbohydrates are formulation goals for many foods, however, not for many sports drinks.

Enhanced sports performance products often use significant amounts of sodium, high-glycemic carbohydrates and other ingredients (Prepared Foods 2007).

2.3 Carbohydrates

Research in exercise nutrition and physiology has shown that performance of moderate to high intensity exercise can be enhanced by carbohydrate consumption when exercise lasts at least an hour (Below and others 2005). A popular strategy used by athletes to promote muscle growth is ingesting carbohydrate, or carbohydrate and protein, before and/or after periods of exercise. The ingestion of carbohydrates before or during prolonged exercise has also been shown to postpone fatigue and improve performance (Coggan and Coyle 1991). These strategies have been based on reports indicating that ingesting carbohydrate-protein before exercise may increase insulin levels, thereby decreasing exercise-induced catabolism (Carli and others 1992), and that ingesting carbohydrate-protein following exercise may hasten recovery, promote a more anabolic hormone profile, decrease myofibrillar protein breakdown, and enhance glycogen resynthesis (Roy and others 1998).

Insulin is the most powerful and multifunctional anabolic hormone in the human body, which has a tissue building effect on the body by promoting protein formation (Kleiner 2001). Insulin is released from the pancreas usually in response to high levels of blood glucose. A well-known role of insulin is that it increases the transport of glucose into the muscles; however, insulin plays many more roles including increased protein synthesis, increased amino acid transport, reduced protein degradation, increased muscle glycogen storage, and suppressed cortisol release (Manninen 2006; Ivy and Portman 2004).

Glycogen depletion has traditionally been the concern of endurance athletes, but it is also an important issue for strength athletes. Muscle glycogen levels following multiple sets can be reduced as much as 40%, and doubling the intensity of the workout doubles the glycogen breakdown. ATP and creatine phosphate provide most of the energy for muscle contraction, but glycolysis still plays an important role. Between sets, muscle cells use the glycolytic pathway to regenerate ATP (Ivy and Portman 2004). The conversion of glucose into glycogen takes place via the activation of the enzyme glycogen synthase. Following exercise, insulin can increase the activity of glycogen synthase by 70 percent, resulting in a tremendous increase in glycogen storage (Ivy and Portman 2004). Other researchers have also observed enhanced exercise performance after the ingestion of carbohydrates one hour before exercise (Gleeson and others 1986; Sherman and others 1991; Thomas and others 1991; Kirwan and others 1998). By consuming a carbohydrate or carbohydrate/protein sports drink during workouts, muscle glycogen can be preserved and strength can be preserved throughout workouts.

As early as 1988, researchers at the University of Texas at Austin showed that the timing of carbohydrate supplementation post-exercise had a significant influence on the rate of muscle glycogen storage. They found that when subjects consumed the supplement immediately after exercise, they stored twice as much muscle glycogen in a two-hour recovery period as when they took the supplement two hours later (Ivy and Portman 2004). Haff and others (2000) studied the effect of carbohydrate supplementation during resistance exercise. They found that when the carbohydrate supplements were provided, the decline in muscle glycogen was 50 percent less and that subjects could perform more work than subjects receiving flavored water. Similarly, researchers at Vanderbilt University found that glucose uptake following exercise was three to four times faster when carbohydrate supplementation was given immediately after exercise rather than three hours later (Ivy and others 2003).

Many studies have proposed that both the type and amount of carbohydrate consumption during workouts might affect gastric emptying, intestinal absorption, hormonal release, and glucose availability for oxidation in the muscle (Jeukendrup and Jentings 2000). The glycemic index (GI) classifies carbohydrates according to their effect on blood sugar levels, with glucose (GI 100) serving as the benchmark. The carbohydrates can be in the form of glucose, fructose, or maltodextrins (Convertino and others 1996; Casa 2000). These sugars enter the blood stream quickly; delivering immediately accessible energy that is then used up very quickly (Meissner 2006). Since glycogen storage is influenced by both insulin and a rapid supply of glucose substrate, it is logical that carbohydrate sources with moderate to high glycemic index (GI) would enhance post exercise refueling (Burke and others 2004).

Davis and others (1988) determined that a 6% carbohydrate solution entered the bloodstream as quickly as water and showed an improvement in endurance capacity. The American College of Sports Medicine (1996) has expressed similar recommendations, in that a sports drink should contain4-8% carbohydrate per 8 oz/240ml of water. These percentages of carbohydrate are ideal. One general recommendation for carbohydrate intake immediately after recovery is $1.0\text{-}1.2 g*kg^{-1}*h^{-1}$ (Burke and others 2004). Ivy and Portman (2004) also recommended consuming 40-50g of high-glycemic carbohydrates in a post-workout beverage.

2.4 Protein

Proteins are assembled from their basic units, the amino acids. The body uses amino acids to synthesize its own variety of proteins (Driskell 2000). Protein ingestion during exercise has potential to serve as a fuel for both oxidation and as acting to stimulate cellular responses that have benefits during exercise (Coyle 2004). At present, there are few data to support specific recommendations regarding the type, amount and timing of protein intake during exercise.

However, according to Tipton and Wolfe (2004), protein availability immediately after exercise may stimulate adaptation and, therefore, it may be practical to ingest protein during exercise.

In addition to serving as a fuel, ingested protein from normal foods has the potential to moderate the metabolic responses during exercise under some conditions. As discussed by Burke and others (2004); Zawadzki and others (1992); Ivy (2001); Ivy and others (2002), the addition of small amounts of protein to carbohydrate ingested after exercise augments the plasma insulin response, which has the potential to alter metabolism.

Athletes involved in intense training have higher dietary protein needs than individuals who do not train. Evidence exists to indicate that these types of athletes have protein needs that are one to two times that of the Recommended Daily Allowance (Kerksick and others 2006). The 1989 Recommended Dietary Allowance (RDA) for protein is 0.75g/kg body weight for adults; however, power and endurance athletes appear to need 1.2 to 1.5g/kg body weight (Driskell 2000).

2.4.1 Whey Protein

Milk is a polyphasic secretion of the mammalian gland containing approximately 5% lactose, 3.2% protein, 4% lipid, and 0.7% mineral salts (Severin and Wenshui 2005). Milk proteins are currently the main source of a range of biologically active peptides (Wu and Ding 2002). The two primary proteins found in milk are whey and casein (Antonio 2002). Whey is the yellow-green liquid that separates from the curd during manufacture of cheese and casein (Smithers and others 1996). Whey represents a rich and heterogeneous mixture of secreted proteins with wide ranging functional attributes for nutritional, biological, and food purposes. The main constituents are β-lactalbumin and α-lactalbumin, two small globular proteins that account for approximately 70-80% of total whey protein (Smithers and others 1996).

The exceptional nutritional quality of the whey proteins of milk has been known for quite some time (Holsinger and others 1974). The anti-carcinogenic properties of whey have been shown by Bounous and others (1991) and McIntosh and others (1995). Whey protein-enriched diets have also exhibited low-density lipoprotein cholesterol lowering and immune system stimulation effects (Zhang and Beynen 1993). Lactoferrin, lactoperoxidase, and lysozyme, and immunoglobulins, all minor whey protein components, have exhibited antimicrobial properties (Temelli and others 2004).

Many whey beverages have been developed using both raw unprocessed liquid whey and whey protein concentrate and isolate powders (Holsinger and others 1974). Whey protein concentrate (WPC) contains protein in concentrations less than 90%, while whey protein isolates (WPI) contain a minimum of 90% protein (Beucler and others 2005). Protein sources such as whey protein contain higher concentrations of branched-chain amino acids such as leucine, isoleucine, and valine, and other essential amino acids are of a higher protein quality and are more effective in promoting protein synthesis (Borsheim and others 2002).

Ingestion of whey protein has been found to cause a rapid transient increase in the plasma levels of amino acids, causing increased protein synthesis and little change in protein catabolism (Boirie and others 1997). Supplementing with whey protein during resistance training has been shown to have positive effect on muscle mass in young adults (Candow and others 2006). Borsheim and others (2004) found that a combination of whey protein, amino acids, and carbohydrates resulted in a greater response of muscle protein net balance after resistance training than when carbohydrates were given alone. They also found that the addition of protein to a mixture of free amino acids resulted in a response lasting beyond the first hour after intake.

2.4.2 Casein

Caseins constitute over 80% of the total protein of milk; however, the relative proportion of whey proteins to casein varies according to the stage of lactation (Varnam and Southerland 2001). Caseins exist in milk as micelles, which are composed of four specific caseins (β, κ, α_{s1}, α_{s2}) (Huffman and Harper 1999). Caseinates, the salt form of casein, are widely used in the food industry. Major applications include beverage powders, retorted or aseptic liquids, coffee whiteners, whipped toppings, and meat and poultry applications (Huffman and Harper 1999). A new protein source on the market is casein hydrolysate. Casein hydrolysates have the same biological benefit as intact protein, and offer water solubility, better taste and mouthfeel, better absorption, fewer gastrointestinal problems and reduced allergic reactions to protein (Siebrecht 2006).

2.4.3 Amino Acids

Resistance training results in significant muscle protein turnover and the rate of muscle protein synthesis following exercise is elevated with oral consumption of amino acids (Tipton and others 2001). Glutamine is the most abundant amino acid found in skeletal muscle and plasma, and it comprises over 60% of the total free amino acid pool (Kerksick and others 2006). Glutamine is also essential for the optimal functioning of a number of tissues in the body and the immune system (Kargotich and others 2005). Glutamine supplementation has been reported to enhance protein synthesis, promote muscle growth and decrease exercise-induced immunosuppression (Kreider 1999).

Leucine, isoleucine and valine, the branched-chain amino acids make up about one-third of muscle protein (Mero 1999). Significant decreases in serum amino acids, particularly leucine and isoleucine, have been found following resistance training (Coburn and others 2006).

Leucine has been shown to stimulate protein synthesis in the muscle and is closely associated with the release of gluconeogenic precursors from the muscle (Mero 1999). Supplementing the diet with leucine and other amino acids increases amino acid availability to the muscles (Tipton and others 1999).

2.5 Antioxidants

The ingestion of antioxidants is a nutritional strategy used to improve recovery in athletes. Antioxidants are components that suppress free radicals from harming cells, but if free radical production exceeds antioxidant activity, oxidative stress will result with cell damage (Finaud and Lac 2006). Exercise, which results in the production of reactive oxygen species, can cause oxidative stress that can lead to pathogenesis of chronic diseases, muscle damage, and reduced immune function (Watson and others 2005). Muscular exercise promotes the production of radicals and other reactive oxygen species in the working muscle. Reactive oxygen species produced from exercise are believed to be caused by a leak of electrons at the mitochondria and an increase in activity of metabolic processes and immune responses (Knez and others 2006). Such antioxidants that can be incorporated into a sports drink are vitamin E, vitamin C, glutathione, α-lipoic acid, carotenoids, flavonoids, and ubiquinones (Powers and others 2004).

2.5.1 Vitamin C

Vitamin C, or ascorbic acid, is an aqueous antioxidant that has the potential to reduce oxidants by the donation of a hydrogen ion (Goldfarb and others 2005). Vitamin C is more abundant in tissues in which the production of reactive oxygen species is more important. In fluids, this antioxidant vitamin has the ability to neutralize reactive oxygen species. Inside of cells, vitamin C reinforces the action of vitamin E by regenerating their active form after they have reacted with a reactive oxygen species (Finaud and Lac 2006). The Dietary Reference

Intake (DRI) for vitamin C is 90mg and the tolerable upper intake level (UL) is 2000mg (Powers and others 2004).

A variety of immune functions are enhanced by vitamin C consumption. Exhaustive exercise induces oxidative stress and it may impair immune response, which could increase athletes' susceptibility to upper respiratory tract infections (Tauler and others 2006). Infections can impair performance, prevent an athlete from competing or interfere with training (Davison and Gleeson 2005). Physical activity also influences changes in serum levels of cortisol and testosterone, depending on the duration and intensity of the exercise (Schroder and others 2001). Recent evidence suggests that high doses of vitamin C can reduce infection incidence following prolonged exercise which might also be related to the reduction of the stress hormone cortisol, which may also be released in response to oxidative stress (Davison and Gleeson 2005).

2.6 Electrolytes

Small amounts of electrolytes, generally sodium, potassium and chloride, are added to sports drinks to improve palatability and to, theoretically, help maintain fluid/electrolyte balance Coombes and Hamilton (2000). The replacement of electrolytes, particularly sodium, in combination with water, is essential for effective rehydration. Researchers have found that rehydration with water alone dilutes the blood rapidly, increases its volume, and stimulates urine output (Burns and Burning 1999). Potassium is another electrolyte involved in maintaining body fluids during exercise.

Studies conducted on the effects of ingestion of water or of commercially available drinks on restoration of fluid balance after exercise-induced dehydration have produced valuable results. Costill and Sparks (1973) showed that ingestion of glucose-electrolyte solution after dehydration resulted in a greater restoration of plasma volume than did plain water. Gonzales-

Alonso and others (1992) confirmed that a dilute carbohydrate-electrolyte solution is more effective in promoting post exercise rehydration than either plain water or a low-electrolyte cola.

2.6.1 Sodium

Sodium is a macro element found in large concentrations in extracellular fluid. Sodium in sports drinks assists in maintaining body fluid balance in plasma volume and total body fluid balance (Burns and Berning 1999). Sodium also enhances beverage taste and replaces sodium lost in sweat (Maughan 1991). Most sports beverages contain from 10 to 25 mEq Na per liter of 55 to 110 mg per 8-oz (240 ml) serving. Gatorade® has 110 mg Na per 8-oz, and PowerAde® and Allsport® both have about 55 mg per 8-oz (Burns and Berning 1999).

Compared with ingesting plain water, consuming adequate salt with water during exercise helps: sustain the osmotic drive to drink, promoting better voluntary intake; maintain greater plasma and extracellular fluid volumes; lower urine output; and blunt the decline in plasma sodium concentrations (Murray 2007). Sodium loss during exercise also contracts extracellular fluid space and may alter ion channels to make neuromuscular junctions or muscle units hyperexcitable, thus evoking involuntary and sustained contractions or cramping (Eichner 2007).

2.6.2 Potassium

Potassium is a cation found primarily intracellular (Driskell and Wolinsky 1999). It has been postulated that the inclusion of potassium would enhance the replacement of intracellular water after exercise and thus promote rehydration (Nadel and others 1990). Experiments have shown that the inclusion of potassium (25 mmol/liter KCl) may be as effective as sodium (60 mmol/liter NaCl) in retaining water ingested after exercise-induced dehydration (Maughan 1994). Most commercially available sports drinks contain 2.4-5 mEq/L potassium (Maughan

1991). Cunningham (1997) suggested that potassium and sodium be present in the fluids ingested during and immediately after any strenuous exercise.

2.7 Supplements

Since the passage of the Dietary Supplement Health and Education Act (DSHEA) in 1994, a wide variety of compounds have become available in the United States. According to DSHEA, a dietary supplement includes on or more of the following ingredients: vitamin, mineral, herb or other botanical, amino acid, concentrate, metabolite, constituent, and/ or extract (Morrison and others 2004). Such products that fall under DSHEA require no pre-market clearance to test the product before it is placed on the shelves of local stores (Dodge and others 2003).

The expanding dietary supplement industry dramatically impacts athletes who are continually seeking a competitive edge (Froiland and others 2004). Krumbach and others (1999) reported that almost 57% of collegiate athletes surveyed reported taking vitamin and mineral supplements. In addition to vitamins and minerals, athletes are experimenting with the latest supplemental trends such as creatine, hydroxy-methyl-butyrate (HMB), ephedrine, and androstendione. Most male collegiate athletes report taking supplements to improve athletic performance and build muscle, while female collegiate athletes report taking supplements because they were recommended by family members (Krumbach and others 1999; Kruskall and Johnson 2001). In a study by Scofield and Unruh (2006), which evaluated dietary supplement use among adolescents, 22.3% were reported as currently using dietary supplements, followed by meal replacement proteins (23.7%), vitamins and minerals (19.4%), and creatine (16%). A similar study conducted by Swirzinksi and others (2000) of high school football players, revealed 31% using supplements, with the majority of them taking creatine. Morrison and others (2004) reported that 84.7% of local gym members surveyed reported taking supplements. The study also revealed that 42.3% consumed protein shakes/bars and 8- 14% reported the selection of carbohydrate shakes/bars, glutamine, ephedra, creatine, or chromium picolinate on a regular basis (greater than 5 times per week).

2.7.1 Creatine Monohydrate

Creatine is a naturally occurring amino acid derived from the amino acids glycine, arginine, and methionine (Beduschi 2003). Most creatine is stored in skeletal muscle, primarily as phosphocreatine (Bolsom and others 1994) and represents an average creatine pool of about 120-140g for an average 70kg person. Creatine is produced endogenously by the liver or ingested from exogenous sources such as meat and fish (Bemben and Lamont 2005). Creatine monohydrate supplementation has been shown to increase total creatine content in skeletal muscle, and to enhance performance in high-intensity, intermittent exercise (Ferguson and Syrotuik 2006). It has also been shown to increase lean muscle mass by 6.5% (Burke and others 2001).

During brief periods of high-intensity exercise, intramuscular phosphocreatine acts as a short-term energy buffer to maintain a rapid rate of adenosine triphosphate (ATP) turnover. As such, phosphocreatine availability is reported to be one of the main limiting factors during this type of work and, consequently, creatine supplementation, in the form of creatine monohydrate, has become a popular ergogenic aid for many athletes (Glaister and others 2006).

2.8 Sensory Evaluation of Sports Drinks

To date, few studies have been published on the development and sensory evaluation of sports drinks. However, the studies that have been published provide integral information on the product development process and sensory evaluation techniques. Bordi and others (2003) conducted a taste comparison of an isolated soy protein carbohydrate-protein beverage and an isolated whey protein carbohydrate-protein beverage. A 9-point hedonic scale was used to measure the degree of liking of flavor, mouthfeel, and preference of product. The just-about-right scale was also used to measure sweetness and thickness. The results showed that the soy beverage had the same acceptability as the whey beverage (Bordi and others 2003).

Temelli and others (2004) evaluated the development of an orange-flavored barley β-glucan beverage with added whey protein isolate (WPI). In this study, trained panelists evaluated the beverage for cloudiness, sweetness, sourness, orange flavor and whey flavor using a 15-cm line scale. According to the trained panel, the cloudiness of the samples were significantly higher than that of a beverage without protein. They also found that with the addition of WPI, the orange-flavor intensity was significantly decreased and the sweetness was not altered (Temelli and others 2004).

2.9 Regulations

2.9.1 Dietary Supplements

The term dietary supplement was established by Congress in the Dietary Supplement Health and Education Act (DSHEA) of 1994. This act states that a dietary supplement is a product that is intended to supplement the diet that contains one or more dietary ingredients such as vitamins, minerals, amino acids, or combinations of these ingredients. They can be found in many forms such as liquid, pills, and powders. According to the FDA website, DSHEA places dietary supplements in a special category under the general umbrella of "foods," not drugs, and requires that every supplement be labeled a dietary supplement. The FDA regulates dietary supplements under a different set of regulations than those covering conventional foods and drug products such as prescription and over-the-counter drugs. It cannot be represented as a sole item of a meal or diet. Because of the Act, the dietary supplement manufacturer is responsible for ensuring that a dietary supplement is safe before it is marketed, not the FDA. The FDA is responsible for taking action against any unsafe dietary supplement product after it reaches the market.

2.9.2 Carbohydrates

Sucrose is obtained by crystallization from sugar cane or sugar beet juice that has been extracted by pressing or diffusion, then clarified and evaporated, and can be used in food with no limitation other than current good manufacturing practice (21CFR184.1854). Dextrose monohydrate is purified and crystallized D-glucose containing one molecule of crystallization with each molecule of D-glucose (21CFR168.111), and the ingredient can be used in food with no limitations other than current good manufacturing practices (21CFR184.1857).

2.9.3 Amino Acids

L-Glutamine and L-Leucine are food additives permitted for the direct addition to food for human consumption. According to section 172.320 of the Code of Federal Regulations, L-Glutamine and L-Leucine are supposed to represent 12.4 and 8.8 percent by weight of total protein, respectively. In accordance with 21CFR172.320 (c), amino acid additives are intended for the use of significantly improving the biological quality of the total protein in a food containing naturally occurring primarily intact protein that is considered a significant dietary protein source. Other stipulations on the addition of amino acids into foods are that the finished food contains at least 6.5 grams of naturally occurring intact protein, the additive (s) results in a protein efficiency ratio (PER) in the finished food equivalent to casein, and each amino acid added results in a statistically significant increase in the PER.

2.9.4 Antioxidants

Ascorbic acid (vitamin C) is generally recognized as safe when used in accordance with good manufacturing practices (21CFR182.3890 and 21CFR182.3013).

CHAPTER 3. PRELIMINARY STUDY: DEVELOPMENT AND CHARACTERIZATION OF CONSUMER SENSORY QUALITIES OF PRE- AND POST-WORKOUT SPORT BEVERAGES

3.1 Introduction

During intense exercise, muscles require quick, readily available energy, most commonly in the form of high glycemic carbohydrates. Protein is also needed to aid in muscle growth and repair. Normal sports drinks on the market contain only small amounts of carbohydrates as a source of energy. The objective of this study was to develop a pre-workout and post-workout sports drink that would be acceptable and marketable to consumers. Both sports drinks contain carbohydrates, protein, amino acids, antioxidants, and other supplements such as creatine and glutamine. The sports drinks were formulated with the goal of reducing muscle damage during exercise, preventing and reducing post-exercise muscle breakdown, increasing post-exercise protein synthesis, and increasing recovery and glycogen synthesis.

3.1.1 Consumer Acceptance Testing

Traditional sensory methods of evaluation are divided into analytical and affective methods (Piggott 1984). Analytical methods use people as machines, not as consumers, to describe products in an accurate and repeatable manner or to discriminate among real differences in products, whereas affective methods measure the evaluative component of consumers' responses (Piggott 1984). Acceptance testing, a type of affective test, is a valuable and necessary component of every sensory program (Stone and Sidel 1993). Acceptance tests measure acceptability or liking for a food by consumers (Stone and Sidel 1993). According to Lawless and Heymann (1998) information from acceptance tests are extremely useful. For example, it can be combined with other sensory analyses, knowledge of consumer expectations, and product formulation constraints in determining the optimal design of food products (Lawless and Heymann 1998).

In foods and consumer products, there are two main approaches to consumer sensory testing: the measurement of preference and the measurement of acceptance (Jillinek 1985). In preference tests, the consumer has a choice, and in the measurement of acceptance or liking, the consumer panelists rate their liking for the product on a scale (Lawless and Heymann 1998). Acceptance measurements can be done on single products and do not require a comparison to another product (Lawless and Heymann 1998). The methods most frequently used to determine preference and quantify acceptance are the paired-preference tests and the acceptance test employing the 9-point hedonic scale, respectively (Resurreccion 1998).

The most common hedonic scale is the 9-point hedonic scale (Lawless and Heymann 1998). The scale has nine points that are given word descriptions ranging from “dislike extremely” to “like extremely” (Peryam 1998). The words chosen for each scale option are based on equal interval spacing as determined by Thurstonian methods, thus the scale has rulerlike properties that are not necessarily present in other less carefully constructed liking scales (Lawless and Heymann 1998). The 9-point hedonic scale is balanced, bipolar, contains a neutral point, and has approximately equal psychological spacing between scale points (Lawless and Klein 1991). According to Lawless and Heymann (1998) the 9-point scale is simple, easy to implement, widely studied, and has been shown to be useful in the hedonic assessment of foods, beverages, and nonfood products.

When a product is beyond the stage of development, it can be submitted to a consumer panel, which must represent the ultimate consumer to be maximally effective (Piggott 1988). If the panel is not a representative sample of the population intended to purchase and use the product, then the data will have little or no predictive value (Lawless and Heymann 1998). The subjects participating in a sensory acceptance test should be qualified based on target demographic and usage criteria or preference scores from survey data (Stone and Sidel 1993). According to Meilgaard and others (1987) some demographic criteria to be considered in selecting sample subjects are age, sex, income, geographic location, nationality, region, race, religion, education and employment. Frequently, industrial sensory specialists will use employee consumer panels for preliminary consumer tests before fieldwork. Employee panels can be problematic. Employees may have unusual patterns of product use because they can get company products for free or at a company store, or due to their brand or company loyalties (Lawless and Heymann 1998). According to Lawless and Heymann (1998) problems can also arise with standing panels. An example would be a sample of consumers from local community organizations who are recruited to participate in product evaluations. These people can easily become over tested, jaded, or overly critical, similar to employee panels that do frequent testing (Lawless and Heymann 1998).

The test location or test site has numerous effects on the results of a study, not only because of the geographic location, but because the place in which the test is conducted defines several other aspects of the way the product is sampled and perceived (Meilgaard and others 1987). Consumer responses needed for the quantification of acceptance can be conducted in a sensory laboratory setting, in central location tests (CLT's), or in home-use tests (HUT's), which are also known as home placement tests (Resurreccion 1998).

Acceptance testing in a laboratory environment is the most frequently used of the various types of sensory acceptance tests (Stone and Sidel 1993). Employees or local residents are the most common type of consumer for laboratory acceptance testing, and 25-50 responses per product are ideal, and 5-6 products per session (Stone and Sidel 1993). Some advantages of laboratory acceptance tests include: controlled conditions, rapid data feedback, "test-wise" subjects, and low cost (Stone and Sidel 1993). Some disadvantages of performing acceptance tests in a laboratory are limited information, and limited product exposure (Stone and Sidel 1993).

Central location tests (CLT's) are frequently used in consumer tests and especially by market research (Stone and Sidel 1993). Central location tests are usually conducted in an area where many potential purchasers congregate or can be assembled (Meilgaard and others 1987). Respondents are intercepted and screened in the open and those selected for testing are led to a closed-off area (Meilgaard and others 1987). Typically 50-300 responses are collected per location (Meilgaard and others 1987), and 5-6 samples per session (Stone and Sidel 1993). Some advantages of CLT's include large number of subjects and no company employees (Stone and Sidel 1993). Some disadvantages include less control, limited information, no lengthy or distasteful tasks, limited instructions, and large number of subjects required (Stone and Sidel 1993).

A Home-use test (HUT) is a consumer test that involves placement of a product in the home for a period of time, in order to determine acceptability or preference under realistic, normal consumption conditions (Lawless and Heymann 1998). Newly developed products can fail due to problems with containers or product usage, so it is reasonable to have a home-use capability test to assess products in the early stages of product formulation or reformulation (Stone and Sidel 1993). Due to the lack of control over conditions of testing in a home-use test, a larger sample than that required for a laboratory test is recommended (Resurreccion 1998). The minimum number of responses is usually 50-100 per product (Resurreccion 1998). HUT usually involves only two products, primarily because of the duration of time needed for each product to be evaluated (Stone and Sidel 1993). Home-use tests are time consuming, expensive, and allow the researcher little or no control (Stone and Sidel 1993). However, all of the family's opinions are obtained, marketing information (pricing, frequency of use, etc.) is obtained, and the product is tested under actual use conditions (Stone and Sidel 1993).

3.2 Materials and Methods

3.2.1 Sports Drink Preparation

Sixteen sports drinks were formulated (Tables 1,2, and 3), eight pre-workout and eight post-workout drinks, containing milk proteins, carbohydrates, and flavors. Two protein sources, two carbohydrate sources and two flavors derived the eight pre-workout formulations. The two protein sources were whey protein isolate (WPI) and whey protein concentrate (WPC). The carbohydrate sources consisted of sucrose and glucose. The pre-workout flavors included berry and tropical fruit. Each pre-workout drink also contained water, sodium, potassium, leucine, and colorants.

Using two protein sources, two carbohydrate sources, and two different flavors, eight post-workout drinks were formulated. The two protein sources included whey protein isolate (WPI), and whey protein concentrate (WPC). Sucrose and glucose were used as the carbohydrate source. Two different flavors including lemon lime and fruit mix were used as flavorings for the post-workout sports drinks. The eight post-workout formulations also included water, creatine, glutamine, vitamin C, and colorants.

Supplement Direct™ brand whey protein isolate was obtained in 2-lb bags from Supplement Direct™, Santa Barbara, CA and contains 92% protein (dry basis), 5.5% moisture, 2.8% ash, 1.6% lactose, less than 1% fat, and has a pH between 5.5 - 6.5. Leprino Foods

(Denver, Colorado) supplied instantized whey protein concentrate (80% Dry Basis Instantized WPC Product Code 49525). The whey protein concentrate contained a minimum of 80% protein, pH between 6.0 and 7.0, 7.0% moisture, 8.5% fat, and 4.0% ash, and had a cream color powdered appearance and a typical dairy flavor. Supplement Direct™ brand dextrose, or glucose, and creatine monohydrate were also purchased from Supplement Direct™ (Santa Barbara, CA). Creatine monohydrate was a micronized powder that is flavorless and dissolves clear in liquid. L-leucine, L-glutamine, and ascorbic acid were white crystalline powders that were obtained from Anmar International Ltd (Bridgeport, CT). Potassium monohydrate, a popular source of potassium used in sports drinks was a white powder that was obtained from The Wright Group (Crowley, La).

Obipektin, Bischofszell, Switzerland, provided all natural fruit flavors including berry, lemon, lime, fruit mix, and tropical fruit. The Berry Mix 231-A contained raspberry, strawberry, elderberry, blackberry, and bilberry. This flavor was produced by vacuum drying, and contained 31% fruit solids, 67.2% added sucrose, 86% total carbohydrates, 5-11% glucose, 6-12% fructose, 62-72% sucrose, and 0.0-1.9% protein. The Lemon 150-BP flavor was produced by low temperature spray drying, and contained 50% fruit solids, 50% added maltodextrin, 55% total carbohydrates, 4-13% glucose, 3-13% fructose, 0-0.35% sucrose, and 0.8-4.0% protein. Lime 150-B flavor was produced by low temperature spray drying, and had 50% fruit solids, 50% added maltodextrin, 56% total carbohydrates, 3-11% glucose, 3-11% fructose, 0-3% sucrose and 1.9-4% protein. The Tropical Fruit 122-D was also produced by low temperature spray drying and contained banana, apricot, pineapple, orange, passion fruit, lemon, grapefruit, mango, and guava. The tropical fruit flavor had 22.8% fruit solids, 45.3% added maltodextrin, 89% total carbohydrates, 2-8% glucose, 2-8% fructose, 28-38% sucrose, and 0.7-1.4% protein. Fruit Mix

137-A was produced by low temperature spray drying and is a free-flowing powder. This flavor contains 37% fruit solids, 14.3% added sugar, 48.7% added maltodextrin, 87% total carbohydrates, 3-9% glucose, 5-15% fructose, 17-25% sucrose, and 0.6-1.6% protein. Apple, orange, banana, pineapple, and citron were the fruits used to make the fruit mix flavor. Sucrose, or table sugar, salt (sodium chloride), and red, yellow, and green food coloring were purchased from a local supermarket (Baton Rouge, LA).

The first step in making the sports drinks was to weigh the ingredients: distilled water, WPI, WPC, sucrose, glucose, vitamin C, sodium, potassium, leucine, glutamine, creatine, tropical fruit flavor, berry flavor, lemon flavor, lime flavor, and fruit mix flavor according to the ingredient percentages in Tables 1 and 2. Table 3 represents the different combinations of WPC, WPI, sucrose, glucose, and flavors that made up the sixteen different sports drink formulas. For each formulation, the appropriate amounts of dry ingredients were added to the distilled water and mixed thoroughly until all particles were dissolved.

Table 1. Ingredient Percentages (%) for Pre-Workout Sports Drinks

	Formulation (%)							
Ingredient	**A**	**B**	C	**D**	**E**	**F**	**G**	**H**
Water	91.26	91.14	91.46	91.34	89.82	88.65	90.01	88.83
Sucrose	5.37		5.38		5.28		5.29	
Glucose		5.36		5.37		5.21		5.23
WPI			1.47	1.46			1.44	1.42
WPC	1.68	1.68			1.65	1.63		
Berry Flavor	1.07	1.21	1.08	1.21				
Tropical Flavor					2.64	3.91	2.65	3.92
Vitamin C	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Sodium	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Potassium	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
L-Leucine	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54

*For formulations A-D, 0.108g of red food coloring added, and for E-H, 0.108g of yellow added.
*WPI=Whey protein Isolate; WPC=Whey protein concentrate.

Table 2. Ingredient Percentages (%) for Post-Workout Sports Drinks

	Formulation (%)							
Ingredient	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**
Water	84.24	84.03	84.57	84.37	83.62	83.21	83.95	83.54
Sucrose	9.91		9.95		9.84		9.88	
Glucose		9.89		9.93		9.79		9.83
WPI			2.71	2.71			2.69	2.68
WPC	3.10	3.09			3.07	3.06		
Lemon Flavor	0.87	0.99	0.87	0.99				
Lime Flavor	0.87	0.99	0.87	0.99				
Fruit Mix Flavor					2.46	2.94	2.47	2.95
Vitamin C	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Glutamine	0.50	0.49	0.50	0.50	0.49	0.49	0.49	0.49
Creatine	0.50	0.49	0.50	0.50	0.49	0.49	0.49	0.49

*****For formulations I-L, 0.108g of yellow and green food coloring were added and for formulations M-P 0.108g of yellow and red food coloring were added.
*****WPI=Whey protein Isolate; WPC=Whey protein concentrate.

Table 3. Protein, Carbohydrate, and Flavor Combinations for Eight Pre-Workout and Eight Post-Workout Sports Drink Formulations

Pre	Post
A: WPC, S, Bry	**I**: WPC, S, LL
B: WPC, G, Bry	**J:** WPC, G, LL
C: WPI, S, Bry	**K:** WPI, S, LL
D: WPI, G, Bry	**L:** WPI, G, LL
E: WPC, S, TF	**M:** WPC, S, FM
F: WPC, G, TF	**N:** WPC, G, FM
G: WPI, S, TF	**O:** WPI, S, FM
H: WPI, G, TF	**P:** WPI, G, FM

*WPI=Whey Protein Isolate, WPC=Whey Protein Concentrate.
*S=Sucrose, G=Glucose.
*Bry=Berry Mix, TF=Tropical Fruit, LL=Lemon/Lime, FM=Fruit Mix.
*See Tables 1 and 2 for descriptions of formulations A-P.

Each mixture was then transferred to a homogenizer to ensure that homogenous mixture was obtained. The homogenizer (Model 300 DJF 4 2PS, Manton-Gaulin Mfg. Co. Inc, Everett, MA) was flushed with water between samples to ensure that there would be no contamination. Each formulation was homogenized in two-gallon batches, for two-fifteen second cycles, totaling 30 seconds. The second stage of the homogenizer was set to 500 psi, and the first stage was set to

1500 psi, for a total of 2000 pounds per square inch of pressure. After homogenizing, the samples were pasteurized in heavy-bottomed stainless steel pots using the batch pasteurization method. The sports drinks were pasteurized at 160°F for 30 minutes to ensure that no pathogens remained in the mixtures. After the mixtures had been heated, the pots were removed from the heating apparatus and placed in a large ice bath to cool. When the mixtures reached 75°F, they were placed in half-gallon plastic milk cartons, capped, and placed in the refrigerator (40°F).

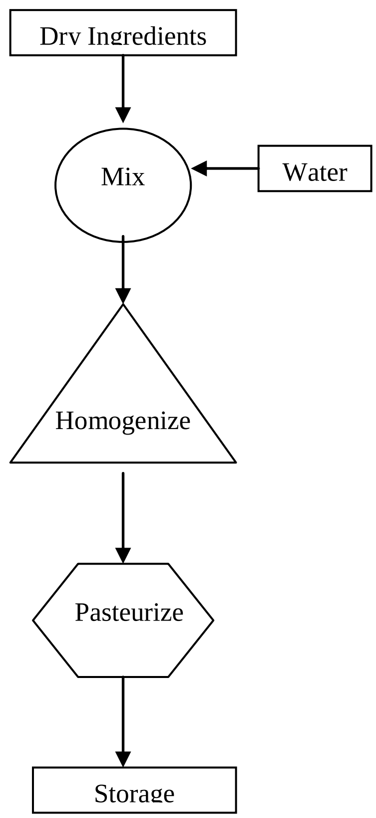

Figure 1. Process Flow Diagram for Pre- and Post-Workout Sports Drink Formulations

3.2.2 Consumer Acceptance Test

Two hundred and eighty untrained consumers participated in the acceptance test. Consumers were randomly chosen from the Louisiana State University Campus in Baton Rouge, LA in December 2007. The following criteria had to be met by all consumers in order to be recruited: 18 years of age or older, not allergic to whey protein, sugar, leucine, glutamine, creatine, and fruits such as citrus, berries, and tropical fruits, and willing and available to participate and complete a survey. The consumers were presented with a packet of papers that contained a consent form, which was pre-approved by the Louisiana State University Institutional Review Board (IRB), and 4 questionnaires for each of the 4 samples to be tested. The consumers were instructed to read and sign the consent form, and how to properly complete the questionnaires.

Based on a balanced incomplete block design (BIB) (Cochran 1957), consumers were presented with 4 2-oz samples, out of the total 16 formulations. The 4 samples presented to the consumers consisted of 2 pre-workout drinks and 2 post-workout drinks, and were served at refrigerated temperature (40°F). The 16 formulations, 8 pre-workout and 8 post-workout, were coded with the letter A to P, for a total of 70 observations per formulation. The participants were provided room temperature water to cleanse their palates between samples. Each consumer evaluated each sample for acceptability of visual appearance, aroma, color, consistency, mouthfeel, flavor, sweetness, and overall liking using a 9-point hedonic scale (1=dislike extremely, 5=neither like nor dislike, 9=like extremely). Binomial type questions (yes/no) were used to determine overall product acceptance, purchase intent, and purchase intent after being given benefits of pre-workout and post-workout sports beverages.

3.2.3 Statistical Data Analysis

All data were analyzed at a predetermined confidence level (α=0.05) using the Statistical Analysis Software System, SAS version 9.1, 2003 (SAS Institute, Cary, NC).

3.2.3.1 Analysis of Variance

Analysis of variance, often abbreviated as ANOVA, is a technique that compares the means from several samples and tests whether they are all (within experimental error) the same, or whether one or more of them are significantly different (O'Mahony 1986). Analysis of variance (ANOVA) was used to determine if differences lie among the eight pre-workout drink formulations and/or among the eight post-workout drink formulations in terms of acceptability of each sensory attribute, and overall liking.

To conduct a valid analysis of variance, the following assumptions must be satisfied: samples taken under each treatment must be randomly picked from their respective populations, the treatments must be independent of each other, samples of scores under each treatment must come from normally distributed populations of scores, and samples of scores under each treatment must come from populations with the same variance (homoscedasticity) (O'Mahony 1986). ANOVA provides evidence that a significant difference exists, but does not give an indication of how the treatments are different.

Tukey HSD (honest significant difference) is an adjustment that was used, so that after all comparisons, both simple pairwise and complex, the overall level of significance was 0.05. Tukey (1953) proposed a multiple-comparison method for pairwise comparisons of *k* means and for simultaneous estimation of differences between means by confidence intervals with a specified confidence coefficient (1-α) (Gacula and Singh 1984). If *n* observations are taken in each of *k* samples and the analysis-of-variance F test is significant, the critical difference to be exceeded for a pair of means to be significantly different is the so-called honest significant difference (HSD), where

$$\text{HSD} = Q_{\alpha,k,v}(\sqrt{\text{Mse}/n}).$$

Table 4 represents a one-way analysis of variance model. The DF column is known as the degrees of freedom for respective SS (sums of squares); the MS column has the mean squares. A SS divided by its DF is called the mean square. The MS is an estimate of the variance contributed by its source to the total. The test statistic for testing the equality of treatments effects is the F ratio, or MStr/MSe. The observed F ratio is compared with percentiles of the F distribution. The null hypothesis of no treatment differences is rejected if the observed F ratio is greater than the tabulated F value at the desired significance level (Gacula and Singh 1984).

Table 4. One-Way Analysis of Variance Model

Source of Variance	DF	SS	MS	F Ratio
Between Treatments	a-1	SStr	MStr	MStr/MSe
Within Treatments	N-a	SSe	MSe	
Total	N-1	SSto		

(Gacula and Singh 1984).

3.2.3.2 MANOVA and DDA

MANOVA (multivariate analysis of variance) is a post-ANOVA technique that was used to determine if significant differences existed among formulations when all of the sensory attributes were compared simultaneously. Descriptive Discriminant Analysis (DDA) was used to determine which of the attributes contributed to the differences among the eight pre-workout and eight post-workout sports drink formulations.

MANOVA and Discriminant Analysis are the preferred methods for determining differences between samples. The chief value of MANOVA is to determine whether treatments applied to a product cause significant differences, and Descriptive Analysis tells the investigator whether certain variables combined are correlated with classes (Piggott 1986). The results of MANOVA provide a single F-statistic, based on Wilks' lambda (Λ), which assesses the influence of all descriptors simultaneously. A significant MANOVA F-statistic (due to a small Wilks' lambda) indicates that the samples differ significantly across dependent variables (Lawless and Heymann 1998).

Techniques of Descriptive Discriminant Analysis (DDA) are closely aligned to the study effects determined by a multivariate analysis of variance (Huberty 1994). In DDA, the basic question of interest pertains to grouping variable effects on the multiple outcome variables or, to group separation or group differences with respect to the outcome variables (Huberty 1994).

3.2.3.3 Logistic Regression

Logistic regression, or logit analysis, uses a regression model to fit a categorical dependent variable. In its most widely used form, the dependent variable is dichotomous (yes/no) and the independent variables are quantitative or categorical. Logistic regression involves the use odds and odds ratios. The odds are an expression of the likelihood of an event happening compared to the likelihood of that event not happening. An odds of less than one corresponds to a probability of less than 0.5, and an odds greater than one corresponds to a probability above 0.5. Odds are used instead of probabilities because they are on a more sensible scale for multiplicative comparisons, they are directly related to the parameters in the logit model, and they are less sensitive to changes in the marginal frequencies. The odds ratio, not to be confused with the odds, is the proportional change in the odds per unit change in X_i. Logistic regression analysis was used to predict both product acceptability and purchase intent based on the odds ratio point estimate.

3.2.3.4 McNemar Test

The McNemar test is one way of comparing proportions from two dependent samples (in this case, responses before and after consumers had been informed of the exercise enhancing benefits) using binary response variables. The test follows a chi-square distribution with df=1 (Agresti 1996). A 95% confidence interval was calculated using marginal sample proportions ($p_{+1} + p_{1+}$), which can be used to estimate the actual differences in the means of purchase decision responses (Beckley and others 2007).

In order to calculate the sample proportions (p_{ij}), the equation

$$p_{ij} = n_{ij}/N$$

was used, where n_{ij} is the number of consumers making response i and response j after knowing the “fact” about exercise enhancing benefits, and N represents the total number of responses from consumers. Next, the 95% confidence interval for the difference in proportions was calculated using the equation

$$(p_{+1} - p_{1+}) \pm z_{\alpha/2}(ASE)$$

where ($p_{+1} - p_{1+}$) represents the difference in proportions between consumers who answer yes after knowing the fact (p_{+1}) and those who answered yes before knowing the fact (p_{1+}); the term $z_{\alpha/2}$ equals 1.96 and represents the standard normal percentile having a right-tailed probability of $\alpha/2$; ASE is the estimated standard error for the proportion difference and was calculated using the equation

$$ASE = ([p_{1+}(1-p_{1+}) + p_{+1}(1-p_{+1}) - 2(p_{11}p_{22} - p_{12}p_{21})]/N)^{1/2}$$

where p_{11} indicates the number of consumers who answered yes both before and after knowing the fact, p_{22} represents the number of consumers who answered no both before and after knowing the fact, p_{12} indicates the number of consumers who answered yes before and no after knowing the fact, and p_{21} represents the number of consumers who answered no before and yes after knowing the fact (Beckley and others 2007).

In this study, the McNemar test was used to determine changes in consumer purchase decision before and after consumers were informed of the exercise enhancing benefits of the sports drinks.

3.3 Results and Discussion

3.3.1 Consumer Acceptability

ANOVA results for acceptability of appearance, aroma, color and consistency for the eight pre-workout sports drink formulations (A-H) (Table 1) and the eight post-workout sports drink formulations (I-P) (Table 2) are presented in Table 5, while acceptability of mouthfeel, flavor, sweetness, and overall liking are represented in Table 6. The numbers in both tables represent the mean score, plus or minus the standard deviation for each sample/sensory attribute combination. Each number in the table has a corresponding superscripted letter. The letters represent the results for Tukey's Studentized Range (HSD) Test. Mean scores with the same letter for each attribute are not significantly different from each other ($p>0.05$).

In regards to the pre-workout drinks (formulations A-H), formulation E (WPC, S, TF) had an acceptability score of 5.11 for appearance, and was significantly different from formulations F (WPC, G,TF) and H (WPI, G, TF). Formulation H (WPI, G, TF) had the lowest mean score (3.83) for appearance. Among berry flavored drinks, formulations B with D with glucose were perceived to be unacceptable in terms of appearance. For aroma, formulation A (WPC, S, Bry) had the greatest mean score (5.44), and was significantly different from all other formulations except B (WPC, G, Bry). Among the formulations with tropical fruit flavor, formulation E (WPC, S, TF) had the highest mean score (4.21) and was significantly different from formulation G (WPI, S, TF), which had the lowest mean score (3.33). The consumers determined that formulations A (WPC, S, Bry) and C (WPI, S, Br) had the best color with mean scores of 5.33 and 5.31, and formulation H (WPI, G, TF) had the lowest with a mean score of 3.40. For the tropical fruit flavored drinks, which were a light yellow color, formulation E (WPC, S, TF) was significantly different from formulations F (WPC, G, TF), G (WPI, S, TF) and H (WPI, G, TF). In terms of consistency, formulation E (WPC, S, TF) had the greatest mean score (5.43) and was significantly different from formulations G, F, and H, which all have tropical fruit flavor. Formulation H (WPI, G, TF) had the worst mean score for consistency, and was significantly different from formulations A-E.

For the post-workout sports drinks, which varied in protein source (WPI or WPC), sugar source (sucrose or glucose), and flavor (lemon/lime or fruit mix), formulation L (WPI, G, LL) had the highest mean score for appearance (5.91), and formulation P (WPI, G, FM) had the lowest (3.81). The appearance of all of the formulations was not significantly different except for formulation P (WPI, G, FM). The consumers perceived formulation N (WPC, G, FM) as having the best aroma (4.63), and formulation P (WPI, G, FM) as have the worst. For color, formulation P (WPI, G, FM) was the only formulation found to be significantly different. Formulation P was also evaluated as having the worst color (3.77) and consistency, and formulation K (WPI, S, LL) had the best color (5.93) and consistency (5.79).

For the pre-workout sports drinks, formulation A (WPC, S, Bry) had the highest mean score (6.01) for mouthfeel, and was significantly different from formulations D, G, F, and H (Table 6). Formulations F (WPC, G, TF) and H were perceived to have the lowest acceptance of mouthfeel and were significantly different from all other formulations. In terms of flavor, formulation A (WPC, S, Bry) had the highest acceptability with a mean score of 5.23, and was significantly different from all other formulations. Out of all of the pre-workout formulations, F (WPC, G, TF) had the lowest mean score for flavor (3.00) and was significantly different from E

(WPC, S, TF) and C (WPI, S, Bry). Of the tropical fruit flavored drinks, formulation E (WPC, S, TF) had the highest mean score (4.20). Formulation A (WPC, S, Bry) had the greatest acceptability of sweetness with a mean score of (5.64), and was found to be significantly from the two other formulations that had berry flavor and glucose (B and D). The tropical fruit flavored drinks had the acceptability scores lower than 5.0. As determined by overall liking, formulation A (WPC, S, Bry) was the most acceptable (5.29) and was significantly different from formulations D, B, G, H, and F. Formulation F (WPC, G, TF) was liked the least.

When evaluating the post-workout drinks for mouthfeel, formulation P (WPI, G, FM) was the only one perceived to be significantly different from the other formulations, and was also evaluated as having the lowest mean score (3.42). All other post-workout drinks were not significantly different form each other, and formulation K (WPI, S, LL) had the greatest acceptability of mouthfeel with a mean score of 5.80. Formulations K (WPI, S, LL) and I (WPC, S, LL) had the highest acceptability of flavor with mean scores of 5.41 and 5.26 respectively, and were not found to be significantly different from each other. Formulation P (WPI, G, FM) was evaluated as having the worst flavor (2.73) and was significantly different from formulations I, K, L, M and O. For sweetness, formulations K (WPI, S, LL) and I (WPC, S, LL) had the greatest acceptability of sweetness, with mean scores of 5.46 and 5.31 respectively. These two formulations were also not significantly different from each other. The formulations with sucrose (K, I, M,) had mean scores for sweetness above 5.0. Formulation P (WPI, G, FM) received the lowest score for sweetness (3.22). For overall liking of the post-workout sports drinks, formulation K (WPI, S, LL) had the highest mean score (5.29), but was not significantly different from formulation I (WPC, S, LL).

Table 5. Mean Acceptability Scores for Appearance, Aroma, Color, and Consistency of Pre- and Post-Workout Sports Drinks

Formulation*	Mean Scores for Sensory Attributes**			
	Appearance	**Aroma**	**Color**	**Consistency**
A	5.06 ± 1.68^{A}	5.44 ± 1.61^{A}	5.33 ± 1.62^{A}	5.35 ± 1.75^{A}
B	4.46 ± 1.69^{ABC}	4.81 ± 1.71^{AB}	4.49 ± 1.59^{ABC}	4.80 ± 1.83^{AB}
C	5.09 ± 1.90^{A}	4.39 ± 1.84^{B}	5.31 ± 1.85^{A}	5.30 ± 1.76^{A}
D	4.87 ± 1.61^{AB}	4.16 ± 1.62^{BCD}	5.03 ± 1.77^{AB}	5.20 ± 1.70^{A}
E	5.11 ± 1.91^{A}	4.21 ± 1.60^{BC}	4.94 ± 1.88^{AB}	5.43 ± 1.72^{A}
F	4.03 ± 1.83^{BC}	3.36 ± 1.69^{CD}	3.77 ± 1.96^{CD}	3.83 ± 1.69^{C}
G	4.23 ± 2.03^{ABC}	3.33 ± 1.67^{D}	4.13 ± 1.87^{CD}	4.14 ± 1.73^{BC}
H	3.83 ± 1.52^{C}	3.46 ± 1.92^{CD}	3.40 ± 1.70^{D}	3.83 ± 1.99^{C}
I	4.73 ± 2.11^{A}	4.23 ± 1.92^{AB}	5.56 ± 1.98^{A}	5.64 ± 1.83^{A}
J	5.68 ± 21.89^{A}	4.39 ± 1.76^{A}	5.56 ± 1.87^{A}	5.39 ± 1.77^{A}
K	5.66 ± 2.04^{A}	4.09 ± 2.14^{AB}	5.93 ± 1.78^{A}	5.79 ± 1.87^{A}
L	5.91 ± 1.55^{A}	4.54 ± 1.89^{A}	5.84 ± 1.58^{A}	5.70 ± 1.62^{A}
M	5.39 ± 1.97^{A}	4.27 ± 1.69^{AB}	5.29 ± 1.98^{A}	5.39 ± 1.93^{A}
N	5.79 ± 1.72^{A}	4.63 ± 1.61^{A}	5.72 ± 1.85^{A}	5.67 ± 1.45^{A}
O	4.96 ± 1.94^{A}	3.77 ± 1.84^{AB}	5.01 ± 1.81^{A}	5.06 ± 2.03^{A}
P	3.81 ± 1.71^{B}	3.43 ± 1.65^{B}	3.77 ± 1.78^{B}	3.56 ± 1.81^{B}

*Formulations A-H represent the eight pre-workout drinks (Table 1), and formulations I-P represent the eight post-workout drinks (Table 2).

** Numbers in the table represent the mean score, plus or minus the standard deviation for each sample/sensory attribute combination. Each number in the table has a corresponding superscripted letter. Mean scores with the same letter for each attribute are not significantly different from each other ($p>0.05$). 70 consumers tested each formulation.

Table 6. Mean Acceptability Scores for Mouthfeel, Flavor, Sweetness, and Overall liking of Pre- and Post-Workout Sports Drinks

Formulation*	Mean Scores for Sensory Attributes**			
	Mouthfeel	**Flavor**	**Sweetness**	**Overall Liking**
A	6.01 ± 1.80^{A}	5.23 ± 1.92^{A}	5.64 ± 1.67^{A}	5.29 ± 1.76^{A}
B	5.44 ± 2.03^{AB}	3.83 ± 1.86^{BC}	4.37 ± 1.73^{BCD}	3.99 ± 1.85^{BCD}
C	5.09 ± 2.07^{ABC}	4.36 ± 2.21^{AB}	4.97 ± 2.17^{AB}	4.50 ± 2.09^{AB}
D	4.99 ± 1.85^{BC}	3.79 ± 1.56^{BC}	4.21 ± 1.58^{BCD}	4.06 ± 1.49^{BCD}
E	5.45 ± 1.71^{AB}	4.20 ± 2.00^{B}	4.84 ± 1.87^{ABC}	4.39 ± 1.76^{ABC}
F	3.73 ± 1.77^{D}	3.00 ± 1.60^{C}	3.67 ± 1.61^{D}	3.21 ± 1.57^{D}
G	4.44 ± 2.03^{CD}	3.43 ± 1.97^{BC}	3.91 ± 1.86^{CD}	3.49 ± 1.87^{CD}
H	3.66 ± 1.89^{D}	3.61 ± 2.09^{BC}	3.96 ± 1.97^{CD}	3.27 ± 2.04^{D}
I	5.67 ± 1.86^{A}	5.26 ± 2.55^{AB}	5.31 ± 2.28^{A}	5.24 ± 2.24^{A}
J	4.96 ± 1.94^{A}	3.60 ± 2.14^{CDE}	3.53 ± 2.08^{CD}	3.77 ± 2.10^{BC}
K	5.80 ± 2.28^{A}	5.41 ± 2.69^{A}	5.46 ± 2.43^{A}	5.29 ± 2.51^{A}
L	5.49 ± 1.86^{A}	4.13 ± 2.33^{BCD}	4.34 ± 2.04^{ABC}	4.44 ± 2.18^{AB}
M	5.27 ± 2.03^{A}	4.69 ± 2.57^{ABC}	5.14 ± 2.34^{AB}	4.77 ± 2.31^{AB}
N	5.10 ± 1.82^{A}	3.37 ± 1.92^{DE}	4.14 ± 1.98^{BCD}	3.91 ± 1.82^{BC}
O	5.03 ± 2.05^{A}	4.10 ± 2.46^{BCD}	4.60 ± 2.31^{ABC}	4.23 ± 2.20^{AB}
P	3.42 ± 1.67^{B}	2.73 ± 1.75^{E}	3.22 ± 1.79^{D}	2.96 ± 1.70^{C}

*Formulations A-H represent the eight pre-workout drinks (Table 1), and formulations I-P represent the eight post-workout drinks (Table 2).
** Numbers in the table represent the mean score, plus or minus the standard deviation for each sample/sensory attribute combination. Each number in the table has a corresponding superscripted letter. Mean scores with the same letter for each attribute are not significantly different from each other. 70 consumers tested each formulation.

In conclusion, for the pre-workout sports drinks, formulation A had the highest acceptability of color, aroma, appearance, mouthfeel, flavor, sweetness, and overall liking. Formulation A was a mixture of whey protein concentrate, sucrose, and berry flavor. In terms of flavor, the consumers liked the berry/sucrose combination, and could tell a difference in flavor between the two proteins, with whey protein concentrate being the more accepted protein source. Formulations with sucrose had a greater acceptability of sweetness, and in particular, the combination of sucrose and berry flavor.

For the post-workout sports drinks, formulation K, which was made from whey protein isolate, sucrose, and lemon/lime flavor, had the greatest acceptability of color, consistency, mouthfeel, flavor, sweetness, and overall liking. The consumers liked the lemon/lime flavor over the fruit mix flavor, and in particular the combination of lemon/lime and sucrose. All post-workout formulations with sucrose were perceived as more acceptable than those made from glucose. When looking at the protein sources, consumers prefer the flavor, consistency, and mouthfeel that a whey protein isolate imparts.

3.3.2 Overall Product Differences

Multivariate analysis of variance (MANOVA) was used to determine if the eight pre-workout sports drinks (Table 7) and the eight post-workout sports drinks (Table 8) were different when all sensory attributes were compared simultaneously. According to the Wilks' Lambda statistic (P>F of <0.0001 in Table 7), there was an overall difference in the eight pre-workout drinks when the eight sensory attributes were compared at the same time. For the eight post-workout drinks, MANOVA resulted in a Wilks' Lambda of 0.6824, and a corresponding probability greater than the F statistic of less than 0.001 (Table 8). These results indicate that there was an overall difference in the eight post-workout sports drinks when the eight sensory attributes (appearance, aroma, color, consistency, mouthfeel, flavor, sweetness, and overall liking) were concurrently compared. In order to determine which of the eight sensory attributes contributed to the product differences, DDA (Descriptive Discriminant Analysis) was used.

Table 7. Multivariate Analysis of Variance for Pre-Workout Sports Drinks

MANOVA	Test Criteria and F Approximations for the Hypothesis of No Overall Form Effect				
H = Type III SSCP Matrix for Forms E = Error SSCP Matrix S = 7 M = 0 N = 268					
Statistic	Value	F Value	Numerator DF	Denominator DF	Pr>F
Wilks' Lambda	0.6328	4.60	56	2902.5	<0.0001
Pillai's Trace	0.4203	4.34	56	3808	<0.0001
Hotelling-Lawley Trace	0.5010	4.80	56	1930.3	<0.0001
Roy's Greatest Root	0.2938	19.98	8	544	<0.0001

Table 8. Multivariate Analysis of Variance for Post-Workout Sports Drinks

MANOVA	Test Criteria and F Approximations for the Hypothesis of No Overall Form Effect				
H = Type III SSCP Matrix for Forms E = Error SSCP Matrix S = 7 M = 0 N = 267					
Statistic	Value	F Value	Numerator DF	Denominator DF	Pr>F
Wilks' Lambda	0.6824	3.80	56	2891.8	<0.0001
Pillai's Trace	0.3561	3.63	56	3794	<0.0001
Hotelling-Lawley Trace	0.4112	3.93	56	1923.1	<0.0001
Roy's Greatest Root	0.2001	13.55	8	542	<0.0001

According to the pooled within canonical structure (r's) values (Can 1 / Table 9), aroma (0.7521), mouthfeel (0.7561), and overall liking (0.6267) were the three sensory attributes that contributed to the differences in the eight pre-workout sports drink formulations. When looking at the second dimension (Can 2), color (0.5158) also made a significant contribution to the overall product differences. When the third dimension (Can 3) was investigated, flavor was a significant sensory attribute (0.6281). These five attributes, aroma, mouthfeel, overall liking, color, and flavor represented 91.14% of the cumulative variance explained. For the eight post-workout sports drinks, mouthfeel (0.7735), flavor (0.7819), and overall liking (0.7459) were the three sensory attributes that significantly contributed to the differences among the formulations (Table 10).

Table 9. Canonical Structure (r's) Describing Group Differences among the Eight Pre-Workout Formulations[1]

Sensory Attribute	Can 1*	Can 2*	Can 3*
Visual Appearance	0.4124	0.4329	0.2730
Aroma	0.7521**	-0.2765	0.0684
Color	0.6203	0.5158**	0.2059
Consistency	0.5963	0.4948	0.1509
Mouthfeel	0.7561**	0.1660	-0.1509
Flavor	0.5303	-0.0983	0.6281**
Sweetness	0.5585	-0.0212	0.5911
Overall Liking	0.6267**	0.1042	0.4514
Cum. Variance Explained	58.65%	80.08%	91.14%

[1]Based on the pooled within group variances.
*Can1 and Can 2 represent pooled within canonical structure in the first and second dimensions, respectively.
**Attributes that contribute to overall differences among samples.

Table 10. Canonical Structure (r's) Describing Group Differences among the Eight Post-Workout Formulations[1]

Sensory Attribute	Can 1**	Can 2**
Visual Appearance	0.5969	-0.5260
Aroma	0.2263	-0.4204
Color	0.6663	-0.4864
Consistency	0.7372	-0.4674
Mouthfeel	0.7735**	-0.1794
Flavor	0.7819**	0.3172
Sweetness	0.7246	0.3085
Overall Liking	0.7459**	0.1656
Cum. Variance Explained	48.65%	85.74%

[1]Based on the pooled within group variances.
*Can1 and Can2 represent pooled within canonical structure in the first and second dimensions, respectively.
**Attributes that contribute to overall differences among samples.

3.3.3 Product Acceptance and Purchase Intent

Product acceptance, purchase intent, purchase intent of a product that would enhance exercise, and purchase intent of a product that would enhance post exercise recovery were evaluated using a binomial (yes/no) scale. For the pre-workout sports drinks, formulation A (WPC, S, Bry) had the greatest acceptance (70.00%) (Table11). This formulation also received the highest mean scores for all sensory attributes (except appearance and consistency) (Table 5). Formulations E (WPC, S, TF) and C (WPI, S, Bry) had the next to highest acceptability scores with 50.72 and 50.00, respectively. These two formulations also had the second and third highest mean scores for overall liking, with formulation A having the highest.

Table 11. Percent Affirmative Responses for Product Acceptance and Purchase Intent of the Eight Pre-Workout Sports Drink Formulations

Formulation*	Acceptance	Purchase Intent	Purchase Intent for During Exercise Enhancement
A	70.00	22.86	57.14
B	38.57	17.14	41.43
C	50.00	24.64	45.71
D	28.99	2.86	37.14
E	50.72	22.86	41.43
F	17.39	5.71	24.29
G	25.71	7.14	20.00
H	24.29	12.86	22.86

*See Tables 1 and 3 for formulations A-H.

For the post-workout drinks, formulation K (WPI, S, LL) had the highest acceptance score of 65.71% (Table 12). Formulation K also received the greatest mean scores for color, consistency, mouthfeel, flavor, sweetness, and overall liking (Table 6). The acceptance of formulation K was closely followed by formulation I (WPC, S, LL) which had an acceptance score of 62.86%. Formulation I had the second highest acceptance score in terms of mouthfeel, flavor, sweetness, and overall liking (Table 6). Formulations M (WPC, S, FM) and O (WPI, S, FM) received the third and fourth highest acceptance scores of 52.86% and 45.59%. Formulation P (WPI, G, FM) received the lowest acceptance score of 15.71%, and the lowest mean acceptability scores for all sensory attributes.

Table 12. Percent Affirmative Responses for Product Acceptability and Purchase Intent of the Eight Post-Workout Sports Drink Formulations

Formulation*	Acceptability	Purchase Intent	Purchase Intent for Post Exercise Enhancement
I	62.86	37.68	51.43
J	41.43	18.57	32.86
K	65.71	50.00	58.57
L	42.86	25.71	42.86
M	52.86	33.33	50.00
N	37.14	18.57	35.71
O	45.59	21.43	40.00
P	15.71	5.71	14.29

*See Tables 2 and 3 for formulations I-P.

The consumers were asked whether or not they would purchase the sports drinks. For the pre-workout sports drinks, purchase intent was low, ranging from 2.86 to 24.64 percent (Table 11). Purchase intent coincided with acceptability for the pre-workout sports drinks. Formulations C, A, and E had much higher purchase intent (24.64%, 22.86%, and 22.86%), which were the same formulations that had high acceptance. Similar results for purchase intent were observed for the post-workout sports drinks. Purchase intent directly correlated with acceptance, resulting in formulations K, I, and M having the highest percentage of purchase intent (50.00, 37.68, 33.33) (Table 12). Formulation P that had the lowest acceptability score (15.71%) also had the lowest purchase intent (5.71%).

Consumers were also asked whether they would purchase the sports drinks if it would help them during exercise (Table 11), and if it would help them recover after exercise (Table 12).

Formulations A, C, and E had the highest purchase intent after consumers were given the knowledge that the drink would help them during a workout, with 57.14%, 45.71%, and 41.43% respectively (Table 11). For formulation A, purchase intent increased from 22.86% to 57.14%, from 24.64% to 45.71% for formulation C, and from 22.86% to 41.43% for E.

For further analysis of purchase intent, consumers were asked whether or not they would buy the product if it would help them to recover after exercise. Formulations K, I, and M had the greatest purchase intent after consumers were given the benefits of post-exercise recovery, with 58.57%, 51.43%, and 50.00% respectively (Table 12). The purchase intent for formulation K increased from 50.00% to 58.57%, from 37.68% to 51.43% for formulation I, and from 33.33% to 50.00% for formulation M. These results indicate that consumers are willing to forgo acceptability for a product that is beneficial, especially a sports drink that would enhance exercise and promote recovery after exercise.

3.3.4 Logistic Regression for Product Acceptance and Purchase Intent

Logistic regression was used to predict product acceptance and purchase intent using all eight attributes evaluated using the 9-point hedonic scale. Tables 13 and 14 represent the predictive models that were used to predict purchase intent and product acceptability for the pre- and post-workout sports drinks. Purchase intent was evaluated before and after given the information about exercise enhancement. Prediction models were established using the intercept and estimate from logistic regression output.

As determined by logistic regression, sensory attributes with a $Pr>\chi^2$ less than α (0.05) were significant sensory attributes that determined product acceptance and purchase intent. For the pre-workout sports drinks, overall liking ($Pr >\chi^2$ of <0.0001), mouthfeel ($Pr >\chi^2$ of 0.0060), and sweetness ($Pr >\chi^2$ of 0.0134) were the most integral sensory attributes in determining consumer acceptance, and color was the least significant (Pr $>\chi^2$ of 0.9711) (Table 15). The corresponding odds ratio point estimates are 2.270, 1.310, and 1.309 for overall liking, mouthfeel, and sweetness. This means that for every one point increase in the acceptability mean score for overall liking, mouthfeel, and sweetness, the probability that the product would be accepted would increase by 127%, 31%, and 30.9% respectively. According to the results of logistic regression, overall liking, followed by mouthfeel and sweetness would affect the probability of acceptance of the pre-workout sports drinks. Product acceptability was predicted with 85.65% accuracy based on the percent hit rate (Table 16).

In terms of purchase intent prior to the knowledge of exercise enhancement of the pre-workout drinks, overall liking and flavor were the two most important sensory attributes (Pr $>\chi^2$ of 0.0005 and 0.0036), and sweetness (Pr $>\chi^2$ of 0.9940) was the least important. The odds ratio point estimates for overall liking and flavor are 2.447, and 1.835, meaning that for every one point increase in the mean scores for overall liking and flavor, there is a corresponding increase in purchase intent of 83.5 and 144.7 percent respectively. Based on the percent hit rate, purchase intent can be predicted with 82.67% accuracy. Similar results were observed when consumers were asked if they would buy the product if it contained exercise enhancing ingredients which would aid during workouts. Overall liking and flavor were the two essential sensory attributes in determining purchase intent after given beneficial information about the product (Pr $>\chi^2$ of 0.0002 and 0.0034). Sweetness was also found to be the least significant (Pr $>\chi^2$ of 0.7822). For every one-point increase in the mean scores for overall liking and flavor, there is an increase in purchase intent of 72.7 and 40.9 percent, respectively. Purchase intent after given facts about the product was predicted with 73.60% accuracy (Table 16).

Table 13. Full Logistic Regression Models for Predicting Acceptance and Purchase Decisions of Pre-Workout Sports Drinks

Attributes	Predictive Model*
Acceptance	Y = -8.2638 + 0.0160 (Appearance) – 0.00736 (Aroma) + 0.00398 (Color) + 0.0763 (Consistency) + 0.2700 (Mouthfeel) + 0.2517 (Flavor) + 0.2696 (Sweetness) + 0.8107 (Overall Liking)
Purchase Intent	Y= -11.2016 + 0.2188 (Appearance) + 0.0269 (Aroma) + 0.0434 (Color) – 0.1179 (Consistency) + 0.0877 (Mouthfeel) + 0.6073 (Flavor) – 0.00121 (Sweetness) + 0.8949 (Overall Liking)
Purchase Intent / During Exercise Enhancement	Y= -4.7657 + 0.1025 (Appearance) – 0.0665 (Aroma) + 0.1572 (Color) – 0.0424 (Consistency) – 0.0482 (Mouthfeel) + 0.3431 (Flavor) – 0.0265 (Sweetness) + 0.5462 (Overall Liking)

*Predictive models based on estimates for each of the sensory attributes that resulted from logistic regression analysis.

Table 14. Full Logistic Regression Models for Predicting Acceptance and Purchase Decisions of Post-Workout Sports Drinks

Attributes	Predictive Model*
Acceptance	Y= -5.6312 - 0.0684 (Appearance) + 0.0202 (Aroma) + 0.0241 (Color) + 0.1599 (Consistency) – 0.1933 (Mouthfeel) + 0.2056 (Flavor) + 0.1641 (Sweetness) + 0.9293 (Overall Liking)
Purchase Intent	Y= -10.7857 + 0.0792 (Appearance) + 0.3056 (Aroma) – 0.0952 (Color) + 0.2271 (Consistency) – 0.4621 (Mouthfeel) + 0.3757 (Flavor) + 0.3621 (Sweetness) + 1.0523 (Overall Liking)
Purchase Intent / Post Exercise Enhancement	Y= -5.0340 - 0.0296 (Appearance) – 0.0369 (Aroma) + 0.0192 (Color) + 0.0462 (Consistency) – 0.0223 (Mouthfeel) + 0.0190 (Flavor) + 0.1161 (Sweetness) + 0.8917 (Overall Liking)

*Predictive models based on estimates for each of the sensory attributes that resulted from logistic regression analysis.

Table 15. Probability $>\chi^2$ and Odds Ratio Point Estimates for Acceptance and Purchase Intent for the Pre-Workout Sports Drinks

Consumer Acceptance			
Parameter	**Estimate**	**Pr $>\chi^2$**	**Odds Ratio**
Appearance	0.0160	0.8951	1.1016
Aroma	-0.0074	0.9345	0.993
Color	0.0040	0.9711	1.004
Consistency	0.0763	0.4849	1.079
Mouthfeel	0.2700	0.0060	1.310
Flavor	0.2517	0.0647	1.286
Sweetness	0.2696	0.0134	1.309
Overall Liking	0.8197	<0.0001	2.270
Consumer Purchase Intent			
Parameter	**Estimate**	**Pr $>\chi^2$**	**Odds Ratio**
Appearance	0.2188	0.1565	1.245
Aroma	0.0269	0.8259	1.027
Color	0.0434	0.7652	1.044
Consistency	-0.1179	0.3928	0.889
Mouthfeel	0.0877	0.5170	1.092
Flavor	0.6073	0.0036	1.835
Sweetness	-0.0012	0.9940	0.999
Overall Liking	0.8949	0.0005	2.447
Consumer Purchase Intent / During Exercise Enhancement			
Parameter	**Estimate**	**Pr $>\chi^2$**	**Odds Ratio**
Appearance	0.1025	0.3067	1.108
Aroma	-0.0665	0.4035	0.936
Color	0.1572	0.0818	1.170
Consistency	-0.0424	0.6424	0.959
Mouthfeel	-0.0482	0.5664	0.953
Flavor	0.3431	0.0034	1.409
Sweetness	-0.0265	0.7822	0.974
Overall Liking	0.5462	0.0002	1.727

*Sensory attributes that have a Pr$>\chi^2$ less than 0.05 are significant.

Table 16. Percent Hit Rate for Product Acceptability and Purchase Decision

Pre-Workout		**Post-Workout**	
Attribute	**% Hit Rate**	**Attribute**	**% Hit Rate**
Acceptance	85.65	Acceptability	82.10
Purchase Intent	82.67	Purchase Intent	86.96
Purchase Intent / During Exercise	73.60	Purchase Intent/ Post Exercise	78.22

Table 17. Probability >χ^2 and Odds Ratio Point Estimates for Acceptance and Purchase Intent for the Post-Workout Sports Drinks

Consumer Acceptance			
Parameter	**Estimate**	**Pr >χ^2**	**Odds Ratio**
Appearance	-0.0684	0.5969	0.934
Aroma	0.0202	0.8352	1.020
Color	0.0241	0.8541	1.024
Consistency	0.1599	0.1946	1.173
Mouthfeel	-0.1933	0.1187	0.824
Flavor	0.2056	0.0957	1.228
Sweetness	0.1641	0.1019	1.178
Overall Liking	0.9293	<0.0001	2.533
Consumer Purchase Intent			
Parameter	**Estimate**	**Pr >χ^2**	**Odds Ratio**
Appearance	0.0792	0.6541	1.082
Aroma	0.3056	0.0106	1.357
Color	-0.0952	0.6076	0.909
Consistency	0.2271	0.1934	1.255
Mouthfeel	-0.4621	0.0106	0.630
Flavor	0.3757	0.0430	1.456
Sweetness	0.3621	0.0149	1.436
Overall Liking	1.0523	<0.0001	2.864
Consumer Purchase Intent / Post Exercise Enhancement			
Parameter	**Estimate**	**Pr >χ^2**	**Odds Ratio**
Appearance	-0.0296	0.8072	0.971
Aroma	-0.0396	0.6750	0.964
Color	0.0192	0.8777	1.019
Consistency	0.0462	0.6905	1.047
Mouthfeel	-0.0223	0.8484	0.978
Flavor	0.0190	0.8732	1.019
Sweetness	0.1161	0.2263	1.123
Overall Liking	0.8917	<0.0001	2.439

*Sensory attributes that have a Pr>χ^2 less than 0.05 are significant.

For the post-workout drinks, overall liking was the only sensory attribute that significantly contributed to consumer acceptance (Pr >χ^2 of <0.0001) (Table 17). The odds ratio for overall liking is 2.533, meaning that for every one point increase in the mean hedonic score for overall liking, there will be an increase in consumer acceptance of 153.3%. For consumer purchase intent, overall liking (Pr >χ^2 of <0.0001), followed by sweetness (Pr >χ^2 of 0.0149), aroma (Pr >χ^2 of 0.0106), mouthfeel (Pr >χ^2 of 0.0106), and flavor (Pr >χ^2 of 0.04300 were influential sensory attributes. For every one-point increase in the mean hedonic score for overall liking and sweetness, there is an increase in purchase intent of 186.4 and 43.6 percent, respectively. Overall liking was also the most influential sensory attribute in terms of predicting consumer purchase intent after exercise enhancing information about the sports drinks was given. For every one-point increase in the acceptability mean score for overall liking, there is a corresponding increase in purchase intent of 143.9%. Consumer acceptance, purchase intent, and purchase intent after given information about post-exercise enhancement was predicted with 82.1%, 86.96%, and 78.22% accuracy respectively (Table 16).

3.3.5 Change in Probability of Purchase Intent

The McNemar test was used to analyze the change in probability of consumer purchase intent before and after being informed about the benefits of the pre and post-workout sports drinks. The null hypothesis for the McNemar test states that there is no significant difference in probability of buying the product before and after consumers have been informed about the health benefits, or

$$H_0: \pi_{+1 \text{ (total yes after)}} - \pi_{1+ \text{ (total yes before)}} = 0.$$

For the pre-workout sports drinks, the probability of purchase intent after being given information about exercise enhancement was significant for all eight formulations (Table 18). The degree at which purchase intent can increase is expressed by the lower confidence interval (LCI) and the upper confidence interval, which are predicted with 95% confidence (Table 18). For example, the purchase intent for formulation A can increase as little as 23.2% or as much as 45.4% after the consumer is made aware of exercise enhancing benefits.

Table 18. Changes in Probability of Purchase Intent for Pre-Workout Sports Drinks

Formulation	χ^2	P-Value*	95% LCI**	95% UCI***
A	24.0000	0.0001	0.232	0.454
B	17.0000	0.0001	0.142	0.343
C	13.2353	0.0003	0.112	0.323
D	24.0000	0.0001	0.232	0.454
E	11.2667	0.0008	0.086	0.285
F	13.0000	0.0003	0.095	0.277
G	9.0000	0.0027	0.050	0.207
H	5.4444	0.0196	0.019	0.181

*P-values < α (0.05) are significant
**LCI- lower confidence interval.
***UCI- upper confidence interval.

For the post-workout drinks, the change in probability of purchase intent was significant for all formulations, except for formulation K (P-value 0.083) (Table 19). Out of all sixteen formulations, the formulation that had the least potential for increase was formulation P, with the lowest upper confidence interval of 15.1%. Formulations A and E had the highest potential for increased purchase intent, with maximum values of 45.4 percent. Overall, consumers were more inclined to purchase the product after knowing about the potential exercise enhancement.

Table 19. Changes in Probability of Purchase Intent for Post-Workout Sports Drinks

Formulation	χ^2	P-Value	95% LCI*	95% UCI**
I	8.3333	0.0039	0.053	0.237
J	10.0000	0.0016	0.061	0.225
K	3.0000	0.0833	-0.009	0.181
L	10.2857	0.0013	0.075	0.268
M	12.0000	0.0005	0.084	0.263
N	12.0000	0.0005	0.083	0.260
O	9.9412	0.0016	0.079	0.293
P	6.0000	0.0143	0.020	0.151

*P-values < α (0.05) are significant.
*LCI- lower confidence interval.
**UCI- upper confidence interval.

3.4 Conclusions

Consumers evaluated the pre-workout formulation A (WPC, S, Bry) as having the greatest acceptability of color, aroma, appearance, mouthfeel, flavor, sweetness, and overall liking. For the post-workout drinks, formulation K (WPI, S, LL) had the highest mean score for acceptability of color, consistency, mouthfeel, flavor, sweetness, and overall liking. MANOVA indicated that there was a difference in the eight pre-workout sports drinks and the eight post-workout sports drinks when all eight sensory attributes (appearance, aroma, color, consistency, mouthfeel, flavor, sweetness, and overall liking) were concurrently compared. Using DDA, aroma, mouthfeel, and overall liking were the three most discriminating sensory attributes that contributed to the differences in the eight pre-workout formulations, and mouthfeel, flavor, and overall liking were the three most discriminating attributes for the post-workout drinks. In terms of acceptability and purchase intent, 70% of consumers perceived formulation A as being acceptable; however, only 22.86% said that they would purchase the product. The purchase intent of formulation A increased from 22.86% to 57.14% after the consumers were made aware of the exercise enhancing benefits. For the post-workout drinks, formulation K received the highest acceptability score, with 65.71% acceptance. Formulation K also had the greatest purchase intent with 50.00%. Purchase intent for this formulation increased to 58.57% after consumers were made aware of post-exercise enhancement. As determined by logistic regression, overall liking, mouthfeel, and sweetness were the most important sensory attributes used to determine consumer acceptance for the pre-workout drinks. Overall liking was the only attribute that significantly contributed to consumer acceptance. Based on the percent hit rate, it can be determined that a new pre and post workout sports drink formulation would be 85.65% and 82.10% acceptable, with 82.67% and 86.96% purchase intent, and 73.60% and 78.22% purchase intent after knowing about pre and post exercise enhancement respectively.

CHAPTER 4. DEVELOPMENT AND CHARACTERIZATION OF CONSUMER SENSORY QUALITIES OF PRE- AND POST-WORKOUT SPORT BEVERAGES

4.1 Introduction

The type of nutrients and the timing of nutrient intake are integral components for athletes to consider when exercising. An ideal method of achieving proper nutrient intake is consuming pre-workout and post-workout sports drinks. Eight pre-workout sports drinks and eight post-workout sports drinks were formulated. Both sports drinks contained carbohydrates, protein, amino acids, antioxidants, and other supplements such as creatine and glutamine. They were formulated with the goal of reducing muscle damage during exercise, preventing and reducing post-exercise muscle breakdown, increasing post-exercise protein synthesis, and increasing recovery and glycogen synthesis.

In a preliminary study conducted on the development of pre- and post-workout sports beverages (Chapter 3), consumers had negative perception and did not prefer the sports drinks, resulting in low overall acceptability of the sensory attributes and low purchase intent. The objectives of this study were to (1) reformulate the eight pre-workout and eight post-workout sports drinks so that they would be more acceptable to consumers, have greater purchase intent, and can be competitive in the sports beverage market (2); target the ideal population of consumers by conducting a consumer acceptance test at the local university recreational facility.

4.1.1 Color

Color and appearance are major aspects of food acceptance. Many colorimetrists believe that color is the most important because if a product does not look right, a consumer may never get to judge the other two aspects (Nielsen 2003). Color systems are ways to describe color, and such systems include verbal or numerical designations for visual matching of colors, and mathematical terms used with instrumentation. Tristimulus colorimetry is a color system that involves a light source, three glass filters with transmittance spectra, and a photocell. All tristimulus colorimeters today depend on this principle with individual refinements in photocell response, stability, sensitivity, and reproducibility (Nielsen 2003).

The CIELCH tristimulus colorimetry system, with parameters L* C* h, is a popular way of evaluating color. The L* value indicates the level of light or dark and may have a value between 0 and 100, the C* value represents the chroma or intensity, and the h value represents the hue angle or actual color. Chroma and hue angle can be calculated using the following equations:

$$C^* \text{ (chroma)} = [(a^*)^2 + (b^*)^2]^{1/2}$$

$$h_{ab} \text{ (hue angle)} = \tan^{-1}(b^*/a^*),$$

where a* represents the redness or greenness, and b* represents the yellowness or blueness. a* and b* values can range from –80 to +80, with –60 to +60 being the most common range in food systems.

Figure 2 represents the L*a*b* color space. The L*C*h color space uses the same diagram as the L*a*b* color space, but uses cylindrical coordinates instead of rectangular coordinates. The value of chroma (C*) is 0 at the center and increases according to the distance from the center. Hue angle (h) is expressed in degrees (0-360°).

4.1.2 pH

pH is defined as the negative logarithm of the molar concentration of hydrogen ions. In food analysis, pH meters are used to test the pH of many food substances. Four major parts of the pH system are needed: a reference electrode, an indicator electrode, a voltmeter or amplifier that is capable of measuring small voltage differences in a circuit of very high resistance, and a sample to be analyzed.

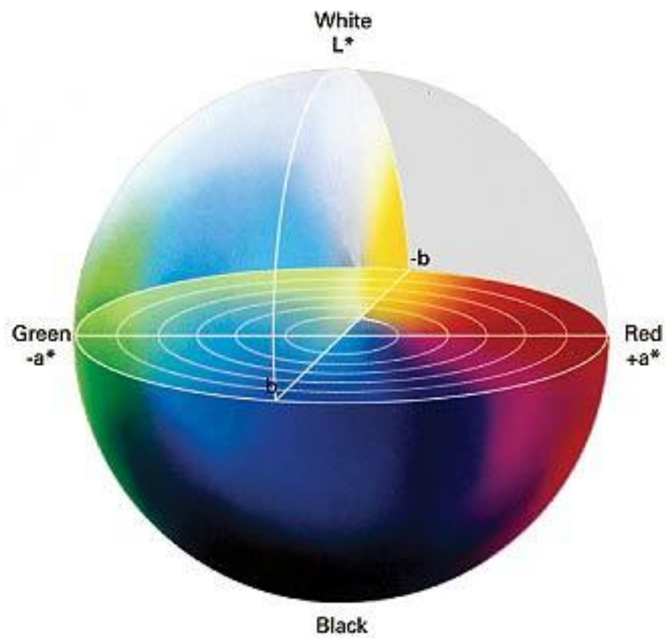

Figure 2. L*a*b* Color Space (Adapted from Anonymous 1998)

Each of the electrodes is designed to produce a constant, reproducible potential. Therefore, in the absence of other ions, the potential difference between the two electrodes is fixed and easily calculated. However, H_3O^+ ions in solution contribute a new potential across an ion-selective glass membrane built into the indicating electrode. This alters the potential difference between the two electrodes in a way that is proportional to the H_3O^+ concentration. The new potential resulting from the combination of all individual potentials is called the electrode potential and is readily convertible to pH readings. The voltage that develops between the two electrodes can then determine hydrogen ion concentration (Nielsen 2003).

4.1.3 Viscosity

Rheology is the study of the deformation and flow of all materials. Rheological properties should be considered a component of the textural properties of foods, because the sensory detection of texture encompasses factors in addition to rheological properties. Rheology is concerned with how all materials respond to applied forces and deformations. Basic concepts of stress and strain are key to all rheological evaluations. Ideal fluids follow Newtonian principles, and the proportionality constant is commonly referred to as viscosity, which is defined as an internal resistance to flow (Nielsen 2003).

4.2 Materials and Methods

4.2.1 Sports Drink Preparation

Sixteen sports drinks were formulated (Tables 21 and 22), eight pre-workout and eight post-workout drinks, containing milk proteins, carbohydrates, and flavors. Using two protein sources, two carbohydrate sources and two flavors, eight pre-workout formulations were derived. The two protein sources were whey protein isolate (WPI) and casein hydrolysate. Both protein sources were formulated by the manufacturers to have high solubility and to dissolve clear in solution. The carbohydrate sources consisted of sucrose and glucose, and the flavors included berry and tropical fruit. Each pre-workout drink also contained water, sodium, potassium, vitamin C, leucine, and colorants. Gums were also added to help keep all particles in solution.

Using two protein sources, two carbohydrate sources, and two flavors different than those used for the pre-workout drinks, eight post-workout drinks were formulated. The two protein sources included whey protein isolate (WPI), and casein hydrolysate. Sucrose and glucose were used as the carbohydrate source. Two different flavors including lemon lime and fruit punch were used as flavorings for the post-workout sports drinks. The eight post-workout formulations also included water, creatine, glutamine, vitamin C, gums, and colorants.

PeptoPro®, casein hydrolysate was obtained from DSM Food Specialties, Ma Delft, The Netherlands. This protein is formulated to have great dissolvability and clarity in water. PeptoPro® contains 0% carbohydrate, 0% lactose, 0% calories from fat, 85% protein, 5% water, 4% ash, 6% malic acid, 1.2% sodium, 0.07% potassium, 0.05% calcium, and 0.18% chloride.

PeptoPro® has a total viable microbiological count <10,000 cfu/g, <50 cfu/g yeast and molds, negative test in 1g for coliforms, negative test in 25g for Salmonella, negative test in 1g for *S. aureus*, and has <10 cfu/g *B. cereus*. Isolac Clear, a whey protein isolate, was obtained from Carbery in Chicago, Illinois. Isolac Clear typically contains 89% protein, 5% moisture, <0.5% fat, 3.5% ash, 2.5% lactose, and has a pH of 6.3. Microbiological specifications for Isolac Clear are as follows: standard plate count (SPC) of <50,000 cfu/g, coliforms <10 cfu/g, *E. coli* negative per 0.1g, *S. aureus* <10 cfu/g, Salmonella negative per 25g, and yeast and molds 50 cfu/g maximum.

Dextrose, or D-glucose, and creatine monohydrate were purchased from Supplement Direct™, Santa Barbara, CA. Creatine monohydrate is a micronized powder that dissolves clear in liquid. L-leucine, L-glutamine, and ascorbic acid are white crystalline powders that were obtained from Anmar International Ltd, Bridgeport, CT. Obipektin fruit powders were provided by The Ingredient Company in Mississauga, ON. All natural berry flavor, lemon, lime, tropical fruit, and orange flavored fruit powders were used to flavor the sports drinks. The Berry Mix 231-A contains raspberry, strawberry, elderberry, blackberry, and bilberry. This flavor is produced by vacuum drying, and contains 31% fruit solids, 67.2% added sucrose, 86% total carbohydrates, 5-11% glucose, 6-12% fructose, 62-72% sucrose, and 0.0-1.9% protein. The Lemon 150-BP flavor is produced by low temperature spray drying, and contains 50% fruit solids, 50% added maltodextrin, 55% total carbohydrates, 4-13% glucose, 3-13% fructose, 0-0.35% sucrose, and 0.8-4.0% protein. Lime 150-B flavor is produced by low temperature spray drying, and has 50% fruit solids, 50% added maltodextrin, 56% total carbohydrates, 3-11% glucose, 3-11% fructose, 0-3% sucrose and 1.9-4% protein. The Tropical Fruit 122-D is also produced by low temperature spray drying and contains banana, apricot, pineapple, orange, passionfruit, lemon, grapefruit, mango, and guava. The tropical fruit flavor has 22.8% fruit solids, 45.3% added maltodextrin, 89% total carbohydrates, 2-8% glucose, 2-8% fructose, 28-38% sucrose, and 0.7-1.4% protein. The orange flavor, Orange 200, is a free-flowing powder produced by vacuum drying. This flavor contains 100% fruit solids, and no added sucrose, or maltodextrin. The orange fruit powder contains a maximum of 3% moisture, 77% total carbohydrates, 14-24% glucose, 15-29% fructose, 20-40% sucrose, and 3-9% protein.

TIC Pretested® Colloid Ultrasmooth Powder, which contains cellulose gum, xanthan gum, and carrageenan was obtained from TIC Gums in Belcamp, MD. This gum blend also contains zero calories from fat, not total fat, no trans fat, no cholesterol, 6690 mg sodium, 579mg potassium, 80g carbohydrates, and no protein per 100 grams. Sucrose, or table sugar, salt (sodium chloride), and red, yellow, and green food coloring (Great Value™) were purchased from a local supermarket in Baton Rouge, LA.

Table 20. Protein, Carbohydrate, and Flavor Combinations for Eight Pre-Workout and Eight Post-Workout Sports Drink Formulations.

Pre	Post
A: CH, S, Bry	**I:** CH, S, LL
B: CH, G, Bry	**J:** CH, G, LL
C: WPI, S, Bry	**K:** WPI, S, LL
D: WPI, G, Bry	**L:** WPI, G, LL
E: CH, S, TF	**M:** CH, S, O
F: CH, G, TF	**N:** CH, G, O
G: WPI, S, TF	**O:** WPI, S, O
H: WPI, G, TF	**P:** WPI, G, O

*CH= Casein Hydrolysate (PeptoPro®), WPI= Whey Protein Isolate (Isolac Clear).
*S= Sucrose, G= Glucose.
*Bry= Berry, TF= Tropical Fruit, LL=Lemon/Lime, O=Orange

The first step in making the sports drinks was to weigh the ingredients: Distilled water, PeptoPro®, Isolac, sucrose, glucose, vitamin C, sodium, potassium, leucine, glutamine, creatine, tropical fruit flavor, berry flavor, lemon lime flavor, orange flavor, and gum according to the formulations (Tables 21 and 22). For each formulation, the appropriate amounts of dry ingredients were added to the distilled water and mixed thoroughly until all particles were dissolved.

Table 21. Ingredient Percentages (%) for Pre-Workout Sports Drinks.

Ingredient	Formulation (%)							
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Water	90.66	90.31	90.72	90.37	90.19	89.06	90.25	89.12
Sucrose	5.12		5.13		5.10		5.10	
Glucose		5.10		5.12		5.03		5.03
PeptoPro®	1.51	1.50			1.50	1.48		
Isolac			1.44	1.43			1.43	1.41
Berry Flavor	1.54	1.91	1.54	1.91				
Lemon Flavor	0.51	0.51	0.51	0.51				
Tropical Flavor					2.55	3.77	2.55	3.78
Vitamin C	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Sodium	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Potassium	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
L-Leucine	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
Gum	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

*Formulations A-D had no color added, and formulations E-F had 0.054g red and 0.054g of yellow food coloring added.

Each mixture was then transferred to a homogenizer to ensure that homogenous mixture was obtained. The homogenizer (Model 300 DJF 4 2PS, Manton-Gaulin Mfg. Co. Inc, Everett, MA) was flushed with water between samples to ensure that there would be no contamination. Each formulation was homogenized in two-gallon batches, for two fifteen-second cycles, totaling 30 seconds. The second stage of the homogenizer was set to 500 psi, and the first stage was set to 1500 psi, for a total of 2000 pounds per square inch of pressure. After homogenizing, the samples were pasteurized in cylindrical stainless steel containers using the batch pasteurization method. The containers were placed in a stainless steel vat with water, and heated until the samples reached 160°F. The sports drinks were then pasteurized at 160°F for 30 minutes to ensure that no pathogens remained in the mixtures. After the mixtures were heated, the pots were removed from the vat and placed in an ice bath until cooled. When the mixtures reached 75°F, they were placed in half-gallon plastic milk cartons, capped, and stored in the refrigerator (40°F).

Table 22. Ingredient Percentages (%) for Post-Workout Sports Drinks.

	Formulation (%)							
Ingredient	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**
Water	85.17	85.17	85.27	85.27	84.15	83.16	84.26	85.27
Sucrose	9.62		9.64		9.51		9.52	
Glucose		9.62		9.64		9.40		9.36
PeptoPro®	2.83	2.83			2.80	2.76		
Isolac			2.71	2.71			2.67	2.71
Lemon Flavor	0.60	0.60	0.60	0.60				
Lime Flavor	0.60	0.60	0.60	0.60				
Orange Flavor					2.38	3.52	2.38	3.53
Vitamin C	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Glutamine	0.48	0.48	0.48	0.48	0.48	0.47	0.48	0.47
Creatine	0.48	0.48	0.48	0.48	0.48	0.47	0.48	0.47
Gum	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19

*0.054g of green and 0.108g of yellow food coloring were added to formulations I-L, and 0.54g of red and 0.108 of yellow were added to formulations M-P.

4.2.2 Consumer Acceptance Test

Two hundred and eighty untrained consumers participated in the acceptance test. Consumers were recruited from the Louisiana State University Campus in Baton Rouge, LA in March 2008. The consumers were asked to participate while entering and exiting the LSU UREC, university recreation facility, in order to achieve the ideal target population (Figure 3). The following criteria had to be met by all consumers in order to be recruited: 18 years of age or older, not allergic to milk protein, sugar, leucine, glutamine, creatine, and fruits such as citrus, berries, and tropical fruits, and willing and available to participate and complete a survey. The consumers were presented with a packet of papers that contained a consent form, which was pre-approved by the Louisiana State University Institutional Review Board (IRB), and 4 questionnaires for each of the 4 samples. The consumers were instructed to read and sign the consent form, and properly complete the questionnaires.

Figure 3. University Recreation Facility at Louisiana State University

A balanced incomplete block design (BIB), Plan 11.9, where t = 8, k = 2, r = 7, and b =28 was used to test the 16 formulations (Cochran 1957). Consumers were presented with 4 2-oz samples, out of the total 16 formulations (Figure 4). The 4 samples presented to the consumers consisted of 2 pre-workout drinks and 2 post-workout drinks, and were served at refrigerator temperature (40°F). The 16 formulations, 8 pre-workout and 8 post-workout, were coded with the letter A to P, for a total of 70 observations per formulation. The participants were provided room temperature bottled water, to cleanse their palates between samples (Figure 4). Each consumer evaluated each sample for acceptability of visual appearance, aroma, color, consistency, mouthfeel, flavor, sweetness, and overall liking using a 9-point hedonic scale (1=dislike extremely, 5=neither like nor dislike, 9=like extremely). Binomial type questions (yes/no) were used to determine product acceptability, purchase intent, and purchase intent after being given benefits of a pre-workout and post-workout sports beverage.

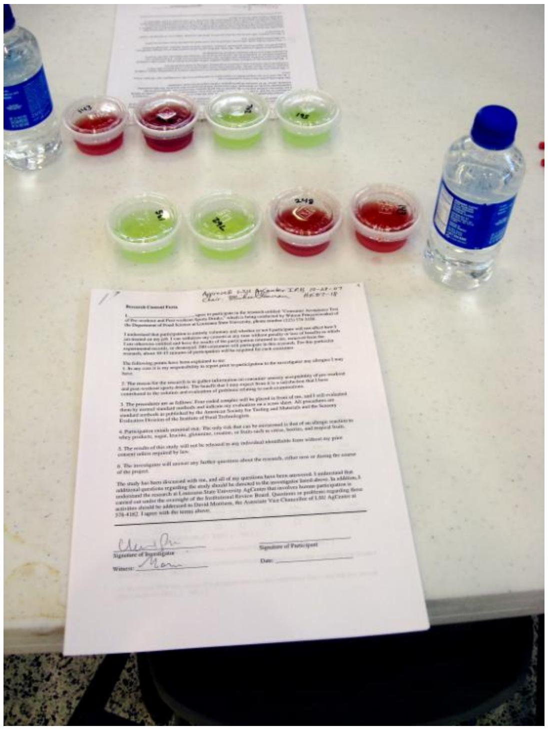

Figure 4. Consumer Acceptance Test Set-Up

4.2.3 Physicochemical Analysis

Physicochemical analysis of foods encompasses many integral analyses such as color, pH, viscosity, and proximate analysis (the analysis of moisture, fat, carbohydrate, protein, and minerals). These analyses not only helped to define a food product, but they can also aid in determining product acceptability.

4.2.3.1 Color

The CIELCH tristimulus colorimetry system, with parameters L* C* h, was used to evaluate color. Using a bench top spectrophotometer (LabScan® XE Hunter Lab Spectrophotometer, Reston, Va.), L*, C*, and h values were measured in triplicate for each of the pre- and post-workout formulations. Each sports drink formulation was placed in an 8-oz white Styrofoam cup to ensure that the color was measured accurately. Before analyzing the samples, the colorimeter was calibrated with both a white (Standard No. LX16857) and black tile. After calibration, the samples were stirred and attached to the orifice of the machine, to ensure that no light would escape, and analyzed.

4.2.3.2 pH

pH was measured using hand-held pH meter (IQ Scientific Instruments, Model IQ150 handheld pH/mV/temperature meter, Carlsbad Ca.). The sports drinks were placed in 100 ml beakers and stirred. The pH probe was then inserted into the sports drink, and the pH was recorded. Triplicate measures were recorded for each of the sixteen sports drink formulations.

4.2.3.3 Apparent Viscosity

Rheological properties of the drinks were evaluated using a rotational viscometer (Brookfield, Model DV-II+, Middleboro, Ma.). The Brookfield viscometer uses a spring as a torque sensor. The bob with spindle RV1 was set to 100 rpm. Once the rotational speed is converted to an angular velocity, the simple shear approximation was used to calculate a shear rate. As the bob moves through the sample, the viscosity impedes free rotation, causing the spring to wind. The degree of spring windup is a direct reflection of the torque magnitude (M), used to determine a shear stress at the bob surface. Using this data, a rheogram was created showing shear stress versus shear rate, ultimately determining the apparent viscosity (Nielsen 2003). The same quantity of each sports drink formula was placed in a 16-oz clear plastic cup. Immediately before measuring, the sports drink samples were stirred fifteen times clockwise, and fifteen times counter clockwise using a spoon. All samples were analyzed at refrigerated temperature (40°F). Viscosity, in centipoises (cp) was measured in triplicate for each of the sixteen sports drink formulations.

4.2.4 Statistical Data Analysis

All data were analyzed at a predetermined confidence level (α=0.05) using the Statistical Analysis Software System, SAS version 9.1, 2003 (SAS Institute, Cary, NC).

4.2.4.1 Analysis of Variance

Analysis of variance, often abbreviated as ANOVA, is a technique that compares the means from several samples and tests whether they are all (within experimental error) the same, or whether one or more of them are significantly different (O'Mahony 1986). Analysis of variance (ANOVA) was used to determine if differences lie among the eight pre-workout drink formulations and/or among the eight post-workout drink formulations in terms of acceptability of each sensory attribute, and overall liking.

For conducting a valid analysis of variance, the following assumptions must be satisfied: samples taken under each treatment must be randomly pick from their respective populations, the treatments must be independent of each other, samples of scores under each treatment must come from normally distributed populations of scores, and samples of scores under each treatment must come from populations with the same variance (homoscedasticity) (O'Mahony 1986). ANOVA provides evidence that a significant difference exists, but does not give an indication of how the treatments are different.

Tukey HSD (honest significant difference) is an adjustment that was used, so that after all comparisons, both simple pairwise and complex, the overall level of significance was 0.05. Tukey (1953) proposed a multiple-comparison method for pairwise comparisons of k means and for simultaneous estimation of differences between means by confidence intervals with a specified confidence coefficient (1-α) (Gacula and Singh 1984). If n observations are taken in each of k samples and the analysis-of-variance F test is significant, the critical difference to be exceeded for a pair of means to be significantly different is the so-called honest significant difference (HSD), where

$$HSD = Q_{\alpha,k,v}(\sqrt{Mse/n}).$$

4.2.4.2 MANOVA and DDA

MANOVA (multivariate analysis of variance) is a post-ANOVA technique that was used to determine if significant differences existed among formulations when all of the sensory attributes were compared simultaneously. Descriptive Discriminant Analysis (DDA) was used to determine which of the attributes contributed to the differences among the eight pre-workout and eight post-workout sports drink formulations.

MANOVA and Discriminant Analysis are the preferred methods for determining differences between samples. The chief value of MANOVA is to determine whether treatments applied to a product cause significant differences, and Descriptive Analysis tells the investigator whether certain variables combined are correlated with classes (Piggott 1986). The results of MANOVA provide a single F-statistic, based on Wilks' lambda (Λ), which assesses the influence of all descriptors simultaneously. A significant MANOVA F-statistic (due to a small Wilks' lambda) indicates that the samples differ significantly across dependent variables (Lawless and Heymann 1998).

Techniques of Descriptive Discriminant Analysis (DDA) are closely aligned to the study effects determined by a multivariate analysis of variance (Huberty 1994). In DDA, the basic question of interest pertains to grouping variable effects on the multiple outcome variables or, to group separation or group differences with respect to the outcome variables (Huberty 1994).

4.2.4.3 Logistic Regression

Logistic regression, or logit analysis, uses a regression model to fit a categorical dependent variable. In its most widely used form, the dependent variable is dichotomous (yes/no) and the independent variables are quantitative or categorical. Logistic regression involves the use odds and odds ratios. The odds are an expression of the likelihood of an event happening compared to the likelihood of that event not happening. An odds of less than one corresponds to a probability of less than 0.5, and an odds greater than one corresponds to a probability above 0.5. Odds are used instead of probabilities because they are on a more sensible scale for multiplicative comparisons, they are directly related to the parameters in the logit model, and they are less sensitive to changes in the marginal frequencies. The odds ratio, not to be confused with the odds, is the proportional change in the odds per unit change in X_i. Logistic regression analysis was used to predict both product acceptability and purchase intent based on the odds ratio point estimate.

4.2.4.4 McNemar Test

The McNemar test is one way of comparing proportions from two dependent samples (in this case, responses before and after consumers had been informed of the exercise enhancing benefits) using binary response variables. The test follows a chi-square distribution with df=1 (Agresti 1996). A 95% confidence interval was calculated using marginal sample proportions ($p_{+1} + p_{1+}$), which can be used to estimate the actual differences in the means of purchase decision responses (Beckley and others 2007).

In order to calculate the sample proportions (p_{ij}), the equation

$$p_{ij} = n_{ij}/N$$

was used, where n_{ij} is the number of consumers making response I and response j after knowing the “fact” about exercise enhancing benefits, and N represents the total number of responses from consumers. Next, the 95% confidence interval for the difference in proportions was calculated using the equation

$$(p_{+1} - p_{1+}) \pm z_{\alpha/2}(ASE)$$

where $(p_{+1} - p_{1+})$ represents the difference in proportions between consumers who answer yes after knowing the fact (p_{+1}) and those who answered yes before knowing the fact (p_{1+}); the term $z_{\alpha/2}$ equals 1.96 and represents the standard normal percentile having a right-tailed probability of $\alpha/2$; ASE is the estimated standard error for the proportion difference and was calculated using the equation

$$ASE = ([p_{1+}(1-p_{1+}) + p_{+1}(1-p_{+1}) - 2(p_{11}p_{22} - p_{12}p_{21})]/N)^{1/2}$$

Where p_{11} indicates the number of consumers who answered yes both before and after knowing the fact, p_{22} represents the number of consumers who answered no both before and after knowing the fact, p_{12} indicates the number of consumers who answered yes before and no after knowing the fact, and p_{21} represents the number of consumers who answered no before and yes after knowing the fact (Beckley and others 2007).

In this study, the McNemar test was used to determine changes in consumer purchase decision before and after consumers were informed of the exercise enhancing benefits of the sports drinks.

4.2.4.5 Principal Component Analysis

Principal Component Analysis (PCA) is a multivariate technique that is used to simplify and/or describe interrelationships among multiple dependent variables and among objects. PCA transforms the original dependent variables into new uncorrelated dimensions, and this simplifies the data structure and helps the analyst to interpret the data (Lawless and Heymann 1998). The primary product of PCA is a data map graphically illustrating various relationships, which is very useful when several dependent variables are correlated with one another.

The effect of PCA is to reduce the dimensionality of the sample space. If 25 variables have been measured, the raw data matrix represents a 25-dimensional space, and a full display of the space requires a number of dimensions equal to the lesser of the number of variables and one less than the number of objects. PCA will then search for linear combinations of variables, which account for the maximum possible proportion of variance in the original data. If two or more variables are strongly correlated, then the majority of variance in the data can be explained by drawing a new axis through the center of the group of observations, so that the sum of squared residual distance is a minimum. The remaining proportion of variance in the data can then be explained by constructing a second new axis, orthogonal to the first (Piggott and Sherman 1986). In this study, PCA was used to graphically depict relationships between the sports drinks and the sensory attributes evaluated by the consumers (appearance, aroma, color, consistency, mouthfeel, flavor, sweetness, and overall liking).

4.3 Results and Discussion

4.3.1 Physicochemical Analysis

4.3.1.1 pH

For the pre-workout sports drinks, the pH values ranged from 4.64 to 6.14 (Table 23). All pre-workout formulations were significantly different from each other, except for formulations C (WPI, G, Bry) and D (WPI, S, Bry). Overall, the formulations with natural berry flavor (A-D) were more acidic than those with the natural tropical fruit flavor (E-H). The pH values for the post-workout sports drinks ranged from 3.24 to 4.05 (Table 23). The pH for all of the formulations are acidic because of the natural lemon, lime, and orange flavors used. Formulations I (CH, S, LL) and J (CH, G, LL) were not significantly different from each other, and formulations K (WPI, S, LL) and L (WPI, G, LL) were not significantly different from each other. Formulation M (CH, S, O), which had the highest pH, was significantly different from all of the other post-workout formulations. Formulations N (CH, G, O) and O (WPI, S, O) were not significantly different from each other. Overall, the pre-workout formulations with whey protein isolate had significantly different pH values than those with casein hydrolysate.

Table 23. Mean pH Values for Pre- and Post-Workout Sports Drinks

Sample	**pH**	**Sample**	**pH**
A	5.03 ± 0.03^{E}	**I**	3.53 ± 0.14^{CD}
B	4.89 ± 0.02^{F}	**J**	3.38 ± 0.05^{DE}
C	4.67 ± 0.02^{G}	**K**	3.29 ± 0.02^{E}
D	4.64 ± 0.02^{G}	**L**	3.24 ± 0.01^{E}
E	6.14 ± 0.03^{A}	**M**	4.05 ± 0.03^{A}
F	5.96 ± 0.00^{B}	**N**	3.86 ± 0.02^{B}
G	5.58 ± 0.02^{C}	**O**	3.84 ± 0.07^{B}
H	5.39 ± 0.03^{D}	**P**	3.62 ± 0.05^{C}

*Numbers represent an average plus or minus the standard deviation of three samples taken per formulation. See Tables 21 and 22 for formulations A-P. Mean values in each column with the same letters are not significantly different ($p>0.05$).

4.3.1.2 Viscosity

Viscosity for the pre-workout drinks ranged from 16.37 to 21.27 centipoise (cP) (Table 24). Of the first four pre-workout formulations (A-D), formulation A (CH, S, Bry) was significantly different from formulation C (WPI, G, Bry). For the last four pre-workout formulas, formulations G and H, which have the same protein and flavor source, were not significantly different from each other. Formulation F (CH, G, TF) was significantly different from all of the other formulations, and also had the highest viscosity (21.27 cP), which may affect sensory acceptability for mouthfeel. Viscosity for the post-workout drinks ranged from 16.17 cP to 21.09 cP (Table 24). Formulation O (WPI, S, O), which had the greatest viscosity of 21.09, was significantly different from all of the other post-workout formulations. Formulation J (CH, G, LL) had the lowest viscosity, and was not significantly different from formulations I (CH, S, LL) and L (WPI, G, LL).

Table 24. Mean Viscosity Values for Pre- and Post-Workout Sports Drinks

Sample	Viscosity (cP)	Sample	Viscosity (cP)
A	18.24 ± 0.61^{BC}	**I**	17.16 ± 0.79^{DE}
B	17.05 ± 0.59^{CD}	**J**	16.17 ± 0.46^{E}
C	16.64 ± 0.07^{D}	**K**	18.94 ± 0.21^{B}
D	17.07 ± 0.18^{CD}	**L**	16.65 ± 0.17^{DE}
E	16.37 ± 0.43^{D}	**M**	17.86 ± 0.16^{CD}
F	21.27 ± 0.34^{A}	**N**	18.68 ± 0.46^{BC}
G	18.40 ± 0.46^{B}	**O**	21.09 ± 0.20^{A}
H	18.24 ± 0.61^{BC}	**P**	18.92 ± 0.45^{B}

*Numbers represent an average plus or minus the standard deviation of three samples taken per formulation. See Tables 21 and 22 for formulations A-P. Mean values in each column with the same letters are not significantly different ($p>0.05$).

4.3.1.3 Color

For the pre-workout drinks, the L* values for formulations A, B, C, and D ranged from 0.10 to 1.27 and were not significantly different from each other, but were significantly different from all other formulations (Table 25). However, the L* value of 1.27 for formulation C indicated that there was more whiteness, which can be attributed to the opacity that the whey protein isolate imparted. Formulations with casein hydrolysate were less opaque (more clear) than those with whey protein isolate (Figures 5 and 6). Formulations E and F were not significantly different from each other, but formulations G and H had significantly different L* values. Among formulations A, B, C and D, formula C (WPI, S, Bry) had the highest chroma, or intensity (3.4) and was significantly different from the other formulations. The chroma (C*) values for formulations E, F, G, and H were significantly different from one another, with formulation E having the highest intensity of color. The hue angle, or actual color of the sports drinks was significantly different among formulations A, B and C. Among formulations E, F, G, and H, formulations E and F were not significantly different from each other in terms of hue angle, and formulations G and H were significantly different from each other and the other formulations. Formulations A-D were a purple/red color and formulations E-H were a pinkish yellow color (Figures 5 and 6).

The L* values for the post-workout drinks ranged from 21.84 to 8.33 (Table 26). Formulations I and J were not significantly different from each other and were not significantly from formulations M and N. These four formulations shared the same protein source, indicating that the whey protein isolate makes the sports drink appear more white. Formulations M and N were significantly different from formulations O and P. Formulations O and P were significantly different from all other formulation, having the highest L* values of 21.84 and 21.80 respectively. In terms of chroma, or intensity, formulations O and P had the greatest intensity of color and were significantly different from the other post-workout formulations. Formulations M and N were not significantly different from each other and formulations I, J, K, and L were not significantly different from each other for chroma. The hue angle for formulations I-L, which were a green/yellow color, ranged from 133.84 to 122.18. Formulas I and J were significantly different from K and L. Among formulations M-P (orange color), formulas M and N were significantly different from each other and from formulas O and P. Formulas O and P had significantly higher hue angle values than M and N. The color of all post-workout sports drink formulations can be seen in Figures 7 and 8.

Table 25. L*, C*, and h Values for the Pre-Workout Sports Drink Formulations

	Color		
Sample	**L***	**C***	**h**
A	0.35 ± 0.25^{D}	1.55 ± 0.23^{FG}	11.03 ± 1.56^{F}
B	0.10 ± 0.01^{D}	0.72 ± 0.14^{G}	13.47 ± 0.14^{E}
C	1.27 ± 0.38^{D}	3.40 ± 0.09^{E}	15.55 ± 0.56^{D}
D	0.32 ± 0.03^{D}	2.08 ± 0.12^{F}	15.11 ± 0.40^{ED}
E	8.91 ± 0.13^{C}	17.60 ± 0.53^{A}	49.39 ± 0.69^{C}
F	10.95 ± 0.09^{C}	14.97 ± 0.52^{B}	50.62 ± 0.05^{C}
G	22.58 ± 1.85^{B}	12.65 ± 0.53^{C}	55.87 ± 0.44^{A}
H	27.37 ± 1.09^{A}	11.04 ± 0.23^{D}	59.68 ± 0.17^{B}

* Numbers represent an average plus or minus the standard deviation of three samples taken per formulation. See Tables 21 and 22 for formulations A-P. Mean values in each column with the same letters are not significantly different (p>0.05).

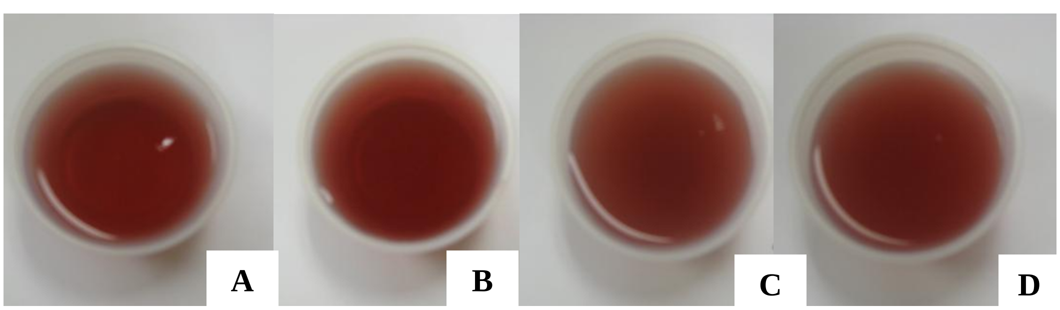

Figure 5. Pre-Workout Sports Drink Formulations A-D

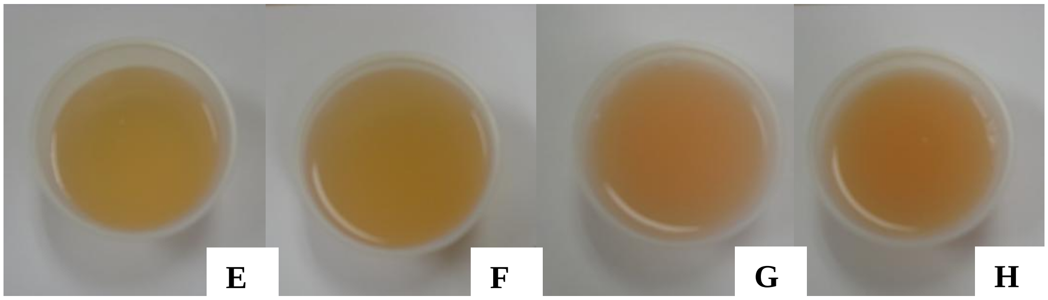

Figure 6. Pre-Workout Sports Drink Formulations E-H

Table 26. L*, C*, and h Values for the Post-Workout Sports Drink Formulations

Color			
Sample	**L***	**C***	**h**
I	8.85 ± 0.07^{CD}	18.23 ± 0.15^{C}	133.84 ± 0.20^{A}
J	8.33 ± 0.04^{D}	18.16 ± 0.10^{C}	133.56 ± 0.07^{A}
K	13.72 ± 0.29^{B}	18.28 ± 0.55^{C}	123.25 ± 0.19^{B}
L	12.66 ± 0.21^{BC}	19.25 ± 0.33^{BC}	122.18 ± 0.70^{B}
M	9.71 ± 0.72^{BCD}	19.92 ± 0.45^{B}	47.58 ± 1.94^{E}
N	11.53 ± 0.77^{BCD}	19.80 ± 0.44^{B}	55.99 ± 1.95^{D}
O	21.80 ± 1.98^{A}	27.92 ± 0.68^{A}	64.21 ± 0.97^{C}
P	21.84 ± 0.48^{A}	28.31 ± 0.32^{A}	65.54 ± 0.97^{C}

*Numbers represent an average plus or minus the standard deviation of three samples taken per formulation. See Tables 21 and 22 for formulations A-P. Mean values in each column with the same letters are not significantly different (p>0.05).

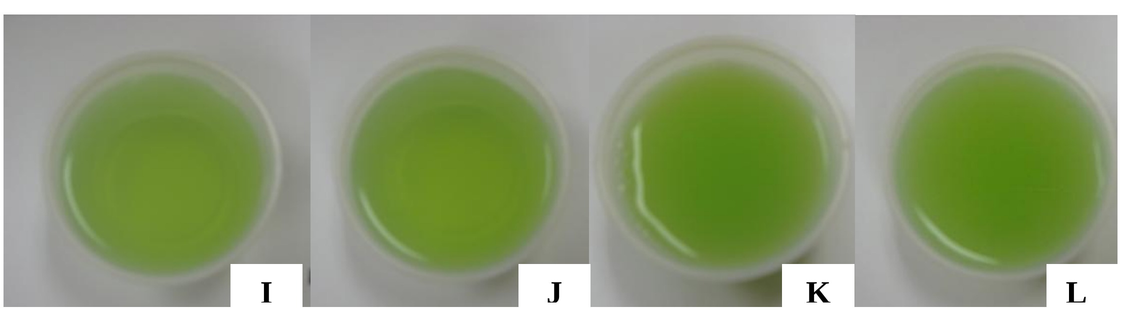

Figure 7. Post-Workout Sports Drink Formulations I-L

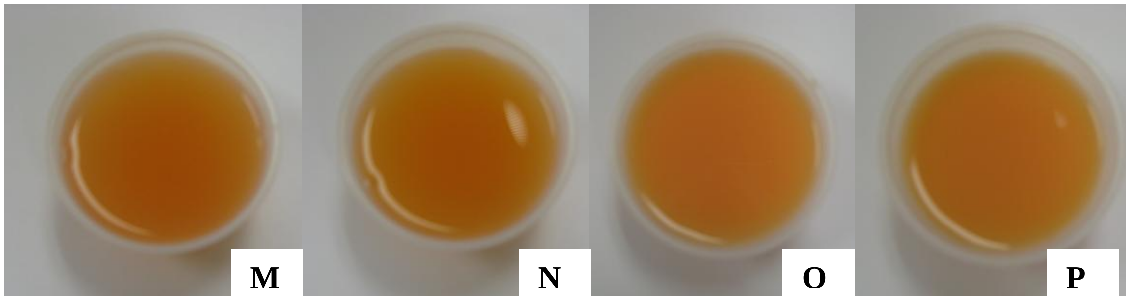

Figure 8. Post-Workout Sports Drink Formulations M-P

4.3.2 Consumer Acceptability

Analysis of variance results for the acceptability of appearance, aroma, color and consistency are presented in Table 27, and acceptability of mouthfeel, flavor, sweetness, and overall liking are represented in Table 28. Formulations A-H represent the eight pre-workout sports drinks (Table 21), and formulations I-P represent the eight post-workout sports drinks (Table 22). The numbers in the tables represent the mean score and standard deviation for each formulation/sensory attribute combination. Each formulation was tested by 70 consumers, for a total of 280 consumers participating in the study. Each set of numbers in the table have a superscripted letter which represents the results from Tukey's Studentized Range (HSD) test. For each sensory attribute, formulations that have the same letter are not significantly different ($p>0.05$) from each other.

In terms of acceptability of appearance of the pre-workout sports drinks, consumers perceived formulation A (CH, S, Bry) as having the highest acceptability of appearance with a mean score of 6.61, however, it was not significantly different from formulas B, C, and D (Table 27). Formulations A, B, C and D, were perceived to be more acceptable than formulations E, F, G, and H. The consumers were able to detect significant differences in the aroma of the pre-workout sports drinks, with the predominant aroma coming from the protein source.

Formulations with casein hydrolysate and whey protein isolate were generally found to be significantly different from each other, except formulation G. Sports drinks that were prepared with Isolac Clear, a whey protein isolate, had a greater acceptability of aroma. Consumers evaluated formulation A (CH, S, Bry) as having the highest acceptability of color, which had a deep purple color from the natural berry flavor that was used. Also, acceptability of formulations A, B, C, and D were perceived to be significantly different from formulations F, G, and H, which were of a different color. Formulation C (WPI, S, Bry) had the greatest acceptability of consistency with a mean score of 6.50, and was found to be significantly different from formulations E, F, G, and H. Formulation E (CH, S, TF) had the lowest acceptability for appearance, aroma, and consistency.

For the post-workout sports drinks, no significant differences were found among the formulations when the consumers evaluated appearance, color, and consistency. In terms of aroma, when evaluating formulations I, J, K and L, which all shared the same lemon/lime flavor, consumers were able to detect significant differences between the formulation with whey protein isolate (K) and the two formulations (I and J) with casein hydrolysate. For formulations M, N, O, and P, formula M (CH, S, O) was significantly different from P (WPI, G, O), which differ in protein and sugar source. Formulation K (WPI, S, LL) had high acceptability of appearance, color, and consistency, and formulation P (WPI, G, O) had high acceptability of aroma.

Table 28 represents results for consumer acceptance of mouthfeel, flavor, sweetness, and overall liking. For the pre-workout drinks, formulation C (WPI, S, Bry) had the highest acceptability mouthfeel, flavor, sweetness, and overall liking, with mean hedonic scores of 6.83, 6.33, 6.39, and 6.23 respectively. When evaluating mouthfeel, consumers perceived formulation C (WPI, S, Bry) as being significantly different from formulas B (CH, G, Bry), E (CH, S, TF), and F (CH, G, TF), which have casein hydrolysate as their protein source. For flavor, sweetness, and overall liking, formula C (WPI, S, Bry) was significantly different from all of the other pre-workout sports drink formulas.

Consumer acceptability of mouthfeel did not coincide with viscosity measurements for the post-workout drinks. Formulations K and P had the greatest acceptability of mouthfeel, but had the second and third highest viscosity readings (18.94 and 18.92). Formulations P (WPI, G, O) and K (WPI, S, LL) had the highest acceptability of mouthfeel, with mean hedonic scores of 6.47, and formulation P also had the greatest acceptability of flavor, sweetness, and overall liking with mean hedonic scores of 6.79, 6.66, and 6.61 respectively. However, consumers did not perceive formulation P as being significantly different from formulation K (WPI, S, LL) when evaluating flavor, sweetness, and overall liking. Formulation J (CH, G, LL) had the lowest mean score for acceptability of mouthfeel, flavor, sweetness, and overall liking, and for sweetness and overall liking, formulation J was significantly from all other formulations.

In conclusion, for the pre-workout sports drinks, formulation C (WPI, S, Bry) had the highest acceptability of aroma, consistency, mouthfeel, flavor, sweetness, and overall liking. This formulation, which has the combination of whey protein isolate, sucrose, and natural berry flavor was perceived to be significantly different, in terms of flavor, sweetness, and overall liking from all other pre-workout formulations. These three sensory attributes are integral in determining overall product acceptability. For the post-workout drinks, formulation P (WPI, G, O) had the highest acceptability of aroma, mouthfeel, flavor, sweetness, and overall liking but was not significantly different from formulation K (WPI, S, LL) for all sensory attributes.

Table 27. Mean Acceptability Scores for Appearance, Aroma, Color, and Consistency of Pre- and Post-Workout sports drinks

Formulation*	**Mean Scores for Sensory Attributes****			
	Appearance	**Aroma**	**Color**	**Consistency**
A	6.61 $\pm$ 1.34^{A}	3.91 $\pm$ 1.75^{C}	6.83 $\pm$ 1.26^{A}	6.10 $\pm$ 1.49^{AB}
B	6.33 $\pm$ 1.58^{AB}	3.87 $\pm$ 1.81^{C}	6.13 $\pm$ 1.63^{AB}	6.00 $\pm$ 1.53^{AB}
C	6.29 $\pm$ 1.49^{AB}	5.69 $\pm$ 1.51^{A}	6.46 $\pm$ 1.38^{A}	6.50 $\pm$ 1.41^{A}
D	5.99 $\pm$ 1.66^{AB}	5.03 $\pm$ 1.79^{AB}	6.11 $\pm$ 1.58^{AB}	6.06 $\pm$ 1.88^{AB}
E	4.57 $\pm$ 1.88^{D}	3.37 $\pm$ 1.63^{C}	5.19 $\pm$ 1.60^{BC}	4.94 $\pm$ 1.64^{C}
F	4.74 $\pm$ 1.54^{D}	3.84 $\pm$ 1.76^{C}	5.00 $\pm$ 1.63^{C}	5.38 $\pm$ 1.82^{BC}
G	5.10 $\pm$ 1.58^{DC}	4.81 $\pm$ 1.29^{C}	5.21 $\pm$ 1.47^{C}	5.33 $\pm$ 1.57^{BC}
H	5.57 $\pm$ 1.60^{BC}	4.97 $\pm$ 1.54^{AB}	5.54 $\pm$ 1.65^{C}	5.58 $\pm$ 1.71^{BC}
I	6.66 $\pm$ 1.68^{A}	4.23 $\pm$ 1.93^{C}	6.67 $\pm$ 1.61^{A}	6.19 $\pm$ 1.66^{A}
J	6.64 $\pm$ 1.99^{A}	4.17 $\pm$ 2.11^{C}	6.62 $\pm$ 1.77^{A}	5.94 $\pm$ 1.70^{A}
K	6.77 $\pm$ 1.60^{A}	5.44 $\pm$ 1.68^{AB}	6.94 $\pm$ 1.41^{A}	6.40 $\pm$ 1.42^{A}
L	6.54 $\pm$ 1.73^{A}	5.09 $\pm$ 1.58^{ABC}	6.57 $\pm$ 1.40^{A}	5.96 $\pm$ 1.53^{A}
M	6.56 $\pm$ 1.55^{A}	4.83 $\pm$ 1.84^{BC}	6.61 $\pm$ 1.47^{A}	6.01 $\pm$ 1.49^{A}
N	6.66 $\pm$ 1.47^{A}	5.20 $\pm$ 1.71^{AB}	6.67 $\pm$ 1.28^{A}	5.80 $\pm$ 1.61^{A}
O	6.37 $\pm$ 1.64^{A}	5.74 $\pm$ 1.76^{AB}	6.50 $\pm$ 1.61^{A}	6.17 $\pm$ 1.58^{A}
P	6.44 $\pm$ 1.49^{A}	5.90 $\pm$ 1.84^{A}	6.46 $\pm$ 1.51^{A}	6.36 $\pm$ 1.61^{A}

*Formulations A-H represent the eight pre-workout drinks (Table 21), and formulations I-P represent the eight post-workout drinks (Table 22).
** Numbers in the table represent the mean score, plus or minus the standard deviation for each sample/sensory attribute combination. Each number in the table has a corresponding superscripted letter. Mean scores with the same letter for each attribute are not significantly different from each other ($p>0.05$). 70 consumers tested each formula.

Table 28. Mean Acceptability Scores for Mouthfeel, Flavor, Sweetness, and Overall liking of Pre- and Post-Workout Sports Drinks

Formulation*	Mean Scores for Sensory Attributes**			
	Mouthfeel	Flavor	Sweetness	Overall Liking
A	6.03 ± 1.76^{AB}	3.69 ± 2.06^{CDE}	4.37 ± 1.84^{BCD}	4.20 ± 1.85^{BCD}
B	5.63 ± 1.99^{BCD}	3.53 ± 2.08^{DE}	3.87 ± 2.00^{DE}	3.94 ± 2.05^{CDE}
C	6.83 ± 1.58^{A}	6.33 ± 1.69^{A}	6.39 ± 1.50^{A}	6.23 ± 1.57^{A}
D	6.03 ± 1.99^{AB}	4.76 ± 2.00^{B}	4.77 ± 1.99^{BCD}	4.99 ± 1.82^{B}
E	4.91 ± 1.77^{D}	3.17 ± 1.80^{E}	4.06 ± 2.01^{CDE}	3.37 ± 1.65^{DE}
F	5.03 ± 1.88^{CD}	2.90 ± 1.70^{E}	3.31 ± 1.68^{E}	3.07 ± 1.71^{E}
G	5.61 ± 1.77^{BDC}	4.46 ± 2.07^{BCD}	5.13 ± 1.73^{B}	4.67 ± 1.89^{BC}
H	5.91 ± 1.68^{ABC}	4.67 ± 1.96^{BC}	4.97 ± 1.79^{BC}	4.71 ± 1.94^{BC}
I	5.80 ± 1.81^{ABC}	4.00 ± 2.93^{DE}	4.50 ± 2.21^{B}	4.40 ± 2.30^{D}
J	4.89 ± 2.16^{C}	2.94 ± 2.15^{E}	3.46 ± 2.16^{C}	3.36 ± 2.25^{E}
K	6.47 ± 1.53^{A}	6.47 ± 1.89^{AB}	6.54 ± 1.66^{A}	6.59 ± 1.51^{A}
L	5.74 ± 1.98^{ABC}	4.39 ± 1.91^{CD}	4.70 ± 2.04^{B}	4.83 ± 1.73^{CD}
M	6.03 ± 1.63^{AB}	5.43 ± 2.34^{BC}	5.89 ± 2.00^{A}	5.44 ± 2.16^{BC}
N	5.53 ± 1.85^{BC}	4.44 ± 2.09^{CD}	4.51 ± 2.03^{B}	4.61 ± 2.03^{CD}
O	6.30 ± 1.72^{AB}	6.39 ± 2.07^{AB}	6.37 ± 1.84^{A}	6.33 ± 1.92^{AB}
P	6.47 ± 1.82^{A}	6.79 ± 1.78^{A}	6.66 ± 1.68^{A}	6.61 ± 1.84^{A}

*Formulations A-H represent the eight pre-workout drinks (Table 21), and formulations I-P represent the eight post-workout drinks (Table 22).
** Numbers in the table represent the mean score, plus or minus the standard deviation for each sample/sensory attribute combination. Each number in the table has a corresponding superscripted letter. Mean scores with the same letter for each attribute are not significantly different from each other (p>0.05). 70 consumers tested each formulation.

4.3.3 Overall Product Differences

Multivariate analysis of variance (MANOVA) was used to determine if the eight pre-workout sports drinks and the eight post-workout sports drinks were different when all sensory attributes were compared simultaneously. According to the Wilks' Lambda statistic of 0.5269, and a probability greater than the F statistic of less than 0.0001 (Table 29), there was a difference among eight pre-workout drinks when the eight sensory attributes were compared at the same time. For the eight post-workout drinks, MANOVA resulted in a Wilks' Lambda of 0.5997, and a corresponding probability greater than the F statistic of less than 0.001 (Table 30). These results indicate that there was a difference among eight post-workout sports drinks when the eight sensory attributes (appearance, aroma, color, consistency, mouthfeel, flavor, sweetness, and overall liking) were concurrently compared. In order to determine which of the eight sensory attributes contributed to the product differences, DDA (Descriptive Discriminant Analysis) was used.

As indicated by the canonical structure in the first dimension (Table 31/Can1), aroma (0.7723), flavor (0.8862), sweetness (0.7998), and overall liking (0.8354) were sensory attributes that contributed to the differences in the pre-workout sports drinks. When looking at the second dimension, Can 2, visual appearance (0.9052) and color (0.8136) also contributed to the overall product differences. These six attributes, aroma, flavor, sweetness, overall liking, visual appearance, and color represented 86.77% of the cumulative variance explained. For the post-workout sports drinks, flavor (0.9137), sweetness (0.8478), and overall liking (0.8322) are the three sensory attributes that contributed the most to the differences in the sports drinks (Table 32/Can1). The sensory attributes flavor, sweetness, and overall liking contribute 81.83% of the cumulative variance explained.

Table 29. Multivariate Analysis of Variance for Pre-Workout Sports Drinks

MANOVA	Test Criteria and F Approximations for the Hypothesis of No Overall Form Effect				
H = Type III SSCP Matrix for Forms E = Error SSCP Matrix S = 7 M = 0 N = 268					
Statistic	Value	F Value	Numerator DF	Denominator DF	Pr>F
Wilks' Lambda	0.5269	6.51	56	288.6	<0.001
Pillai's Trace	0.5680	5.97	56	3787	<0.001
Hotelling-Lawley Trace	0.7290	6.94	56	1919.5	<0.001
Roy's Greatest Root	0.3912	26.46	8	541	<0.001

Table 30. Multivariate Analysis of Variance for Post-Workout Sports Drinks

MANOVA	Test Criteria and F Approximations for the Hypothesis of No Overall Form Effect				
H = Type III SSCP Matrix for Forms E = Error SSCP Matrix S = 7 M = 0 N = 267					
Statistic	Value	F Value	Numerator DF	Denominator DF	Pr>F
Wilks' Lambda	0.5997	5.16	56	2902.5	<0.001
Pillai's Trace	1.4380	4.54	56	3808	<0.001
Hotelling-Lawley Trace	0.6070	5.82	56	1930.3	<0.001
Roy's Greatest Root	0.4967	33.77	8	544	<0.001

Table 31**. Canonical Structure (r's) Describing Group Differences among the Eight Pre-Workout Formulations**[1]

Sensory Attribute	**Can 1***	**Can 2***
Visual Appearance	0.2192	0.9052**
Aroma	0.7723**	0.0710
Color	0.1881	0.8136**
Consistency	0.2510	0.5195
Mouthfeel	0.4702	0.3941
Flavor	0.8862**	0.2101
Sweetness	0.7998**	0.1384
Overall Liking	0.8354**	0.3298
Cum. Variance Explained	53.67%	86.77%

[1]Based on the pooled within group variances.
*Can1 and Can2 represents pooled within canonical structure in the first and second dimensions, respectively.
**Attributes that contribute to overall differences among samples.

Table 32. Canonical Structure (r's) Describing Group Differences among the Eight Post-Workout Formulations[1]

Sensory Attribute	Can 1**	Can 2**
Visual Appearance	-0.0483	0.1068
Aroma	0.4919	-0.5961
Color	-0.0164	0.1910
Consistency	0.1544	0.2291
Mouthfeel	0.4439	0.1988
Flavor	0.9137**	0.0579
Sweetness	0.8478**	0.3051
Overall Liking	0.8322**	0.1051
Cum. Variance Explained	81.83%	91.69%

[1]Based on the pooled within group variances.
*Can1 and Can2 represents pooled within canonical structure in the first and second dimensions, respectively.
**Attributes that contribute to overall differences among samples.

4.3.4 Product Acceptance and Purchase Intent

After evaluating the sports drinks for acceptability of the eight sensory attributes (appearance, aroma, color, consistency, mouthfeel, flavor, sweetness, and overall liking), consumers were asked yes/no questions regarding whether they thought the products were acceptable, whether they would purchase the product, and whether they would purchase the product after given information about exercise enhancement. The results for acceptance, purchase intent, and purchase intent after given information about the pre-workout sports drinks are presented in Table 33, and the same results for the post-workout sports drinks are in Table 34.

Formulation C (WPI, S, Bry) had the highest acceptance of 85.71%. Formulation D (WPI, G, Bry) had the second highest acceptability with 67.14% acceptance, followed by formulation H (WPI, G, TF) with 61.76% acceptance. Formulation C (WPI, S, Bry) also had the greatest purchase intent with 58.57%, followed by formulations D and H with only 27.14%. For purchase intent after given information about health benefits during exercise enhancement, formulation C (WPI, S, Bry) had the greatest purchase intent of 78.57%, followed by formulation

D (WPI, G, Bry) with 62.86%. Formulation E (CH, S, TF) had the lowest acceptance (24.29%), a low purchase intent (7.14), and the lowest purchase intent after given information about the product (32.86%). Formulation C (WPI, S, Bry), which had the greatest acceptability, purchase intent, and purchase intent after given exercise enhancing information about the product, also had the highest mean hedonic scores aroma, consistency, mouthfeel, flavor, sweetness, and overall liking (Tables 26 and 27).

Table 33. Percent Affirmative Responses for Product Acceptance and Purchase Intent of the Eight Pre-Workout Sports Drink Formulations

Formulation*	Acceptance	Purchase Intent	Purchase Intent for During Exercise Enhancement
A	42.86	11.43	52.86
B	37.68	19.12	46.38
C	85.71	58.57	78.57
D	67.14	27.14	62.86
E	24.29	7.14	32.86
F	30.00	5.71	35.71
G	53.62	21.43	40.00
H	61.76	27.14	44.29

*See Table 21 for formulations A-H.

For the post-workout sports drinks, formulation P (WPI, G, O) had the highest acceptance of 89.71%, followed closely by formulations K (WPI, S, LL), and O (WPI, S, O), with acceptability percentages of 85.29, and 84.06, respectively. Formulation P also had the highest purchase intent of 67.14%, followed by formulations O and K with 60.87 and 58.57 percent purchase intent. Consumers evaluated formulations K (WPI, S, LL) and O (WPI, S, O) as having the highest purchase intent (75.71%) after given benefits of post exercise enhancement. Formulations K and O were followed closely by formulation P (WPI, G, O) having a purchase intent of 74.29% after given benefits of the sports drink. Formulation J had the lowest acceptance, purchase intent, and purchase intent for post exercise enhancement (31.43%, 20.29%, 31.43%). Formulation P, which had the highest acceptability and purchase intent, also had the greatest mean scores for acceptability aroma, mouthfeel, flavor, sweetness, and overall liking (Tables 26 and 27). Formulation J, which had the lowest acceptability, purchase intent, and purchase intent for post exercise enhancement, also had the lowest mean hedonic scores for aroma, mouthfeel, flavor, sweetness, and overall liking (Tables 26 and 27).

Table 34. Percent Affirmative Responses for Product Acceptance and Purchase Intent of the Eight Post-Workout Sports Drink Formulations

Formulation*	Acceptance	Purchase Intent	Purchase Intent for Post Exercise Enhancement
I	50.00	24.29	42.86
J	31.43	20.29	31.43
K	85.29	58.57	75.71
L	59.42	31.43	52.86
M	71.43	48.53	60.00
N	57.14	25.71	44.29
O	84.06	60.87	75.71
P	89.71	67.14	74.29

*See Table 22 for formulations I-P.

4.3.5 Logistic Regression for Product Acceptance and Purchase Intent

Logistic regression was used to predict product acceptance and purchase intent using all eight attributes evaluated using the 9-point hedonic scale. Tables 35 and 36 represent the predictive models that were used to predict purchase intent and product acceptability for the pre- and post-workout sports drinks. Purchase intent was evaluated before and after given the information about exercise enhancement. Prediction models were established using the intercept and estimate from logistic regression output.

Table 35. Full Logistic Regression Models for Predicting Acceptance and Purchase Decisions of Pre-Workout Sports Drinks

Attributes	Predictive Model*
Acceptance	Y = -5.2580 + 0.1370 (Appearance) + 0.1196 (Aroma) – 0.0649 (Color) + 0.0603 (Consistency) – 0.0200 (Mouthfeel) + 0.4278 (Flavor) + 0.0484 (Sweetness) + 0.5100 (Overall Liking)
Purchase Intent	Y= -13.7176 + 0.0610 (Appearance) + 0.4225 (Aroma) + 0.0475 (Color) + 0.0541 (Consistency) + 0.0387 (Mouthfeel) + 0.2658 (Flavor) + 0.1088 (Sweetness) + 1.2366 (Overall Liking)
Purchase Intent / During Exercise Enhancement	Y= -4.6847 + 0.1985 (Appearance) – 0.00466 (Aroma) – 0.0391 (Color) + 0.1643 (Consistency) - 0.0678 (Mouthfeel) +0.0243 (Flavor)+ 0.1306 (Sweetness) + 0.5816 (Overall Liking)

*Predictive models based on estimates for each of the sensory attributes that resulted from logistic regression analysis.

Table 36. Full Logistic Regression Models for Predicting Acceptance and Purchase Decisions of Post-Workout Sports Drinks

Attributes	Predictive Model*
Acceptance	Y= -7.7517 + 0.0696 (Appearance) – 0.0621 (Aroma) – 0.0247 (Color) + 0.2896 (Consistency) – 0.0163 (Mouthfeel) +0.5966 (Flavor)+ 0.3208 (Sweetness) + 0.5887 (Overall Liking)
Purchase Intent	Y= -11.9807 – 0.0416 (Appearance) + 0.0393 (Aroma) + 0.1291 (Color) + 0.4357 (Consistency) – 0.2130 (Mouthfeel)+ 0.6234 (Flavor) + 0.0717 (Sweetness) + 0.9253 (Overall Liking)
Purchase Intent / Post Exercise Enhancement	Y= -5.8409 + 0.0239 (Appearance) – 0.0252 (Aroma) + 0.0116 (Color) + 0.2668 (Consistency) – 0.1327 (Mouthfeel) – 0.1160 (Flavor)+ 0.1414 (Sweetness) + 0.9821 (Overall Liking)

* Predictive models based on estimates for each of the sensory attributes that resulted from logistic regression analysis.

As seen in Tables 37 and 38, logistic regression produces probabilities greater than the χ^2 statistic and odds ratios. If the sensory parameter (appearance, aroma, color, consistency, mouthfeel, flavor, sweetness, and overall liking) proves to be significant, the corresponding odds ratio can help predict consumer acceptance, purchase intent, and purchase intent after given information about the product. Parameters that are significant have a Pr>χ^2 less than 0.05.

For the pre-workout sports drinks, flavor (Pr>χ^2 of 0.0002) and overall liking (Pr>χ^2 of <0.0001) are significant variables in predicting consumer acceptance (Table 37). The corresponding odds ratio indicates that for a one point increase in the mean hedonic scores for flavor and overall liking there will be a corresponding increase in consumer acceptance of 53.4 and 66.5 percent, respectively. For consumer purchase intent, aroma (Pr>χ^2 of 0.0002) and overall liking (Pr>χ^2 of <0.0001) are significant variables, indicating that for a one point increase in the mean hedonic scores for aroma and overall liking, purchase intent will increase 1.526 and 3.444 times respectively. When evaluating purchase intent for during exercise enhancement, appearance and overall liking are significant variables that will help predict consumer purchase intent after consumers are given the exercise enhancing information about the sports drinks. The odds ratio shows that for a one point increase in the mean hedonic scores for appearance and overall liking, there will be a resultant increase in consumer purchase intent after given information about the product of 22.0% and 78.9% ,respectively. For overall liking, the odds ratio decreased from 3.444 to 1.789 when comparing purchase intent to purchase intent for during exercise enhancement. This trend indicates that consumers are willing to sacrifice overall liking for the potential exercise enhancement. Consumer acceptance, purchase intent, and purchase intent after given information about the sports drinks could be predicted with 79.42%, 84.42%, and 75.14% accuracy, respectively (Table 38).

Table 37. Probability $>\chi^2$ and Odds Ratio Point Estimates for Acceptance and Purchase Intent for the Pre-Workout Sports Drinks

Consumer Acceptance			
Parameter	**Estimate**	**Pr $>\chi^2$**	**Odds Ratio**
Appearance	0.1370	0.1837	1.147
Aroma	0.1196	0.1359	1.127
Color	-0.0649	0.5438	0.937
Consistency	0.0630	0.5234	1.062
Mouthfeel	-0.0200	0.8224	0.980
Flavor	0.4278	0.0002	1.534
Sweetness	0.0484	0.6051	1.050
Overall Liking	0.5100	<0.0001	1.665
Consumer Purchase Intent			
Parameter	**Estimate**	**Pr $>\chi^2$**	**Odds Ratio**
Appearance	0.0610	0.7119	1.063
Aroma	0.4225	0.0020	1.526
Color	0.0475	0.7806	1.049
Consistency	0.0541	0.7066	1.056
Mouthfeel	0.0387	0.7891	1.039
Flavor	0.2658	0.1185	1.304
Sweetness	0.1088	0.4766	1.115
Overall Liking	1.2366	<0.0001	3.444
Consumer Purchase Intent / During Exercise Enhancement			
Parameter	**Estimate**	**Pr $>\chi^2$**	**Odds Ratio**
Appearance	0.1985	0.0333	1.220
Aroma	-0.00466	0.9487	0.995
Color	-0.0391	0.6846	0.962
Consistency	0.1643	0.0516	1.179
Mouthfeel	-0.0678	0.4000	0.934
Flavor	0.0243	0.8265	1.025
Sweetness	0.1306	0.1172	1.140
Overall Liking	0.5816	<0.0001	1.789

*Sensory attributes that have a Pr$>\chi^2$ less than 0.05 are significant.

Table 38. Percent Hit Rate for Product Acceptance and Purchase Decision

Pre-Workout		**Post-Workout**	
Attribute	**% Hit Rate**	**Attribute**	**% Hit Rate**
Acceptance	79.42	Acceptability	85.15
Purchase Intent	84.42	Purchase Intent	83.63
Purchase Intent / During Exercise	75.14	Purchase Intent/ Post Exercise	80.29

Table 39. Probability $>\chi^2$ and Odds Ratio Point Estimates for Acceptance and Purchase Intent for the Post-Workout Sports Drinks

Consumer Acceptance			
Parameter	**Estimate**	**Pr $>\chi^2$**	**Odds Ratio**
Appearance	0.0696	0.6763	1.072
Aroma	-0.0621	0.6056	0.940
Color	-0.0247	0.8868	0.976
Consistency	0.2896	0.0806	1.336
Mouthfeel	-0.0163	0.9127	0.984
Flavor	0.5966	0.0007	1.816
Sweetness	0.3208	0.0154	1.378
Overall Liking	0.5887	0.0011	1.802
Consumer Purchase Intent			
Parameter	**Estimate**	**Pr $>\chi^2$**	**Odds Ratio**
Appearance	-0.0416	0.8137	0.959
Aroma	0.0393	0.7169	1.040
Color	0.1291	0.4726	1.138
Consistency	0.4357	0.0221	1.546
Mouthfeel	-0.2130	0.2457	1.158
Flavor	0.6234	0.0008	1.865
Sweetness	0.0717	0.6577	1.074
Overall Liking	0.9253	<0.0001	2.532
Consumer Purchase Intent / Post Exercise Enhancement			
Parameter	**Estimate**	**Pr $>\chi^2$**	**Odds Ratio**
Appearance	0.0239	0.9338	1.024
Aroma	-0.0252	0.7855	0.975
Color	0.0116	0.0468	1.012
Consistency	0.2668	0.8596	1.306
Mouthfeel	-0.1327	0.2869	0.876
Flavor	-0.1160	0.4332	0.890
Sweetness	0.1414	0.2264	1.152
Overall Liking	0.9821	<0.0001	2.670

*Sensory attributes that have a Pr$>\chi^2$ less than 0.05 are significant.

For the post-workout sports drinks, flavor (Pr$>\chi2$ of 0.0007), sweetness (Pr$>\chi2$ of 0.0154), and overall liking (Pr$>\chi2 < 0.0001$), are significant variables when predicting consumer acceptance (Table 39). The resultant odds ratio implies that for a one point increase in the mean hedonic scores for flavor, sweetness, and overall liking, acceptance will increase 1.816, 1.378, and 1.802 times, respectively. Consistency (Pr$>\chi2$ of 0.0221), flavor (Pr$>\chi2$ of 0.0008), and overall liking (Pr>χ2 of <0.0001) are significant sensory attributes when predicting consumer purchase intent. For a one-point increase in the mean hedonic scores for consistency, flavor, and overall liking, there will be an increase in purchase intent of 54.6%, 86.5%, and 153.2% respectively. When predicting purchase intent after the consumers were given information about the sports drink, overall liking is the most significant variable (Pr>χ2 of <0.0001), followed by color. If the mean hedonic score for overall liking were to increase by one point, there would be an increase in purchase intent after given information about the sports drink of 167.0%. Consumer acceptance, consumer purchase intent, and purchase intent after given information about post-exercise enhancement could be predicted with 85.15%, 83.63%, and 80.29% accuracy, respectively (Table 38).

4.3.6 Change in Probability of Purchase Intent

The McNemar test was used to analyze the change in probability of consumer purchase intent before and after being informed about the benefits of the pre and post-workout sports drinks. The null hypothesis for the McNemar test states that there is no significant difference in probability of buying the product before and after consumers have been informed about the health benefits, or

$$H_0: \pi_{+1\ (\text{total yes after})} - \pi_{1+\ (\text{total yes before})} = 0.$$

For the pre-workout sports drinks, the probability of purchase intent after given information about exercise enhancement was significant for all eight formulations (Table 40). The degree at which purchase intent can increase is expressed by the lower confidence interval (LCI) and the upper confidence interval, which are predicted with 95% confidence (Table 40). For example, the purchase intent for formulation A (CH, S, Bry) can increase as little as 29.9% or as much as 53.0% after the consumer is made aware of exercise enhancing benefits. The least significant formulation was H (WPI, G, TF), which only resulted in an increase in purchase intent between 7.5 and 26.8 percent.

Table 40. Changes in Probability of Purchase Intent for Pre-Workout Sports Drinks

Formulation	χ^2	P-Value*	95% LCI**	95% UCI***
A	29.0000	0.0001	0.299	0.530
B	19.0000	0.0001	0.173	0.386
C	12.2500	0.0005	0.098	0.302
D	23.1481	0.0001	0.238	0.476
E	18.0000	0.0001	0.155	0.360
F	21.0000	0.0001	0.193	0.407
G	11.2667	0.0008	0.086	0.285
H	10.2857	0.0013	0.075	0.268

* P-values < α (0.05) are significant.
**LCI- lower confidence interval.
***UCI- upper confidence interval. See Table 21 for formulations.

The p-values for the post workout drinks indicate that all formulations had significant increases in purchase intent after given information about the sports drink, except for formulation P (P-value of 0.0588) (Table 41). Formulations I (CH, S, LL) and L (WPI, G, LL) had the most significant p-values indicating an increase in purchase intent between 9.5%-27.7% and 11.0%-31.8%, respectively. Formulation P was not significant because the purchase intent was already high (67.14%) before given information about the product.

Table 41. Changes in Probability of Purchase Intent for Post-Workout Sports Drinks

Formulation	χ^2	P-Value*	95% LCI**	95% UCI***
I	13.0000	0.0003	0.095	0.277
J	6.4000	0.0114	0.030	0.202
K	12.0000	0.0005	0.083	0.260
L	13.2353	0.0003	0.110	0.318
M	7.3636	0.0067	0.042	0.223
N	9.9412	0.0016	0.079	0.293
O	9.3077	0.0023	0.064	0.255
P	3.5714	0.0588	-0.001	0.144

* P-values < α (0.05) are significant.
**LCI- lower confidence interval.
***UCI- upper confidence interval. See Table 22 for formulations.

4.3.7 Principal Component Analysis

Principal component analysis produced a bi-plot expressing the relative positions of the pre- and post-workout drinks and the sensory attributes. Figures 9 and 10 show the results in which the eight sensory attributes (appearance, aroma, color, consistency, mouthfeel, flavor, sweetness, and overall liking) are displayed in the plot of the first two principal components of the product acceptability data for the pre and post-workout sports drinks. The end points for the sensory attribute vectors were obtained by projecting the attributes into the product space. Orthogonal projections of the product formulation points on an attribute vector give an approximate ordering of the formulations on the attribute rating.

In Figure 9 we can see that for the pre-workout drinks, color and appearance are strongly correlated with each other, and with consistency and mouthfeel. Aroma and sweetness are also strongly correlated with each other and with overall liking and flavor. On the other hand, color and appearance are perpendicular to aroma, sweetness and mouthfeel, indicating a negative correlation between these attributes. Moreover, aroma, sweetness, flavor and overall liking are discriminating attributes for the pre-workout formulations. The discriminating attributes depicted by PCA correlate with the results obtained from descriptive discriminant analysis in which aroma, sweetness, flavor, and overall liking contributed the greatest to the product differences.

According to the groupings of formulations and the corresponding attributes, it is observed that formulations E (CH, S, TF) and F (CH, G, TF) were least related to all attributes, but had the lowest mean scores for all of the sensory attributes and had the lowest percentages for acceptance (24.29 and 30.00) and purchase intent (7.14 and 5.71). Formulations A and B, which were graphically correlated with color and appearance; both had the highest mean scores for acceptability of appearance (6.61 and 6.33) and the highest and third highest mean scores for acceptability of color (6.83 and 6.13), respectively. Formulations C (WPI, S, Bry) and D (WPI, G, Bry) had the highest mean scores for overall liking (6.23 and 4.99) and had the greatest acceptability (85.71 and 67.14) and purchase intent (58.57 and 27.14). Formulations H and G were not directly graphically correlated with any of the sensory attributes but had the third and fourth greatest acceptability percentages of 61.76 and 53.62, respectively.

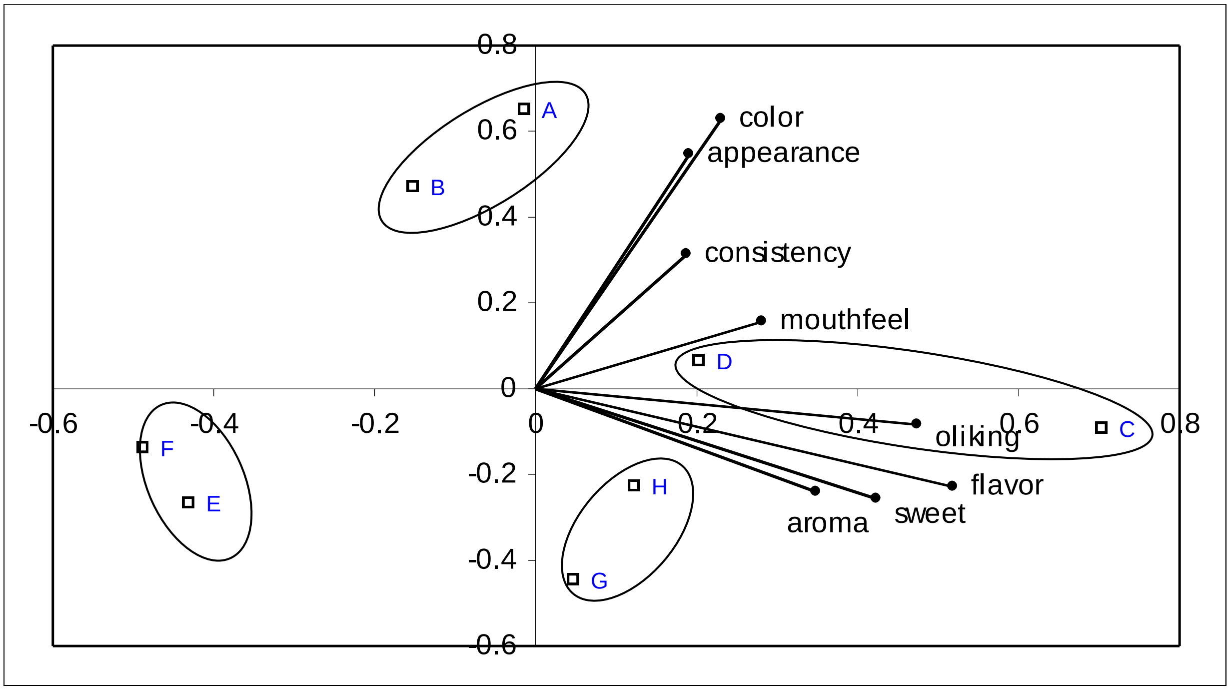

Figure 9. A PCA Bi-Plot of Product-sensory Acceptability of Pre-Workout Sports Drinks

Figure 10 represent the PCA bi-plot on consumer acceptance of the eight post-workout sports drink formulations. According to the bi-plot, appearance and color are highly correlated, along with flavor and overall liking. It is also observed that mouthfeel and aroma, and color and overall liking are inversely related because of their perpendicular formation on the bi-plot. We can also see that the consumers did not like the aroma of the products. The bi-plot also depicts that flavor, sweetness, and overall liking are discriminating sensory attributes, which correlates with the results of descriptive discriminant analysis.

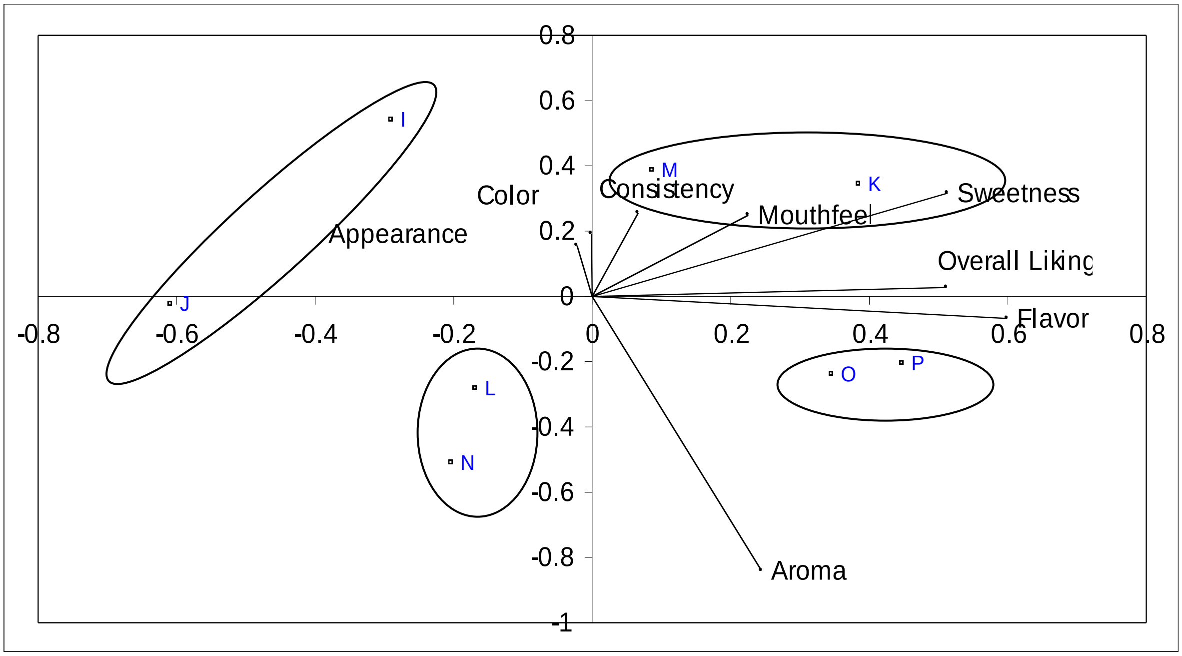

Figure 10. A PCA Bi-plot of product-sensory Acceptability of Post-Workout Sports Drinks

According to the groupings of formulations and the corresponding attributes for the post-workout sports drinks, it was observed that formulations I (CH, S, LL) and J (CH, G, LL) had low mean scores for all of the sensory attributes except for appearance and color, and the lowest percent acceptance (50.00% and 31.43%). The bi-plot also depicts that formulations L (WPI, G, LL) and N (CH, G, O) were not closely correlated with any of the sensory attributes. Formulations P (WPI, G, O) and K (WPI, S, LL) both graphically appear to be strongly correlated with flavor, sweetness, and overall liking, however formulation P had greater acceptability mean scores for these attributes (Table 28), and greater percentages for acceptance and purchase intent (Table 34).

4.4 Conclusions

The results of the physicochemical analysis indicated that for the pre-workout drinks, formulations with tropical fruit flavor had higher pH values than those formulations with berry flavor, which were more acidic. For the post-workout sports drinks, formulations with the lemon/lime flavor were more acidic than those with orange flavor. Overall, formulations with casein hydrolysate were less acidic than formulations with whey protein isolate. For viscosity, pre-workout formulation F (CH, G, TF) had the highest viscosity, and also had the second lowest mean acceptability score for mouthfeel. Formulations E (CH, S, TF) and C (WPI, S, Bry) had the lowest viscosity readings. For the post-workout drinks, formulation O (WPI, S, O) had the greatest viscosity, and formulation J (CH, G, LL) had the lowest viscosity. Viscosity readings did not correlate with acceptability of mouthfeel for the post-workout sports drinks. In terms of color, formulation C (WPI, S, Bry) had the highest chroma or intensity out of all the pre-workout drinks. Formulations O (WPI, S, O) and P (WPI, G, O) had the greatest chroma of all the post-workout sports drinks. Finally, formulations with whey protein isolate had higher L* values than those with casein hydrolysate. This can be attributed to the whiteness, or opacity the whey protein isolate imparts on the sports drinks.

For acceptability of the eight sensory attributes, formulation C (WPI, S, Bry) had the highest acceptability of aroma, consistency, mouthfeel, flavor, sweetness, and overall liking among the pre-workout sports drinks. This formulation, which has the combination of whey protein isolate, sucrose, and natural berry flavor was perceived to be significantly different, in terms of flavor, sweetness, and overall liking from all other pre-workout formulations. These three sensory attributes are integral in determining overall product acceptability. For the post-workout drinks, formulation P (WPI, G, O) had the highest acceptability of aroma, mouthfeel, flavor, sweetness, and overall liking but was not significantly different from formulation K (WPI, S, LL) for all sensory attributes.

Multivariate Analysis of Variance was significant for both the pre- and post-workout sports drinks. Following MANOVA, DDA indicated that aroma, flavor, sweetness, overall liking, visual appearance, and color are the most discriminating sensory attributes for a pre-workout drink. DDA also indicated that flavor, sweetness and overall liking were sensory attributes that contributed to the differences in the post-workout sports drinks. When evaluating acceptance and purchase intent, formulation C (WPI, S, Bry) had the highest acceptance (85.71%), the highest purchase intent (58.57%), and the highest purchase intent after given the pre-exercise enhancement information (62.86%). Among the post-workout drinks, formulation P (WPI, G, O) had the greatest acceptance (89.71%) and purchase intent (67.14%). Formulation K (WPI, S, LL) and O (WPI, S, O) had the highest purchase intent after given post-exercise enhancing information.

According to logistic regression analysis for the pre-workout sports drinks, flavor and overall liking helped predict consumer acceptance, while aroma and overall liking helped predict consumer purchase intent, and appearance and overall liking are significant variables that help to predict consumer purchase intent after consumers are made aware of the exercise enhancing benefits. For the post-workout sports drinks, flavor, sweetness and overall liking are the three significant sensory attributes that help predict consumer acceptance. Consistency, flavor, and overall liking are the three significant attributes that help to predict purchase intent, while overall liking is the only significant attribute that aids in the prediction of consumer purchase intent after they are made aware of the post-exercise enhancing information.

The McNemar test indicated that all sports drink formulations had significant changes in consumer purchase intent after they were given information about the product, except for formulation P. Formulation P (WPI, G, O) already had a high purchase intent percentage. The PCA bi-plot for the pre-workout sports drinks illustrated that flavor, sweetness, and overall liking were discriminating sensory attributes, which correlated with the results of descriptive discriminant analysis (DDA). The bi-plot for the post-workout sports drinks reiterated that formulations P (WPI, G, O) and K (WPI, S, LL) are strongly correlated with flavor, sweetness, and overall liking; however formulation, P had greater acceptability mean scores for these attributes and greater percentages for acceptability and purchase intent.

CHAPTER 5. CONSUMER VALIDATION AND MARKET POTENTIAL OF ACCEPTABLE PRE- AND POST-WORKOUT SPORT BEVERAGES

5.1 Introduction

Strength training, or weight lifting is a common practice among athletes and the every day gym attendants, who are usually looking for a competitive edge. The consumption of sports drinks is a popular way for athletes to get the proper nutrients before, during, or after exercise. Today's beverage market, in particular, sports drinks, is a multi-billion dollar market. For this study, the most acceptable pre- and post-workout formulations from Chapter 4, were selected for further analysis. The pre-workout drink selected was a combination of whey protein isolate, sucrose, and berry flavor, and the selected post-workout drink contained whey protein isolate, sucrose, and orange flavor. Two commercially available beverages, one to compare to the pre-workout drink and another to compare to the post-workout drink, were also selected. A large-scale consumer acceptance test was conducted to confirm the acceptability of the newly formulated pre- and post-workout beverages. The objectives of this study were (1) To validate the acceptance of the newly formulated pre and post-workout sports drinks, and to determine whether these beverages have market potential; (2) to evaluate demographic information associated with consumers of sports drinks.

5.2 Materials and Methods

5.2.1 Sports Drink Preparation

The most acceptable pre-workout beverage was prepared using whey protein isolate, sucrose, and berry flavor, and the most acceptable post-workout beverage was prepared using whey protein isolate, glucose, and orange flavor. The pre-workout drink also contained distilled water, sodium, potassium, vitamin C, leucine, gums, and colorants, and the post-workout drink contained distilled water, creatine, glutamine, vitamin C, gums, and colorants. Two commercially available samples were also prepared which included, Accelerade ® and Cytomax® Recovery.

Isolac Clear, the whey protein isolate used in the sports drink preparation, was obtained from Carbery in Chicago, Illinois. Isolac Clear typically contains 89% protein, 5% moisture, <0.5% fat, 3.5% ash, 2.5% lactose, and has a pH of 6.3. Microbiological specifications for Isolac Clear are as follows: standard plate count (SPC) of <50,000/cfug, coliforms <10/g, E. *coli* negative per 0.1g, S. *aureus* <10cfu/g, Salmonella negative per 25g, and yeast and molds 50cfu/g maximum. Dextrose, or D-glucose, and creatine monohydrate were purchased from Supplement Direct™, Santa Barbara, Ca. Creatine monohydrate is a micronized powder that dissolves clear in liquid. L-leucine, L-glutamine, and ascorbic acid are white crystalline powders that were obtained from Anmar International Ltd, Bridgeport, CT. The potassium source, potassium monophosphate, was obtained from The Wright Group in Crowley, La.

The Ingredient Company in Mississauga, ON provided Obipektin fruit powders to flavor the sports drinks. All natural berry flavor, lemon, and orange flavored fruit powders were used to flavor the sports drinks. The Berry Mix 231-A contains raspberry, strawberry, elderberry, blackberry, and bilberry. This flavor is produced by vacuum drying, and contains 31% fruit solids, 67.2% added sucrose, 86% total carbohydrates, 5-11% glucose, 6-12% fructose, 62-72% sucrose, and 0.0-1.9% protein. The Lemon 150-BP flavor is produced by low temperature spray drying, and contains 50% fruit solids, 50% added maltodextrin, 55% total carbohydrates, 4-13% glucose, 3-13% fructose, 0-0.35% sucrose, and 0.8-4.0% protein. The orange flavor, Orange 200, is a free-flowing powder produced by vacuum drying. This flavor contains 100% fruit solids, and no added sucrose, or maltodextrin. The orange fruit powder contains a maximum of 3%

moisture, 77% total carbohydrates, 14-24% glucose, 15-29% fructose, 20-40% sucrose, and 3-9% protein.

TIC Pretested® Colloid Ultrasmooth Powder, which contains cellulose gum, xanthan gum, and carrageenan was obtained from TIC Gums in Belcamp, MD. This gum blend also contains zero calories from fat, not total fat, no trans fat, no cholesterol, 6690 mg sodium, 579mg potassium, 80g carbohydrates, and no protein per 100 grams. Sucrose, or table sugar, salt (sodium chloride), and food coloring (Great Value™ Assorted Food Colors) were purchased from a local supermarket in Baton Rouge, La.

Accelerade ®, mountain berry flavor, was purchased from REI®, Houston, Tx, and contains filtered water, sugar, trehalose, whey protein isolate, citric acid, phosphoric acid, natural flavors, lactic acid, magnesium carbonate, salt, monopotassium phosphate, vitamin E acetate, blue 1, and sodium ascorbate. Cytomax ® Recovery, orange smoothie flavor, was purchased from Supplement Direct™, Santa Barbara, Ca, and contains Evopro Plus™ (micellar alpha and beta caseins and caseinates, whey concentrates rich in alphalactalbumin, whey isolates, milk protein isolates, whey peptides, L-glutamine, L-argenine, L-isoleucine, L-leucine, L-valine, and lactoferrin), Leanlipids™ (trans fat-free lipid complex consisting of canola oil, sunflower and/or safflower oil, MCT's, L-carnitine), Cytocarb III™ (unique complex carbohydrates blend including amylopectin starches, maltodextrins, and fructose), Cytovite I™ (vitamin and mineral premix consisting of vitamin A acetate, beta carotene, cholecalciferol, D-alpha-tocopherol acetate, ascorbic acid, folate, thiamine mononitrate, riboflavin, niacinamide, pyridoxine HCl, cyanocobalamin, biotin, pantothenic acid, di-calcium phosphate, potassium iodide, potassium chloride, ferrous fumarate, magnesium oxide, copper glaciated, zinc oxide, chromium nicotinate), Alpha-L-Polylactate™ (patented L-lactate formulation containing non-acidic l-lactate ionically bond to L-arginine), natural and artificial flavors, acesulfame potassium, sucralose, and soy lecithin.

Table 42. Ingredient Percentages for the Acceptable Pre and Post-Workout Sports Drinks

Ingredients	**Formulation %**	
	Pre-Workout (C)	**Post-Workout (P)**
Water	90.72	83.27
Sucrose	5.13	
Glucose		9.41
Isolac	1.44	2.64
Berry Flavor	1.54	
Lemon Flavor	0.51	
Orange Flavor		3.53
Vitamin C	0.01	0.02
Sodium	0.03	
Potassium	0.02	
L-Leucine	0.51	
L-Glutamine		0.47
Creatine		0.47
Gum	0.10	0.19

Sports drink formulations C (WPI, S, Bry) and P (WPI, G, O) were prepared by weighing the ingredients: Distilled water, Isolac, sucrose, glucose, vitamin C, sodium, potassium, leucine, glutamine, creatine, berry flavor, lemon flavor, orange flavor, and gum. For each formulation, the appropriate amounts of dry ingredients (Table 42) were added to the distilled water and mixed thoroughly until all particles were dissolved. Yellow (0.05g) and red (0.05g) food coloring (Great Value™ Assorted Colors, Baton Rouge, La) were also added to formulation P until the desired color and intensity was achieved. Each mixture was then transferred to a homogenizer to ensure that homogenous mixture was obtained. The homogenizer (Model 300 DJF 4 2PS, Manton-Gaulin Mfg. Co. Inc, Everett, MA) was flushed with sanitizer between samples to ensure that there would be no contamination. Each formulation was homogenized in three-gallon batches, for three fifteen-second cycles, totaling 45 seconds. The second stage of the homogenizer was set to 500 psi, and the first stage was set to 1500 psi, for a total of 2000 pounds per square inch of pressure. After homogenizing, the samples were pasteurized in cylindrical stainless steel containers using the batch pasteurization method. The containers were placed in a stainless steel vat with water, and were heated until the samples reached 160°F. The sports drinks were then pasteurized at 160°F for 30 minutes to ensure safety. After the mixtures were pasteurized, the stainless steel containers were removed from the vat and placed in an ice bath until cooled. When the mixtures reached 75°F, they were placed in half-gallon plastic milk cartons, capped, and stored in the refrigerator (40°F).

For the commercial samples, Accelerade ® required no preparation because it is a ready to drink (RTD) beverage. However, Cytomax ® Recovery is only available in powder form. Cytomax ® Recovery was prepared according to the directions given by the manufacturer. Two scoops of powder (75g) was mixed with 12 ounces of cold water and mixed until all of the ingredients were dissolved. A total of two gallons of Cytomax ® Recovery was prepared, and red and yellow food coloring (0.05g each) was added to avoid consumer bias based on the color of the sample. The samples were then stored in the refrigerator (40°F).

5.2.2 Consumer Acceptance Test

Three hundred untrained consumers participated in the acceptance test. Consumers were recruited from the Louisiana State University Campus in Baton Rouge, LA in May 2008. The consumers were asked to participate while entering and exiting the LSU UREC, university recreation facility, in order to achieve the ideal target population. The following criteria had to be met by all consumers in order to be recruited: 18 years of age or older, not allergic to milk protein, soy protein, sugar, leucine, glutamine, creatine, artificial sweeteners, and fruits such as citrus, berries, and tropical fruits, and willing and available to participate and complete a survey.

The consumers were presented with a packet of papers that contained a consent form, which was pre-approved by the Louisiana State University Institutional Review Board (IRB), and 5 questionnaires; of which one survey inquiring about exercise and sports drink consumption, and four questionnaires corresponding to the four samples. The consumers were instructed to read and sign the consent form, and properly complete the questionnaires.

Each of the 300 consumers was presented with 4 2-oz samples, which were coded with a 3-digit number (Table 43). The 4 samples presented to the consumers consisted of the two formulated pre and post-workout drinks, and the two commercially available pre and post-workout drinks. The beverages were served at refrigerated temperature (40°F). To avoid consumer bias from the order in which the samples were presented, the first 150 consumers evaluated formulations C and P first, followed by the commercial samples, and the last 150 consumers evaluated the commercial samples first, followed by formulations C and P. The participants were provided with room temperature bottled water to cleanse their palates between samples.

Table 43. Sample Codes for Pre and Post-Workout Sports Drinks Evaluated by Consumers

Sample	**Code**
C (WPI, S, Bry)	345
Accelerade®	141
P (WPI, G, O)	368
Cytomax® Recovery	262

*See Table 42 for formulation C and P.

Each consumer evaluated each sample for acceptability of visual appearance, aroma, color, consistency, mouthfeel, flavor, sweetness, and overall liking using a 9-point hedonic scale (1=dislike extremely, 5=neither like nor dislike, 9=like extremely). Binomial type questions (yes/no) were used to determine product acceptability, purchase intent, and purchase intent after being given benefits of a pre-workout and post-workout sports beverage. Consumers were also presented with a survey which inquired about the following questions: if they perform resistance exercises (lifting weights), gender, age, body weight, if they consume sports drinks before and during exercise to aid in hydrations and supply the body with energy, if they consume sports drinks after exercise to aid in recovery, and if the consumers answered yes to the questions about sports drink consumption, they were asked which quality (flavor, nutrients, consistency, odor, color, or price) was the most important when purchasing a sports drink.

5.2.3 Physicochemical Analysis

5.2.3.1 Color

L*C*and h values were measured in triplicate for each of the pre-workout and post-workout sports drinks using a bench top spectrophotometer (LabScan® XE Hunter Lab Spectrophotometer, Reston, Va.). Before analyzing the samples, the colorimeter was calibrated using a black tile and a white tile (Standard No. LX16857). The sports drink samples, both formulated and commercial were placed in a 8-oz white Styrofoam cup. The cups were filled until they were almost full. Each cup was then placed on the orifice of the colorimeter and the L*, C*, and h values were analyzed.

5.2.3.2 pH

pH was measured using a hand-held pH meter (IQ Scientific Instruments, Model IQ150 handheld pH/mV/temperature meter, Carlsbad Ca.). The pH meter was calibrated using buffers of pH 4.0 and 7.0. The sports drinks were poured into 100-ml glass beakers for pH analysis. The sports drinks were mixed and the pH probe was inserted. Three replicate measures were recorded for pre and post-workout formulations and the commercial sports drinks.

5.2.3.3 Viscosity

Rheological properties of the drinks were evaluated using a rotational viscometer (Brookfield, Model DV-II+, Middleboro, Ma.) rotational viscometer. The Brookfield viscometer uses a spring as a torque sensor. The bob with spindle RV-1 was set to 100 revolutions per minute (rpm). Once the rotational speed was converted to an angular velocity, the simple shear approximation was used to calculate a shear rate. As the bob moves through the sample, the viscosity impedes free rotation, causing the spring to wind. The degree of spring windup is a direct reflection of the torque magnitude (M), used to determine a shear stress at the bob surface. Using this data, a rheogram was created showing shear stress versus shear rate, ultimately determining the apparent viscosity (Nielsen 2003). Each sports drink was placed in a 16-oz clear plastic cup. Immediately before measuring, the sports drink samples were stirred fifteen times clockwise, and fifteen times counter clockwise using a spoon. All samples were analyzed at refrigerated temperature (40°F). Viscosity, in centipoises (cp) was measured in triplicate for all four samples both formulated and commercial.

5.2.3.4 Microbial Analysis

Microbial analysis was conducted at day zero to ensure that the sports drinks were safe for consumption. Three different microbial tests were conducted, and included yeast and mold, total aerobic plate count, and coliforms/E.*coli*. 3M™Petrifilms™ were used for all three analyses. To create a sterile environment, all surfaces were wiped with ethanol, and a flame was lit in the working area. Working close to the flame, one milliliter of each sample (code 141, 345, 262, 368) was placed in the center of each petrifilm. After pipetting the samples onto the petrifilms, a weighted spreader was placed on top to ensure that the sample spread over the entire growth area. The petrifilms were then allowed to incubate. The yeast and mold petrifilms were left at room temperature for 48 hours, the total aerobic plates were incubated at 32°F for 48 hours, and the coliform/E.*coli* plates were incubated at 32°F for 24 hours. Three replicates of each sample were performed, and the bacterial colonies were counted after the respected incubation times.

5.2.3.5 Proximate Analysis

Protein, carbohydrate, and mineral analysis was conducted on the two most acceptable pre- and post workout sports drinks (345 and 368). Protein analysis was conducted using EPA method 351.2, which is the Kjeldahl method. Minerals were analyzed using EPA method 200.7, which is a test for metals and trace elements by ICP/atomic emission spectrometry. Carbohydrates were measured by calculation.

5.2.4 Statistical Data Analysis

All data were analyzed at a predetermined confidence level (α=0.05) using the Statistical Analysis Software System, SAS version 9.1, 2003 (SAS Institute, Cary, NC).

5.2.4.1 Analysis of Variance

Analysis of variance, often abbreviated as ANOVA, is a technique that compares the means from several samples and tests whether they are all (within experimental error) the same, or whether one or more of them are significantly different (O'Mahony 1986). Analysis of variance (ANOVA) was used to determine if differences lie among the two pre-workout drinks (formulated vs. commercial) an/or the two post-workout drinks (formulated vs. commercial) in terms of acceptability of each sensory attribute, and overall liking.

To conduct a valid analysis of variance, the following assumptions must be satisfied: samples taken under each treatment must be randomly picked from their respective populations, the treatments must be independent of each other, samples of scores under each treatment must come from normally distributed populations of scores, and samples of scores under each treatment must come from populations with the same variance (homoscedasticity) (O'Mahony 1986). ANOVA provides evidence that a significant difference exists, but does not give an indication of how the treatments are different.

Tukey HSD (honest significant difference) is an adjustment that was used, so that after all comparisons, both simple pairwise and complex, the overall level of significance was 0.05. Tukey (1953) proposed a multiple-comparison method for pairwise comparisons of *k* means and for simultaneous estimation of differences between means by confidence intervals with a specified confidence coefficient ($1-\alpha$) (Gacula and Singh 1984). If *n* observations are taken in each of *k* samples and the analysis-of-variance F test is significant, the critical difference to be exceeded for a pair of means to be significantly different is the so-called honest significant difference (HSD), $HSD = Q_{\alpha,k,v}(\sqrt{Mse}/n)$.

5.2.4.2 MANOVA and DDA

MANOVA (multivariate analysis of variance) is a post-ANOVA technique that was used to determine if significant differences existed between formulations when all of the sensory attributes were compared simultaneously. Descriptive Discriminant Analysis (DDA) was used to determine which of the attributes contributed to the differences among the eight pre-workout and eight post-workout sports drink formulations.

MANOVA and Discriminant Analysis are the preferred methods for determining differences between samples. The chief value of MANOVA is to determine whether treatments applied to a product cause significant differences, and Descriptive Analysis tells the investigator whether certain variables combined are correlated with classes (Piggott 1986). The results of MANOVA provide a single F-statistic, based on Wilks' lambda (Λ), which assesses the influence of all descriptors simultaneously. A significant MANOVA F-statistic (due to a small

Wilks' lambda) indicates that the samples differ significantly across dependent variables (Lawless and Heymann 1998).

Techniques of Descriptive Discriminant Analysis (DDA) are closely aligned to the study effects determined by a multivariate analysis of variance (Huberty 1994). In DDA, the basic question of interest pertains to grouping variable effects on the multiple outcome variables or, to group separation or group differences with respect to the outcome variables (Huberty 1994).

5.2.4.3 Logistic Regression

Logistic regression, or logit analysis, uses a regression model to fit a categorical dependent variable. In its most widely used form, the dependent variable is dichotomous (yes/no) and the independent variables are quantitative or categorical. Logistic regression involves the use odds and odds ratios. The odds are an expression of the likelihood of an event happening compared to the likelihood of that event not happening. An odds of less than one corresponds to a probability of less than 0.5, and an odds greater than one corresponds to a probability above 0.5. Odds are used instead of probabilities because they are on a more sensible scale for multiplicative comparisons, they are directly related to the parameters in the logit model, and they are less sensitive to changes in the marginal frequencies. The odds ratio, not to be confused with the odds, is the proportional change in the odds per unit change in X_i. Logistic regression analysis was used to predict both product acceptability and purchase intent based on the odds ratio point estimate.

5.2.4.4 McNemar Test

The McNemar test is one way of comparing proportions from two dependent samples (in this case, responses before and after consumers had been informed of the exercise enhancing benefits) using binary response variables. The test follows a chi-square distribution with df=1

(Agresti 1996). A 95% confidence interval was calculated using marginal sample proportions (p_{+1} + p_{1+}), which can be used to estimate the actual differences in the means of purchase decision responses (Beckley and others 2007).

In order to calculate the sample proportions (p_{ij}), the equation

$$p_{ij} = n_{ij}/N$$

was used, where n_{ij} is the number of consumers making response I and response j after knowing the “fact” about exercise enhancing benefits, and N represents the total number of responses from consumers. Next, the 95% confidence interval for the difference in proportions was calculated using the equation

$$(p_{+1} - p_{1+}) \pm z_{\alpha/2}(ASE)$$

where ($p_{+1} - p_{1+}$) represents the difference in proportions between consumers who answer yes after knowing the fact (p_{+1}) and those who answered yes before knowing the fact (p_{1+}); the term $z_{\alpha/2}$ equals 1.96 and represents the standard normal percentile having a right-tailed probability of $\alpha/2$; ASE is the estimated standard error for the proportion difference and was calculated using the equation

$$ASE = ([p_{1+}(1-p_{1+}) + p_{+1}(1-p_{+1}) - 2(p_{11}p_{22} - p_{12}p_{21})]/N)^{1/2}$$

Where p_{11} indicates the number of consumers who answered yes both before and after knowing the fact, p_{22} represents the number of consumers who answered no both before and after knowing the fact, p_{12} indicates the number of consumers who answered yes before and no after knowing the fact, and p_{21} represents the number of consumers who answered no before and yes after knowing the fact (Beckley and others 2007).

In this study, the McNemar test was used to determine changes in consumer purchase decision before and after consumers were informed of the exercise enhancing benefits of the sports drinks.

5.2.4.5 Cochran's Q Test

The Cochran's Q test (Cochran 1950) is often used in the situation where T_i , i=1,2,…m is the total number of correct responses in the N panelists for sample i, i=1,2,…,m; S_j is the total number of correct responses in the m samples for panelist j, j=1,2,…,N, and T is the total number of correct responses in the N panelists for all m samples. The Cochran's Q test statistic asymptotically follows a chi-square distribution with m-1 degrees of freedom (Bi 2006).

$$Q = (m-1) \times \frac{m\sum_{i=1}^{m} T_i^2 - T^2}{mT - \sum_{j-1}^{N} S_j^2}$$

If significant differences among the correlated proportion are detected, the (1-α)-level simultaneous confidence intervals for all pairwise comparisons for the correlated proportions can be obtained from

$$P_{ci} - P_{cj} \in P'_{ci} - P'_{cj} \pm z^{(\alpha*)} \sqrt{(} P'_{ci} + P'_{cj} - 2\, P'_{cij} - (P'_{ci} - P'_{cj}) / N).$$

Cochran's Q test was used to determine if differences exist in acceptability, purchase intent, and purchase intent after given benefits about the sports drinks, between the two pre and two post-workout sports drinks evaluated by the consumers.

5.3 Results and Discussion

5.3.1 Physicochemical Analysis

5.3.1.1 pH

pH was measured for both the formulated and commercial sports drink samples (Table 44). For the pre-workout sports drinks, the formulated beverage (141: WPI, S, Bry) had a higher pH (4.67) than the commercial product (3.26), and the two products were significantly different from each other. For the post-workout drinks, the pH for the commercial sample 262 (8.71) was significantly higher than that of the formulated sample (3.62). The acidic pH of sample 368 can be attributed to the natural orange flavor used.

Table 44. Mean pH Values for Pre- and Post-Workout Sports Drinks

Sample	**pH**
Pre-Workout	
141	3.26 ± 0.01^{A}
345	4.67 ± 0.02^{B}
Post-Workout	
262	8.71 ± 0.02^{A}
368	3.62 ± 0.05^{B}

*****pH values with the same superscripted letter for the two pre- and two post-workout sports drinks are not significantly different from each other (p>0.05). Values represent an average ± standard deviation of three replicates. See Table 42 for formulations.

5.3.1.2 Viscosity

Mean viscosity values, in centipoise (cp), for the pre- and post workout sports drinks are presented in Table 45. The viscosity values for the two pre-workout drinks were significantly different, with the commercial sample (141) having a lower viscosity (13.17) than the formulated sample (345: 16.14). Similar results were observed for the post-workout sports drinks. The commercially available drink was significantly less viscous than the formulated beverage (Table 45).

5.3.1.3 Color

L*, C*, and h values were taken for the two formulated sports drinks and the two commercial beverages (Table 46). The L* value, which represents lightness or darkness, was not significantly different between the two pre-workout sports drinks. The chroma, or intensity however was significantly different between the two drinks. Sample 141 had a significantly higher intensity (7.58) than sample 345 (3.40). For the hue angle, the pre-workout sports drinks were significantly different from each other. Sample 141 had a hue angle of 256.91, which represents a blue color (Figure 11). Formulation 345 had a hue angle of 15.55, which represents a reddish color (Figure 11).

The post-workout drinks were not significantly different from each other in terms of L* values and hue angle (h). The L* values are 17.6 and 21.84 for samples 262 and 368 respectively. The hue angle values of 64.95 and 64.87 represent an orange color for samples 262 and 368 respectively. These two samples however, differed in intensity, with sample 368 being more intense (28.31) than sample 262 (20.27).

Table 45. Mean Viscosity Values for Pre- and Post-Workout Sports Drinks

Sample	Viscosity (cP)
Pre-Workout	
141	13.17 ± 0.11^{A}
345	16.64 ± 0.07^{B}
Post-Workout	
262	16.67 ± 0.04^{A}
368	18.91 ± 0.45^{B}

*****Viscosity values with the same superscripted letter for the two pre- and two post-workout sports drinks are not significantly different from each other (p>0.05). Values represent an average ± standard deviation of three replicates. See Table 42 for formulations.

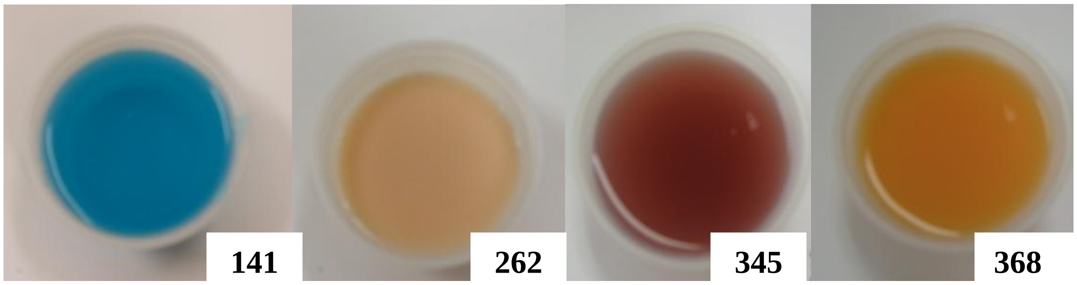

Figure 11. Images of Commercial and Formulated Sports Drinks

Table 46. L*, C*, and h Color Values for the Pre-Workout Sports Drink Formulations

Sample	L*	C*	h
Pre-Workout			
141	1.84 ± 0.23^A	7.58 ± 0.56^A	256.91 ± 0.84^A
345	1.27 ± 0.38^A	3.40 ± 0.09^B	15.55 ± 0.56^B
Post-Workout			
262	17.60 ± 3.13^A	20.27 ± 0.81^A	64.95 ± 2.61^A
368	21.84 ± 3.48^A	28.31 ± 0.32^B	64.87 ± 2.12^A

L, C*, and h values with the same superscripted letter for the two pre- and two post-workout sports drinks are not significantly different from each other ($p>0.05$). Values represent an average ± standard deviation of three replicates. See Table 42 for formulations.

5.3.1.4 Microbial Analysis

Total aerobic plate counts, yeast and molds, and coliform/E.*coli* tests were conducted. Following incubation, all petrifilms were observed for growth. There was no microbial growth on any of the petrifilms, therefore the samples were safe, and the pasteurization method was appropriate.

5.3.1.5 Proximate Analysis

Table 47 represents the amounts of carbohydrate, protein, and minerals in the commercial and formulated beverages. Proximate analysis was conducted on the two formulated sports drinks (345 and 368). Kjeldahl protein analysis results indicated that the formulated pre-workout sports drink had 1.175% protein, and the post-workout drink had 3.725% protein. Total mineral, or ash analysis showed that the pre-workout sports drink had 0.525% minerals, and the post-workout drink had 3.85%. ICP (Inductively Coupled Plasma) was able to detect percentages of specific minerals such as potassium and sodium.100 mg of sodium and 80mg of potassium were added to the formulated pre-workout drink, as electrolyte sources. Mineral analysis showed that there was 54.24 mg of sodium and 109.5 mg of potassium per serving. Finally, carbohydrate percentages were determined by calculation, which resulted in 6.45% and 12.13% for the formulated pre- and post-workout drinks respectively.

Table 47. Carbohydrate, Protein, and Mineral Analysis for Commercial and Formulated Sports Beverages

Formulation	**Mean Quantities of Nutrients**			
	Carbohydrate (%)	**Protein (%)**	**Sodium (mg/serving)**	**Potassium (mg/serving)**
Pre-Workout				
141	5.0	1.3	120	15
345	6.5	1.2	54	110
Post-Workout				
368	12.1	3.7	ND	ND
262	7.0	52.0	ND	ND

*Sodium and Potassium content was analyzed for pre-workout drinks only.

For the pre-workout beverages, the formulated drink (345) had a higher percentage of carbohydrates than the commercial beverage. The two beverages were similar in protein content, but differed in sodium and potassium content. The formulated pre-workout beverage was supposed to have 100 mg of sodium; however, some sodium may have been lost during processing because only 54 mg was detected by ICP analysis. The commercial pre-workout drink has 120 mg of sodium and only 15 mg potassium. The formulated beverage had more potassium (110 mg) than the commercial drink (15 mg). The post-workout drinks were vastly different in terms of protein and carbohydrate content. The commercial post-workout drink Cytomax® Recovery was formulated for recovery; however, different ingredients and quantities of ingredients were used compared to the formulated post-workout beverage. The commercial beverage has 7% carbohydrates, which is lower than what the formulated beverage contains (12.1), and has substantially more protein (52%) than the formulated beverage (3.7%).

5.3.2 Demographic Information

Consumers were asked several questions based on their exercise history and purchasing habits of sports drinks before and after workout. Tables 48-56 represent frequencies, percentages, cumulative frequencies and cumulative percentages of consumers who responded to each question. Firstly, consumers were asked if they performed resistance-training exercises such as lifting weights. Out of 299 consumers, 264 or 88.29% of consumers said that they perform resistance-type exercises (Table 48). Of the consumers that resistance train, 81.55% were males, and 18.42% were females (Table 49). Most participating consumers (81.13%) were between 18 to 24 years of age (Table 50).

Table 48. Frequency of Consumers That Resistance Train.

Resistance Train?	Frequency	Percent (%)	Cumulative Frequency	Cumulative Percent (%)
Yes	264	88.29	264	88.29
No	35	11.71	299	100.00

Table 49. Frequency of Consumer Gender.

Gender	Frequency	Percent (%)	Cumulative Frequency	Cumulative Percent (%)
Male	217	81.58	217	81.58
Female	49	18.42	266	100.00

Table 50. Frequency of Consumer Age

Age	Frequency	Percent (%)	Cumulative Frequency	Cumulative Percent (%)
18-24	215	81.13	215	81.13
25-34	31	11.70	246	92.83
35-44	10	3.77	256	96.60
45-54	5	1.89	261	98.49
Over 55	4	1.51	265	100.00

The consumers were also divided into one of five different weight categories (Table 51). About one-third of the consumers (35.34%) fell into the 160-189 pound category. 20.30% of consumers weighed between 130-159 pounds, and 19.92% of consumers weighed between 190-219 pounds. The under 100 pound category and over 220-pound category had the lowest percentages of consumers with 1.13 and 10.90 percent, respectively. The consumers were also asked how frequently they performed resistance-training exercises per week (Table 52). The majority of consumers lift weights 3-5 days per week (66.17%). Twenty-four percent of consumers lift weights 1-2 times per week, and only 9.77% of consumers lift weights more than five days per week.

Table 51. Frequency of Consumer Body Weight

Body Weight (lbs)	Frequency	Percent (%)	Cumulative Frequency	Cumulative Percent (%)
Under 100	3	1.13	3	1.13
100-129	33	12.41	36	13.53
130-159	54	20.30	90	33.83
160-189	94	35.34	184	69.17
190-219	53	19.92	237	89.10
Over 220	29	10.90	266	100.00

Table 52. Frequency of Consumer Exercise Frequency

Frequency of Exercise	Frequency	Percent (%)	Cumulative Frequency	Cumulative Percent (%)
1-2 days/week	64	24.06	64	24.06
3-5 days/week	176	66.17	240	90.23
Over 5 days/week	26	9.77	266	100.00

The consumers were also asked if they consumed sports drinks before and during exercise, and if they did, they were asked which of the following qualities (flavor, nutrients, consistency, odor, color, and price) were the most important to them when purchasing such a beverage (Tables 53 and 54). Sixty percent of consumers said that they purchased sports drinks to consume before and during a resistance-training workout. Of that sixty percent of consumers, 59.75% said that nutrients were the most important quality. Flavor followed nutrients as being an important quality for a pre-workout sports drink, with 30.19% of consumer responses. Price, consistency, color and odor were the least chosen qualities with 4.40, 3.14, 2.52, and 0.00 percent, respectively.

Table 53. Frequency of Consumers That Consume Sports Drinks Before/During Exercise

Consume Sports Drinks Before/During Exercise	Frequency	Percent (%)	Cumulative Frequency	Cumulative Percent (%)
Yes	159	60.00	159	60.00
No	106	40.00	265	100.00

Table 54. Frequency of Important Qualities Consumers Look for When Purchasing a Pre-Workout Drink

Quality	Frequency	Percent (%)	Cumulative Frequency	Cumulative Percent (%)
Flavor	48	30.19	48	30.19
Nutrients	95	59.75	143	89.94
Consistency	5	3.14	148	93.08
Odor	0	0.00	148	93.08
Color	4	2.52	152	95.60
Price	7	4.40	159	100.00

Sixty-eight percent of the consumers said that they consumed a sports drink after resistance training to aid in recovery (Table 55). Of that sixty eight percent, an overwhelming 76.92% of consumers expressed that nutrients were the most important quality when purchasing a post-workout sports drink (Table 56). Flavor followed Nutrients as an important quality for a post-workout beverage, with only 15.93% responses. Only 3.30% and 3.85% of consumers were concerned about the consistency and price of an after workout beverage, and no consumers were concerned with odor and color.

Table 55. Frequency of Consumers That Consume Sports Drinks After Exercise

Consume Sports Drinks After Exercise	Frequency	Percent (%)	Cumulative Frequency	Cumulative Percent (%)
Yes	182	68.42	182	68.42
No	84	31.58	266	100.00

Table 56. Frequency of Important Qualities Consumers Look for When Purchasing a Post-Workout Drink

Quality	Frequency	Percent (%)	Cumulative Frequency	Cumulative Percent (%)
Flavor	29	15.93	29	15.93
Nutrients	140	76.92	169	92.85
Consistency	6	3.30	175	96.15
Odor	0	0.00	175	96.15
Color	0	0.00	175	96.15
Price	7	3.85	182	100.00

5.3.3 Consumer Acceptability

Analysis of variance results for the two pre- and two post- workout sports drinks are presented in Table 57. Differences in acceptability of eight attributes (appearance, aroma, color, consistency, mouthfeel, flavor, sweetness, and overall liking) were determined. For the pre-workout sports drinks, the commercial sample (141) had higher mean scores than sample 345 for all sensory attributes except sweetness. The commercial sample received high acceptability scores for appearance (7.57), aroma (7.24), color (7.56), and consistency (7.13). The low acceptability score (5.82) for sweetness of sample 141may have been influenced by its pH. Sample 141 was highly acidic, and consumers expressed that this sample was tart and sour. For the formulated pre-workout sports drink, consumers evaluated the product as having an acceptable appearance (6.07), color (6.18), consistency (6.28), and mouthfeel (6.28), while the other sensory attributes (aroma, flavor, sweetness, and overall liking) were less acceptable. Aroma received the lowest acceptability score of 4.89 for the formulated pre-workout sports drink.

For the post-workout sports drinks, the formulated beverage (368) was evaluated as having greater acceptability of appearance (6.16), color (6.11), consistency (6.10), and mouthfeel (6.01). This product received low acceptability of aroma, with a mean hedonic score of 5.41.

Consumers evaluated the commercially available sample (262) as having higher acceptability of aroma (5.94). The sensory attributes with low acceptability scores were color and appearance, having mean scores of 4.55 and 4.79, respectively. The commercially available post-workout drink was significantly different from the formulated beverage in terms of all sensory attributes except flavor, sweetness, and overall liking.

Table 57. Mean Acceptability Scores for All Eight Sensory Attributes of Formulated and Commercial Sports Drinks

Sensory Attributes	Mean Score for Sensory Attributes**			
	Pre*		Post*	
	141	345	262	368
Appearance	7.57 ± 1.36 [A]	6.07 ± 1.76 [B]	4.79 ± 1.97 [B]	6.16 ± 1.89 [A]
Aroma	7.24 ± 1.36 [A]	4.89 ± 1.95 [B]	5.94 ± 2.00 [A]	5.41 ± 2.06 [B]
Color	7.56 ± 1.27 [A]	6.18 ± 1.67 [B]	4.55 ± 1.67 [B]	6.11 ± 1.85 [A]
Consistency	7.13 ± 1.37 [A]	6.28 ± 1.60 [B]	5.36 ± 2.05 [B]	6.10 ± 1.81 [A]
Mouthfeel	6.66 ±1.72 [A]	6.28 ± 1.78 [B]	5.65 ± 2.10 [B]	6.01 ± 1.92 [A]
Flavor	6.10 ± 1.86 [A]	5.35 ± 2.23 [B]	5.61 ± 2.38 [A]	5.61 ± 2.32 [A]
Sweetness	5.82 ± 1.84 [A]	5.83 ± 1.85 [A]	5.69 ± 2.28 [A]	5.90 ± 2.04 [A]
Overall Liking	6.29 ± 1.69 [A]	5.67 ± 2.00 [B]	5.49 ± 2.16 [A]	5.72 ± 2.14 [A]

* Samples 141 and 345 represent the commercial and formulated pre-workout beverages, respectively, and samples 262 and 368 represent the commercial and formulated post-workout beverages, respectively.
** Numbers in the table represent the mean score, plus or minus the standard deviation for each sample/sensory attribute combination. Each number in the table has a superscripted letter. Mean scores with the same letter for each sensory attribute (each row) are not significantly different ($p>0.05$). 300 consumers tested each sample.

Overall, the commercially available pre-workout beverage (141) received higher mean scores for all sensory attributes than the formulated beverage 345. However, no significant differences were detected in the sweetness of both pre-workout drinks.For the post-workout drinks, formulated beverage (368) received higher mean scores than the commercial beverage for all sensory attributes, except for aroma.

5.3.4 Overall Product Differences

Multivariate analysis of variance was used to determine if the two pre-workout sports drinks and/or the two post-workout sports drinks were different from each other when all eight sensory attributes were compared simultaneously. According to the Wilks' Lambda statistic for the pre- workout sports drinks (0.6087), there is a significant difference (Pr>F of <0.001) in the two beverages when all eight sensory attributes were compared simultaneously (Table 58). For the post-workout drinks, the results for MANOVA indicated that there was a difference in the two post-workout drinks when all eight sensory attributes were compared concurrently (Pr>F of <0.001) (Table 59). In order to determine exactly which sensory attributes contributed to the overall difference in the products, descriptive discriminant analysis (DDA) was used.

Table 58. Multivariate Analysis of Variance for Pre-Workout Beverages

MANOVA	Test Criteria and F Approximations for the Hypothesis of No Overall Form Effect				
H = Type III SSCP Matrix for Forms E = Error SSCP Matrix S = 1 M = 3 N = 291					
Statistic	Value	F Value	Numerator DF	Denominator DF	Pr>F
Wilks' Lambda	0.6087	46.93	8	584	<0.001
Pillai's Trace	0.3913	46.93	8	584	<0.001
Hotelling-Lawley Trace	0.6429	46.93	8	584	<0.001
Roy's Greatest Root	0.6429	46.93	8	584	<0.001

Table 60 presents the canonical structure (r-values), which indicates the sensory attributes that contribute to the product differences. According to the canonical structure in the first dimension, it is observed that visual appearance and aroma are the sensory attributes that differentiate the formulated pre-workout drink from the commercially available drink. For the post-workout sports drinks, visual appearance and color are the discriminating attributes (Table 60). Visual appearance and aroma, and visual appearance and color, both represent 100% of the cumulative variance explained for the pre- and post-workout sports beverages respectively.

Table 59. Multivariate Analysis of Variance for Post-Workout Beverages

MANOVA	Test Criteria and F Approximations for the Hypothesis of No Overall Form Effect				
H = Type III SSCP Matrix for Forms E = Error SSCP Matrix S = 1 M = 3 N = 289.5					
Statistic	Value	F Value	Numerator DF	Denominator DF	Pr>F
Wilks' Lambda	0.7342	26.29	8	581	<0.001
Pillai's Trace	0.2658	26.29	8	581	<0.001
Hotelling-Lawley Trace	0.3620	26.29	8	581	<0.001
Roy's Greatest Root	0.3620	26.29	8	581	<0.001

Table 60. Canonical Structure (r's) Describing Group Differences among the Pre- and Post-Workout Formulations[1]

Sensory Attribute	**Can 1***	
	Pre	**Post**
Visual Appearance	0.6078**	0.5738**
Aroma	0.8770**	-0.2245
Color	0.5942	0.6757**
Consistency	0.3584	0.3166
Mouthfeel	0.1450	0.1448
Flavor	0.2325	-0.0024
Sweetness	0.0048	0.0024
Overall Liking	0.2176	0.0827
Cum. Variance Explained	100%	100%

[1]Based on the pooled within group variances
*Can 1 represents pooled within canonical structure in the first dimension
**Attributes that contribute to differences among samples

5.3.5 Product Acceptance and Purchase Intent

After evaluating the acceptance of each of the eight sensory attributes, consumers were asked if they thought the products were acceptable, if they would purchase the product, and if they would purchase the product after given exercise enhancing information. These three questions were evaluated on a binomial (yes/no) scale. Between the two pre-workout drinks, the commercially available product had a higher acceptance (86.62%), purchase intent (58.33%), and purchase intent after given information about exercise enhancement (69.67%) (Table 61). For the formulated pre-workout beverage, 71.24% of consumers evaluated it as acceptable. However, only 45.33% of consumers would purchase the product. The purchase intent for the formulated pre-workout sports drink increased from 45.33 to 61.00 percent after the consumers were given exercising enhancing information about the product (Table 61).

Acceptance, purchase intent, and purchase intent after given information about the product were higher for the formulated post-workout beverage (Table 61). For formulation 368, 72.97% of consumers perceived the product to be acceptable, 50.00% of consumers thought the product was worthy of purchasing, and 59.87% of consumers said they would purchase the product after they were given the exercise enhancing information. The percent acceptance, purchase intent, and purchase intent after given exercise enhancement information, were 66.11, 46.98, and 53.51 for the commercially available post-workout drink, respectively.

Table 61. Percent Affirmative Responses for Product Acceptance and Purchase Intent for the Pre- and Post-Workout Beverages

	Percent Affirmative Responses			
	Pre		**Post**	
	141	**345**	**262**	**368**
Acceptability	86.62	71.24	66.11	72.97
Purchase Intent	58.33	45.33	46.98	50.00
Purchase Intent After Given Health Benefits	69.67	61.00	53.51	59.87

In order to determine if the differences in acceptance, purchase intent, and purchase intent after given information about the products were significant among the two-pre and two-post sports beverages; the Cochran's Q test was employed. The results for Cochran's Q test produces calculated confidence intervals for each paired comparison (Table 62). If the confidence interval does not include zero, then the two samples being compared are significantly different from each other. For consumer acceptance, the formulated pre-workout drink was not significantly different from the commercial pre-workout drink. Also, the formulated post-workout drink was not significantly different from the commercially available post-workout drink in terms of acceptance. When comparing the pre-workout drink to the post-workout drink for acceptance, the formulated pre- and post-workout drinks were not significantly different from each other, and the commercial pre- and post-workout drinks were not significantly different from each other. The results for purchase intent, and purchase intent after given information about the sports drinks were similar to those from consumer acceptance.

Table 62. Confidence Intervals for Pairwise Comparisons from Cochran's Q-Test

Comparisons	**Cochran's Q-Test**	
	Confidence Interval for Pairwise Comparison	**Significantly Different**
	Acceptance	
141 / 345	(-1.637, 1.337)	No
262 / 368	(-1.758, 1.851)	No
345 / 368	(-1.240, 1.333)	No
141 / 262	(-1.487, 1.874)	No
	Purchase Intent	
141 / 345	(-2.060, 1.810)	No
262 / 368	(-2.040, 1.700)	No
345 / 368	(-1.590, 1.710)	No
141 / 262	(-1.590, 1.630)	No
	Purchase Intent (After)	
141 / 345	(-1.790, 1.863)	No
262 / 368	(-1.292, 1.085)	No
345 / 368	(-1.477, 1.804)	No
141 / 262	(-1.535, 1.582)	No

5.3.6 Logistic Regression for Acceptability and Purchase Intent

Logistic regression was used to predict product acceptance and purchase intent using all eight sensory attributes evaluated using the 9-point hedonic scale. Tables 63 and 64 present the predictive models that were used to predict purchase intent and product acceptance. Purchase intent was evaluated before and after given the information about exercise enhancement. Prediction models were established using the intercept and estimate from logistic regression output.

As determined by logistic regression, sensory attributes with a $Pr>\chi^2$ less than $\alpha=0.05$ are significant when determining consumer acceptance and purchase intent. For the pre-workout sports drinks, flavor and overall liking are significant sensory attributes when determining consumer acceptance, with $Pr>\chi^2$ of 0.0004 and <0.0001, respectively (Table 65). The corresponding odds ratios indicate that for a one-point increase in the mean hedonic score for flavor and overall liking, there will be an increase in consumer acceptance of 60.6% and 100.3% respectively. Appearance ($Pr>\chi^2$ of 0.7874) and sweetness ($Pr>\chi^2$ of 0.7288) were the two sensory attributes that are least significant in determining consumer acceptance.

Overall liking was the only significant sensory attribute when determining consumer purchase intent ($Pr>\chi^2$ of <0.0001). The odds ratio indicates that for a one-point increase in the mean hedonic value for overall liking, consumer purchase intent would increase 3.3 times. Appearance ($Pr>\chi^2$ of 0.0125), aroma ($Pr>\chi^2$ of 0.0157), sweetness ($Pr>\chi^2$ of 0.0384), and overall liking ($Pr>\chi^2$ of <0.0001) are significant attributes when determining consumer purchase intent after given exercise enhancing information about the two pre-workout sports drinks. The odds ratios specify that for a one-point increase in the mean hedonic scores for aroma, sweetness, and overall liking, there will be an increase in consumer purchase intent after given information about the products of 20.1%, 22.1%, and 93.1%, respectively. Consumer acceptance, purchase intent, and purchase intent after given information about the pre-workout sports drinks could be correctly predicted with 82.02%, 81.45%, and 79.60 percent accuracy (Table 66).

Table 63. Full Logistic Regression Models for Predicting Acceptance and Purchase Decisions of Pre-Workout Sports Drinks

Attributes	Predictive Model*
Acceptability	Y = -6.6837 + 0.0420 (Appearance) + 0.1225 (Aroma) + 0.1020 (Color) + 0.0575 (Consistency) + 0.0873 (Mouthfeel) + 0.4734 (Flavor) - 0.0459 (Sweetness) + 0.6946 (Overall Liking)
Purchase Intent	Y= -9.1413 – 0.0283 (Appearance) + 0.0993 (Aroma) + 0.1085 (Color) - 0.1022 (Consistency) – 0.1212 (Mouthfeel) + 0.2187 (Flavor) + 0.1486 (Sweetness) + 1.2029 (Overall Liking)
Purchase Intent / During Exercise Enhancement	Y= -4.4243 - 0.3098 (Appearance) + 0.1828 (Aroma) + 0.1842 (Color) + 0.0184 (Consistency) – 0.1390 (Mouthfeel) + 0.1277 (Flavor)+ 0.1999 (Sweetness) + 0.6583 (Overall Liking)

*Predictive models based on estimates for each of the sensory attributes that resulted from logistic regression analysis.

Table 64. Full Logistic Regression Models for Predicting Acceptance and Purchase Decisions of Post-Workout Sports Drinks

Attributes	Predictive Model*
Acceptability	Y= -6.0358 + 0.1239 (Appearance) + 0.0055 (Aroma) + 0.0192 (Color) + 0.1355 (Consistency) – 0.0115 (Mouthfeel) +0.0652 (Flavor)+ 0.2040 (Sweetness) + 0.8483 (Overall Liking)
Purchase Intent	Y= -8.1247 + 0.1455 (Appearance) + 0.0394 (Aroma) – 0.0247 (Color) + 0.0497 (Consistency) + 0.0054 (Mouthfeel) + 0.4082 (Flavor) + 0.0919 (Sweetness) + 0.6752 (Overall Liking)
Purchase Intent / Post Exercise Enhancement	Y= -5.4948 + 0.0413 (Appearance) + 0.0035 (Aroma) + 0.1376 (Color) + 0.0646 (Consistency) – 0.0335 (Mouthfeel) + 0.1710 (Flavor)+ 0.2112 (Sweetness) + 0.4602 (Overall Liking)

*Predictive models based on estimates for each of the sensory attributes that resulted from logistic regression analysis.

Table 65. Probability $>\chi^2$ and Odds Ratio Point Estimates for Acceptance and Purchase Intent for the Pre-Workout Sports Drinks

Consumer Acceptance			
Parameter	**Estimate**	**Pr $>\chi^2$**	**Odds Ratio**
Appearance	0.0420	0.7874	1.043
Aroma	0.1225	0.1728	1.130
Color	0.1020	0.5114	1.107
Consistency	0.0575	0.6484	1.059
Mouthfeel	0.0873	0.3898	1.091
Flavor	0.4734	0.0004	1.606
Sweetness	-0.0459	0.7288	0.955
Overall Liking	0.6946	<0.0001	2.003
Consumer Purchase Intent			
Parameter	**Estimate**	**Pr $>\chi^2$**	**Odds Ratio**
Appearance	-0.0283	0.8320	0.972
Aroma	0.0933	0.2821	1.098
Color	0.1085	0.4255	1.115
Consistency	-0.1022	0.4046	0.903
Mouthfeel	-0.1212	0.2400	0.886
Flavor	0.2187	0.0747	1.244
Sweetness	0.1486	0.1701	1.160
Overall Liking	1.2029	<0.0001	3.330
Consumer Purchase Intent / During Exercise Enhancement			
Parameter	**Estimate**	**Pr $>\chi^2$**	**Odds Ratio**
Appearance	-0.3098	0.0125	0.734
Aroma	0.1828	0.0157	1.201
Color	0.1842	0.1298	1.202
Consistency	0.0184	0.8596	1.019
Mouthfeel	-0.1390	0.1089	0.870
Flavor	0.1277	0.2255	1.136
Sweetness	0.1999	0.0384	1.221
Overall Liking	0.6583	<0.0001	1.931

*Sensory attributes that have a $Pr>\chi^2$ less than 0.05 are significant.

Table 66. Percent Hit Rate for Product Acceptance and Purchase Decision

Pre-Workout		**Post-Workout**	
Attribute	**% Hit Rate**	**Attribute**	**% Hit Rate**
Acceptance	82.02	Acceptability	79.83
Purchase Intent	81.45	Purchase Intent	81.28
Purchase Intent / During Exercise	79.60	Purchase Intent/ Post Exercise	78.68

Table 67. Probability $>\chi^2$ and Odds Ratio Point Estimates for Acceptance and Purchase Intent for the Post-Workout Sports Drinks

Consumer Acceptance			
Parameter	**Estimate**	**Pr $>\chi^2$**	**Odds Ratio**
Appearance	0.1239	0.2923	1.132
Aroma	0.0055	0.9487	1.006
Color	0.0192	0.8650	1.019
Consistency	0.1355	0.2341	1.145
Mouthfeel	-0.0115	0.9192	0.989
Flavor	0.0652	0.6349	1.067
Sweetness	0.2040	0.0743	1.226
Overall Liking	0.8483	<0.0001	2.336
Consumer Purchase Intent			
Parameter	**Estimate**	**Pr $>\chi^2$**	**Odds Ratio**
Appearance	0.1455	0.1992	1.157
Aroma	0.0394	0.6164	1.040
Color	-0.0274	0.7983	0.973
Consistency	0.0497	0.6553	1 051
Mouthfeel	0.0054	0.9631	1.005
Flavor	0.4082	0.0032	1.504
Sweetness	0.0919	0.4562	1.096
Overall Liking	0.6752	0.0002	1.964
Consumer Purchase Intent / During Exercise Enhancement			
Parameter	**Estimate**	**Pr $>\chi^2$**	**Odds Ratio**
Appearance	0.0413	0.6782	1.042
Aroma	0.0035	0.9607	1.003
Color	0.1376	0.1389	1.148
Consistency	0.0646	0.5087	1.067
Mouthfeel	-0.0335	0.7396	0.967
Flavor	0.1710	0.1499	1.186
Sweetness	0.2112	0.0379	1.235
Overall Liking	0.4602	0.0023	1.584

*Sensory attributes that have a $Pr>\chi^2$ less than 0.05 are significant.

Overall liking ($Pr>\chi^2$ of <0.0001) was the only significant sensory attribute in determining consumer acceptance of the post-workout sports drinks (Table 67). If the consumer acceptance of overall liking were to increase by one-point, then the odds ratio predicts that consumer acceptability will increase 2.336 times. Flavor ($Pr>\chi^2$ of 0.0032) and overall liking ($Pr>\chi^2$ of 0.0002) were the two most integral attributes used to determine consumer purchase intent. The odds ratio values for flavor and overall liking predict that for a one-point increase in the mean acceptability scores for the stated attributes, there would be an increase in consumer purchase intent of 50.4% and 96.4% respectively. According to logistic regression, sweetness ($Pr>\chi^2$ of 0.0379) and overall liking ($Pr>\chi^2$ of 0.0023) were the two significant attributes in determining consumer acceptance after consumers were given information about the sports drinks. The purchase intent after given information about the sports drinks has the potential to increase 23.5 and 58.4 percent, if there is a corresponding increase in the mean hedonic scores for sweetness and overall liking respectively. Consumer acceptance, purchase intent, and purchase intent after given exercise-enhancing information about the sports beverage could be predicted correctly with 79.83%, 81.28%, and 78.68% accuracy, respectively, based on the percent hit rate (Table 66).

5.3.7 Change in Probability of Purchase Intent

The McNemar test was used to analyze the change in probability of consumer purchase intent before and after being informed about the benefits of the pre and post-workout sports drinks. The null hypothesis for the McNemar test states that there is no significant difference in probability of buying the product before and after consumers have been informed about the health benefits, or

$$H_0: \pi_{+1 \text{ (total yes after)}} - \pi_{1+ \text{ (total yes before)}} = 0.$$

The changes in probability of purchase intent were significant for all formulations (Table 68). According to the upper and lower confidence limits, the purchase intent for formulation 141 has the potential to increase between 7.0 and 15.7 percent after additional information is given about the product. Formulation 345 has the potential to increase as much as 20.5% or as low as 10.9%. The commercial post-workout sports drink had the largest confidence interval, ranging from

1.9% to 18.0% increase in purchase intent after given additional information about the product. Finally, the purchase intent for formulation 368 has the potential to increase as much as 14.3 percent or as low as 5.9% after given additional information about the sports drinks.

Table 68. Changes in Probability of Purchase Intent for Pre- and Post-Workout Sports Drinks

Pre-Workout				
Formulation	χ^2	**P-Value***	**95% LCI****	**95% UCI*****
141	24.0833	0.0001	0.070	0.157
345	36.2132	0.0001	0.109	0.205
Post-Workout				
Formulation	χ^2	**P-Value***	**95% LCI****	**95% UCI*****
262	7.6809	0.0056	0.019	0.180
368	20.4545	0.0001	0.059	0.143

* P-values < α (0.05) are significant.
**LCI- lower confidence interval.
***UCI- upper confidence interval. See Table 42 for Formulations.

5.4 Conclusions

Physicochemical results indicated the two pre-workout drinks and the two post-workout sports drinks were significantly different in terms of pH. Commercial sample 141 had the most acidic pH, which can be indirectly linked to a low mean acceptability score for sweetness. For viscosity, the two formulated beverages (345 and 368) were significantly thicker than their commercial counterparts. Color analysis indicated that the lightness or darkness (L*) values were not significantly different among the two pre-workout drinks and the two post-workout drinks. However, some differences were observed in the C* and h values. Commercial sample 141 had a significantly higher intensity (C*), and a blue color, which was indicated by the hue angle (h). Sample 141 also had the higher mean acceptability score for color. Formulated post-workout sample 368 was significantly more intense in color; however, its hue did not differ from commercial sample 262. Proximate analysis indicated that the two pre-workout drinks were similar in protein and carbohydrate content, but were different in electrolyte content. The commercial post-workout drink was formulated for recovery; however, vastly different ingredients were used than the formulated post-workout beverage.

Demographic information suggested that out of a population of 300 consumers that attended the gym, 88% of those people perform resistance-training exercises. Eight-two percent of those people are males, 81 percent are 18 to 24 years of age, and 66% exercise three to five days per week. Sixty percent of the consumers that resistance train purchase sports drinks to consume before and during their workout to supply the body with energy and aid in hydration. Of that 60 percent of consumers, 60 percent indicated that nutrients were the most important quality they look for in a sports drink. Sixty-eight percent of the consumers that resistance train consume a sports drink to help recover after exercising, and 77 percent of those consumers were most concerned about the nutrients in the beverage.

ANOVA indicated that the commercially available pre-workout beverage (141) received higher mean scores for all sensory attributes than the formulated beverage 345, except sweetness. Analogous results were observed for the post-workout drinks. The formulated beverage (368) received higher mean scores than the commercial beverage for all sensory attributes except for aroma. MANOVA was significant for both pre and post-workout formulations, indicating that there are significant differences among the pre and post workout sports drinks when all sensory attributes are compared simultaneously. DDA suggested that appearance and aroma were the two sensory attributes that led to the differences in the two pre-workout drinks, and appearance and color were the two most significant attributes that led to the differences in the post-workout drinks.

The commercial pre-workout beverage had higher percentages of acceptance, purchase intent, and purchase intent after given information about the product. However, the results for the formulated post workout-drink showed greater percentages of acceptance, purchase intent, and purchase intent after given information about the product. Although there were differences in acceptance, purchase intent, and purchase intent after among the two pre- and two post workout sports drinks, Cochran's Q test indicated that they are not significantly different.

LRA, logistic regression analysis predicted that flavor and overall liking are significant variables that help determine and predict consumer acceptance, while overall liking is significant in determining purchase intent, whereas appearance, aroma, sweetness, and overall liking are the significant in determining consumer purchase intent after given information about the pre-workout drinks. For the pre-workout sports drinks, overall liking is the only significant attribute that will help to determine consumer acceptance, while flavor and overall liking help determine and predict purchase intent, whereas sweetness and overall liking are significant in determining consumer purchase intent after given exercise enhancing information about the sports drinks. Finally, the McNemar test showed that there was a significant increase in purchase intent after the consumers were made aware of the exercise enhancing benefits. According to the results of this study, formulations 345 and 368 have the potential to compete in the sports beverage market; however, some improvements need to be made, such as increasing the intensity of color, and improving the aroma.

CHAPTER 6. SUMMARY AND CONCLUSIONS

In the first study, sixteen sports drinks were formulated using whey protein isolate, whey protein concentrate, sucrose, glucose, L-leucine, L-glutamine, creatine monohydrate, potassium monophosphate, sodium chloride, vitamin C, and all natural fruit powders (berry, tropical fruit, lemon, lime, and fruit mix flavors). A consumer acceptance test was conducted with 280 consumers evaluating eight pre-workout and eight post-workout beverages. Consumers evaluated acceptability of appearance, aroma, color, consistency, flavor, mouthfeel, sweetness and overall liking using a 9-point hedonic scale. Product acceptance, purchase intent, and purchase intent after given exercise enhancing information about the product were evaluated using a binomial (yes/no) scale. Consumers preferred pre-workout formulation A (WPC, S, Bry), which received the highest mean scores for overall liking (5.29), sweetness (5.64), flavor (5.23), mouthfeel (6.01), aroma (5.44), and color (5.33). Formulation A had the highest acceptance rating (70.00%), the second highest purchase intent (22.86%), and the highest purchase intent after given the benefits of a pre-workout sports drink (57.14). The Wilks' Lambda statistic (Pr>F of <0.0001) indicated that there were significant differences between the pre-workout drinks when all eight sensory attributes were compared simultaneously. Aroma, mouthfeel, overall liking, color, and flavor were the sensory attributes that contributed to the differences in the pre-workout sports drinks. Mouthfeel and overall liking were the two most significant attributes in determining consumer acceptance; flavor and overall liking were significant in predicting and determining consumer purchase intent; and flavor and overall liking were significant when determining consumer purchase intent after given benefits of a pre-workout sports beverage. There were significant changes in purchase intent for all formulations after the consumers were given extra information about the products. Formulation K(WPI, S, LL) was the most accepted of the post-workout drinks. Formulation K received the highest mean acceptability scores for overall liking (5.29), sweetness (5.46), flavor (5.41), mouthfeel (5.80), color (5.93), and consistency (5.29). The acceptance, purchase intent, and purchase after the consumers were given benefits of a post-workout sports drink were 65.71%, 50.00%, and 58.57% , respectively. There were significant differences among the post-workout sports drinks when all eight sensory attributes were compared simultaneously. Mouthfeel, flavor, and overall liking were the sensory attribute that contributed to those differences. Overall liking was the only significant attribute that will help predict consumer acceptance; aroma, mouthfeel, flavor, sweetness, and overall liking were significant attributes that determine consumer purchase intent; overall liking was the only attribute that determines purchase intent after given additional information about the post-workout sports drink.

In the second study, sixteen sports drinks were reformulated so they would be more acceptable to consumers. The sports drinks included the same ingredients as in the first study except for protein sources and flavors. Two new clear protein sources were used, which included whey protein isolate and casein hydrolysate. Berry, tropical fruit, lemon/lime, and orange fruit powders were used to flavor the sports drinks. A consumer acceptance test was conducted with 280 consumers evaluating eight pre-workout and eight post-workout beverages. Consumers evaluated acceptability of appearance, aroma, color, consistency, flavor, mouthfeel, sweetness and overall liking using a 9-point hedonic scale. Product acceptance, purchase intent, and purchase intent after given exercise enhancing information about the product were evaluated using a binomial (yes/no) scale. Pre-workout formulation C (WPI, S, Bry) received the highest mean acceptability scores for overall liking (6.23), sweetness (6.93), flavor (6.33), mouthfeel (6.83), consistency (6.50), and aroma (5.69). Formulation C had the greatest acceptance

(85.71%), purchase intent (58.57), and purchase intent after given information about the sports drink (78.57%). There were significant differences among the pre-workout drinks when all eight sensory attributes were compared simultaneously. Aroma, flavor, sweetness, and overall liking were the sensory attributes that contributed to those differences. Overall liking and flavor were significant attributes in determining consumer acceptance; aroma and overall liking were significant in determining consumer purchase intent; and appearance and overall liking were significant in determining consumer purchase intent after given additional information about the product. All eight pre-workout sports drinks had significant increases in purchase intent after the consumers were made aware of the exercise enhancing benefits. Post-workout formulation P (WPI, G, Orange) had the greatest acceptability of overall liking (6.61), flavor (6.66), sweetness (6.79), mouthfeel (6.47) and aroma (5.90). Formulation P had the highest acceptance (89.71%) and the highest purchase intent (67.14%). Significant differences were found among the formulations when all eight sensory attributes were compared simultaneously, and flavor, sweetness, and overall liking are the sensory attributes that contribute to those differences. Flavor, sweetness and overall liking are significant sensory attributes that determine consumer acceptance; consistency, flavor, and overall liking help determine consumer purchase intent; overall liking is the only significant sensory attribute that predicts consumer purchase intent after additional information is given about the product. The change in purchase intent after consumers were made aware of the exercise enhancing benefits was significant for all post-workout formulation except for formulation P.

The last study compared the most acceptable pre- and post-workout formulation (C and P) to two similar commercial beverages. A consumer acceptance test was conducted with 300 consumers evaluating the two acceptable formulated beverages and two commercial beverages.

Consumers evaluated acceptability of appearance, aroma, color, consistency, flavor, mouthfeel, sweetness and overall liking using a 9-point hedonic scale. Product acceptance, purchase intent, and purchase intent after given exercise enhancing information about the product was evaluated using a binomial (yes/no) scale. Demographic information suggested that out of a population of 300 consumers that attended the gym, 88% of those people perform resistance-training exercises. Eighty-two percent of those people are males, 81 percent are 18 to 24 years of age, and 66% exercise three to five days per week. Sixty percent of the consumers that resistance train purchase sports drinks to consume before and during their workout to supply the body with energy and aid in hydration. Sixty-eight percent of the consumers who resistance train consume a sports drink to help recover after exercising. Consumers who consume sports drinks either before or after exercise expressed that the nutrients in the sports drink were the most important quality when purchasing such a beverage. Consumers evaluated the commercially available pre-workout beverage as having higher mean acceptability scores for all of the sensory attributes except for sweetness. The commercially available sports drink had a higher acceptance (86.62), purchase intent (58.33%) and purchase intent after given information about the product (69.67%), but was similar in nutrient content to the formulated beverage. Although the commercially available pre-workout beverage had higher acceptance, purchase intent, and purchase intent after, it is not significantly different from the formulated pre-workout beverage. The formulated post-workout drink was viewed as having higher acceptance of all the sensory attributes except for aroma, compared to the commercial beverage. The formulated beverage also had greater acceptance (72.97%), purchase intent (50.00%), and purchase intent after given post-exercise enhancement information; however, it is not significantly different from the commercial beverage in terms of the aforementioned qualities. The commercial post-workout beverage was very different in terms of ingredients, and is also sold as a powder to mix with water. Consumers preferred the qualities of the formulated beverage, which is a novel product, dissimilar to sports drinks available in today's market.

An acceptable and novel pre- and post- workout sports drink has been developed; however, some future improvements should be made to increase acceptability and consumer purchase intent. The studies indicated that improvements in odor and intensity of color need to be made. Possible future studies include: (1) loss of nutrients during processing; (2) shelf-life of the products; (3) effectiveness of other antioxidant/anti-inflammatory sources such as polyphenolics; (4) consumer acceptance of both the pre- and post-workout sports drinks together, and (5) actual physiological benefits of sports drinks both during and after exercise.

REFERENCES

American College of Sports Medicine position stand on exercise and fluid replacement. 1996. Med. Sci. Sports Exercise. 28(i).

Anonymous. 1998. Precise color communication: color control from perception to instrumentation. Minolta Co., Ltd.

Antonio, J. 2004. Postworkout carbohydrate and protein supplementation. Strength and Conditioning Journal. 26 (3): 43-44.

Antonio J, Sanders MS, Van Gammeren D. 2001. Effects of bovine colostrums supplementation on body composition and exercise performance in active men and women. Nutrition. 17 (3): 243-247.

Beckley JH, Foley MM, Topp EJ, Huang JC and Prinyawiwatkul W. 2007. Accelerating new food product development. Blackwell Publishing. 284.

Beduschi G. 2003. Current popular ergogenic aids used in sports: a critical review. Nutrition and Dietetics. 60: 104-118.

Bemben MG, and Lamont HS. 2005. Creatine supplementation and exercise performance. Sports Medicine. 35 (2): 107-125.

Beucler J, Drake M, Foegeding EA. 2005. Design of a beverage from whey permeate. Journal of Food Science. 70 (4): S277-S285.

Beverage Industry. 2006. Beverages Ride the Tide. Food and Beverage Supplement. 97: 10-26.

Biolo G, Tipton KD, Klein s and Wolfe RR. 1997. An abundant supply of amino acids enhances the metabolic effect of exercise on muscle protein. Am J Physiology. 273:E122-E129.

Boirie Y, Dangin M, Gachon P, Vasson MP, Maubois JL, Beufrere B. 1997. Slow and fast dietary proteins differently modulate postprandial protein accretions. Proceedings of the National Academy of Sciences, USA. 94: 14930-14935.

Bordi PL, Salvaterra G, Cole C, Cranage DA, Borja M, Choi Y. 2003. A taste comparison of an isolated soy protein carbohydrate-protein beverage and an isolated whey protein carbohydrate-protein beverage. Foodservice Research International. 14: 23-33.

Borsheim E, Aarsland A, Wolfe RR. 2004. Effect of an amino acid, protein, and carbohydrate mixture on net muscle protein balance after resistance exercise. International Journal of Sport Nutrition and Exercise Metabolism. 14: 255-271.

Bounous G, Batist G, Gold P. 1991. Whey proteins in cancer prevention. Cancer Lett. 57:91-4.

Brouns F, van Nieuwehoven M, Jeukendrup A and van Marken Lichtenbelt W. 2002. Functional foods and food supplements for athletes: from myths to benefit claims substantiation through the study of selected biomarkers. Br J Nutr. 88:S177-S186.

Burke DG, Chilibeck PD, Davison KS, Candow DG, Farthing J, Smith-Palmer T. 2001. The effect of whey protein supplementation with and without creatine monohydrate combined with resistance training on lean tissue mass and muscle strength. International Journal of Sport Nutrition and Exercise Metabolism. 11: 349-364.

Burke LM, Kiens B, Ivy JL. 2004. Carbohydrates and fat for training and recovery. In Maughan RJ, Burke LM, Coyle EF, editors. Food, nutrition and sports performance II. Routledge: New York. 24-44.

Burns JH and Berning JR. 1999. Sports Beverages. In Driskell JA and Wolinsky I, editors. Macroelements, water , and electrolytes in sports nutrition. CRC Press: New York. 211-236.

Candow DG, Burke NC, Smith-Palmer T, Burke DG. 2006. Effect of whey and soy protein supplementation combined with resistance training in young adults. International Journal of Sport Nutrition and Exercise Metabolism. 16: 233-244.

Carli G, Bonifazi M, Lodi L. 1992. Changes in exercise-induced hormone response to branched chain amino acid administration. J Appl Physiol Occup Physiol. 64: 272-7.

Casa DJ. 2000. National athletic trainer's association position statement: fluid replacement for athletes. Journal of Athletic Training. 35:212-224.

Coburn JW, Housh DJ, Housh TJ, Malek MH, Beck TW, Cramer JT, Johnson GO, Donlin PE. 2006. Effects of leucine and whey protein supplementation during eight weeks of unilateral resistance training. Journal of Strength and Conditioning Research. 20 (2): 284-291.

Coggan AR and Coyle EF. 1991. Carbohydrate ingestion during prolonged exercise: effects on metabolism and performance. Exercise Sports Science Review. 19: 1-40.

Convertino V, Armstrong L, Coyle E, Mack G, Sawka M, Senay L, and Sherman W. 1996. American College of Sports Medicine position stand: exercise and fluid replacement. Medicine and Science in Sports and Exercise. 28. i-vii.

Coombes JS, and Hamilton KL. 2000. The effectiveness of commercially available sports drinks. Sports Medicine. 29 (3): 181-209.

Costill DL and Sparks KE. 1973. Rapid fluid replacement following thermal dehydration. J. Appl. Physiol. 34:299.

Coyle EF. 2004. Fluid and fuel intake during exercise. In Food, nutrition and sports performance II. Maughan RJ, Burke LM and Coyle EF, editors. New York: Routledge. 64-70.

Cunningham JJ. 1997. Is potassium in needed in sports drinks for fluid replacement during exercise? International Journal of Sport Nutrition. 7: 154-159.

Davis JM, Lamb DR, Pate RR, Slentz CA, Burgess WA, and Bartoli WP. 1988. Carbohydrate-electrolyte drinks: effects on endurance cycling in the heat. American Journal of Clinical Nutrition. 48:1023.

Davison G and Gleeson M. 2005. Influence of acute vitamin C and/or carbohydrate ingestion on hormonal, cytokine, and immune responses to prolonged exercise. International Journal of Sport Nutrition and Exercise Metabolism. 15: 485-479.

Dodge JR, Ford MA, Perko MA. 2003. From ephedra to creatine: using theory to respond to dietary supplement use in young athletes. American Journal of Health Studies. 18: 111-116.

Driskell JA. 2000. Sports Nutrition. CRC Press: New York.

Driskell JA and Wolinsky I. 1999. Summary: macroelements, water, and electrolytes in sports nutrition. In Driskell JA and Wolinsky I, editors. Macroelements, water, and electrolytes in sports nutrition. CRC Press: New York. 243-247.

Eichner ER. 2007. The role of sodium in 'heat cramping'. Sports Medicine. 37: 368-370.

Ferguson TB, and Syrotuik DG. 2006. Effects of creatine monohydrate supplementation on body composition and strength indices in experienced resistance trained women. Journal of Strength and Conditioning Research. 20 (4): 939-946.

Finaud J, Lac G, Filaire E. 2006. Oxidative stress. Sports Medicine. 36 (4): 327-358.

Froiland K, Koszewski W, Hingst J, Kopecky L. 2004. Nutritional supplement use among college athletes and their sources of information. International Journal of Sport Nutrition and Exercise Metabolism. 14: 104-120.

Gacula MC, Singh J. 1984. Statistical methods in food and consumer research. New York: Academic Press, Inc.

Glaister M, Lockey RA, Abraham CS, Staerck A, Goodwin JE,, McInnes G. 2006. Creatine supplementation and multiple sprint running performance. Journal of Strength and Conditioning Research. 20 (2): 273-277.

Gleeson M, Maughan RJ and Greenhaff PL. 1986. Comparison of the effects of preexercise feeding of glucose, glycerol and placebo on endurance performance and fuel homeostasis in man. European Journal of Applied Physiology. 55:645-653.

Goldfarb AH, Patrick SW, Bryer S, You T. 2005. Vitamin C supplementation affects oxidative-stress blood markers in response to a 30-minute run at 75% VO_{2max}. International Journal of Sport Nutrition and Exercise Metabolism. 15: 279-290.

Gonzales-Alonso J, Heaps CL, Coyle EF. 1992. Rehydration after exercise with common beverages and water. International Journal of Sports Medicine. 13: 399.

Haff, GG, Koch, AJ, Potteiger, JA. 2000. Carbohydrate supplementation attenuates muscle glycogen loss during acute bouts of resistance exercise. International Journal of Sport Nutrition and Exercise Metabolism. 10: 326-339.

Hoffman JR, Stout JR, Falvo MJ, Kang J, Ratamess NA. 2005. Effect of low-dose, short-duration creating supplementation on aerobic exercise performance. Journal of Strength and Conditioning Research. 19 (2): 260-264.

Holsinger VH, Posati LP, DeVilbiss ED. 1974. Whey beverages: a review. J Dairy Science 57 (7):849-59.

Huberty CJ. 1994. Applied Discriminant Analysis. New York: Wiley and Sons 496.

Huffman LM and Harper WJ. 1999. Symposium: marketing dairy value through technology; maximizing the value of milk through separation technologies. J Dairy Sci. 82:2238-2244.

Ivy JL, Res PT, Sprague RC, Widzer MO. 2003. Effect of a carbohydrate-protein supplement on endurance performance during exercise of varying intensity. International Journal of Sport Nutrition and Exercise Metabolism. 13:382-395.

Ivy J. and Portman R. 2004. Nutrient Timing. Basic Health Publications: New Jersey. 21-67.

Ivy JL. 2001. Dietary strategies to promote glycogen synthesis after exercise. Canadian J Applied Physiology. 26:S236-S245.

Ivy JL, Goforth HW Jr, Damon BM, McCauley TR, Parsons EC and Price TB. 2002. Early postexercise muscle glycogen recovery is enhanced with a carbohydrate-protein supplement. J. Applied Physiology. 93:1337-1344.

Jillinek G. 1985. Sensory evaluation of food: theory and practice. England: Ellis Horwood.308.

Kargotich S, Goodman C, Dawson B, Morton AR, Keast D, Joske DJL. 2005. Plasma glutamine responses to high-intensity exercise before and after endurance training. Research in Sports Medicine. 13: 287-300.

Kerksick CM, Rasmussen CJ, Lancaster SL, Magu B, Smith P, Melton C, Greenwood M, Almada AL, Earnest CP, Kreider RB. 2006. The effects of protein and amino acid supplementation on performance and training adaptations during ten weeks of resistance training. Journal of Strength and Conditioning Research. 20 (3): 643-653.

Kirwan JP, O'Gorman D and Evans WJ. 1998. A moderate glycemic meal before endurance exercise can enhance performance. Journal of applied Physiology. 84:53-59.

Kleiner SM. 2001. Power eating. Champagne: Human Kinetics.

Knez WL, Coombes JS, Jenkins DG. 2006. Ultra-endurance exercise and oxidative damage: Implications for cardiovascular health. Sports Medicine. 36 (50): 429-441.

Kreider, RB, Ferreira M, Wilson M, and Almada AL. 1999. Effects of calcium beta-hdroxy-beta-methylbutyrate (HMB) supplementation during resistance training on markers of catabolism, body composition and strength. International Journal of Sports Medicine. 20:503-509.

Krumbach CJ, Ellis DR, Driskell JA. 1999. A report of vitamin and mineral supplement use among university athletes in a division I institution. International Journal of Sport Nutrition. 9: 416-425.

Lawless HT, Heymann H. Sensory evaluation of food: principles and practices. New York: Chapman & Hall/International Thomson Pub. 608.

Lawless HT, Klein BP. 1991. Sensory science theory and application in foods. New York: Marcel Dekker, Inc. 144.

Manninen AH. 2006. Hyperinsulinaemia, hyperaminoacidaemia and post-exercise muscle anabolism: the search for the optimal recovery drink. Br. J. Sports Med. 40:900-905.

Maughan RJ. 1991. Development and efficacy of carbohydrate-electrolyte sports drinks. Trends in Food Science and Technology. 2 (7): 162-165.

Maughan RJ. 1994. Fluid and electrolyte loss and replacement in exercise. In Harries M, Williams C,, Stanish WD, Micheli LJ, editors. Oxford Textbook of Sports Medicine. Oxford: Oxford University Press. 82-93.

Maughan RJ. 1998. The sports drink as a functional food: formulations for successful performance. Proceedings of the Nutritional Society. 87:15-23.

Maughan RJ, Bethell LR and Leiper JB. 1998. Effects of ingested fluids on exercise capacity and on cardiovascular and metabolic responses to prolonged exercise in man. Exp Physiol. 81:847-859.

McIntosh GH, Regester GO, LeLeu RK, Royl PJ, Smithers GW. 1995. Dairy proteins protect against dimethylhydrazine-induced intestinal cancers in rats. J Nutr. 125:809-16.

Meilgaard M, Civille GV, Caar BT. 1999. Sensory evaluation techniques. 3rd ed. Boca Raton: CRC Press. 119.

Mero A. 1999. Leucine supplementation and intensive training. Sports Medicine. 27 (6): 347-358.

Millard-Stafford M, Warren GL, Thomas LM, Doyle JA, Snow T, Hitchcock K. 2005. Recovery from run training: efficacy of a carbohydrate-protein beverage? Human Kinetics. 15: 610-624.

Miller RK and Associates. 2008. 2008 beverage market research handbook.

Murray B. 2007. The role of salt and glucose replacement drinks in the marathon. Sports Medicine. 37: 358-360.

Nadel ER, Mack GW, Nose H. 1990. Influence of fluid replacement beverages on body fluid homeostasis during exercise and recovery. In Gisolfi CV and Lamb DB, editors. Perspectives in Exercise Science and Sports Medicine. Vol 3. Carmel: Benchmark Press. 181-205.

Nielsen SS. 2003. Food Analysis. 3rd ed. New York: Kluwer Academic.

Ohr LM. 2003. More for the sport. Food Technology. 63-66.

O'Mahony. 1986. Sensory evaluation of food: statistical methods and procedures. New York: Marcel Dekker, Inc.

Peryam DR. 1998. The 9-point hedonic scale. Peryam & Kroll Research Corporation.

Piggot JR. 1984. Sensory analysis of foods. London: Elsevier Applied Science.

Piggot JR. 1986. Statistical procedures in food research. London: Elsevier Applied Science.

Powers SK, DeRuisseau KC, Quindry J. Hamilton KL. 2004. Dietary antioxidants and exercise. In Maughan RJ, Burke LM, Coyle EF, editors. Food, nutrition and sports performance II. Routledge: New York. 130-145.

Prepared Foods. January 2007. Formulating for performance. 81-86.

Resurreccion AVA. 1998. Consumer sensory testing for product development. Gaithersburg: Aspen Publishers, Inc.

Roy BD and Tarnopolsky MA. 1998. Influence of differing macronutrient intakes on muscle glycogen resynthesis after resistance exercise. Journal of Applied Physiology. 73:1986-95.

Sales Trend Handbook. 2007. Isotonics and energy drinks: Energized. 48.

Scofield DE, Unruh S. 2006. Dietary supplement use among adolescent athletes in central Nebraska and their sources of information. Journal of Strength and Conditioning Research. 20 (2): 452-455.

Seifert J, Harmon J, DeClercq P. 2006. Protein added to a sports drink improves fluid retention. International Journal of Sport Nutrition and Exercise Metabolism. 16: 420-429.

Severin S and Wenshui X. 2005. Milk biologically active components as neutraceuticals: review. Critical Reviews in Food Science and Nutrition. 45: 645-656.

Sherman WM, Peden MC and Wright DA. 1991. Carbohydrate feedings 1hour before exercise improve cycling performance. American Journal of Clinical Nutrition. 54:866-870.

Smithers GW, Ballard FJ, Copeland AD, DeSilva KJ, Dionysius DA, Francis GL, Goddard C, Grieve PA, McIntosh GH, Mitchell IR, Pearce RJ, Regester GO. 1996. New opportunities from the isolation and utilization of whey protein. Journal of Dairy Science. 79: 1454-1459.

Stone H and Sidel JL. 1993. Sensory evaluation practices. 2nd ed. New York: Academic Press, Inc. 243-266.

Svanberg E, Moller-Loswick A, Matthews DE, Korner U and Lundholm K. 2001. The effect of glutamine on protein balance and amino acid flux across arm and leg tissues in healthy volunteers. Clinical Physiology. 21(4):478-489.

Tauler P, Aguilo A, Gimeno I, Fuentespina E, Tur JA, Pons A. 2006. Response of blood cell antioxidant enzyme defenses to antioxidant diet supplementation and to intense exercise. European Journal of Nutrition. 45: 187-195.

Temelli F, Bansema C, Stobbe K. 2004. Development of an orange-flavored barley β-glucan beverage with added whey protein isolate. Journal of Food Science. 69 (7): S237-S242.

Thomas DE, Brotherhood JR and Brand JC. 1991. Carbohydrate feeding before exercise: effect of glycemic index. International Journal of Sports Medicine. 12:180-186.

Tipton KD, Ferrando AA, Phillips SM, Doyle D Jr. and Wolfe RR. 1999. Postexercise net protein synthesis in human muscle from orally administered amino acids. Am J Physiology. 276:E628-E634.

Tipton KD, Rasmussen BB, Miller SL, Wolf SE, Owens-Stovall SK, Petrini BE and Wolfe RR. 2001. Timing of amino acid-carbohydrate ingestion alters anabolic response of muscle to resistance exercise. Am J Physiology. 281:E197-E206.

Tipton KD and Wolfe RR. 2004. Protein and amino acids for athletes. In Maughan RJ, Burke LM, Coyle EF, editors. Food, nutrition and sports performance II. Routledge: New York. 104-124.

Vending International. 2006. Datateam Publishing Ltd.

Watson TA, MacDonald-Wicks LK, Garg ML. 2005. Oxidative stress and antioxidants in athletes undertaking regular exercise training. Human Kinetics. 15: 131-146.

Westrate JA, van Poppel G and Verschuren PM. 2002. Functional foods, trends and future. Br J Nutr. 88:S233-S235.

Wu JP and Ding XL. 2002. Characterization of inhibitory stability of soy protein-derived angiotensin-I-converting enzyme inhibitory peptides. 1992. Food Research International. 35:367-375.

Zawadzki KM, Yaspelkis BB III and Ivy JL. 1992. Carbohydrate-protein complex increases the rate of muscle glycogen storage after exercise. J Applied Physiology. 72:1854-1859.

Zegler J. 2007. Tournament of champions. Beverage Industry. 98 (6):14-18.

Zhang X and Beynen A. 1993. Lowering effect of dietary milk-whey protein vs. casein on plasma liver cholesterol concentration in rats. Br J Nutr. 70:139-46.

21CFR184.1854. Revised as of April 1, 2007. Code of Federal Regulations. From U.S. Government Printing Office via GPO Access. Title 21, Volume 1.

21CFR168.111. Revised as of April 1, 2007. Code of Federal Regulations. From U.S. Government Printing Office via GPO Access. Title 21, Volume 1.

21CFR184.1857. Revised as of April 1, 2007. Code of Federal Regulations. From U.S. Government Printing Office via GPO Access. Title 21, Volume 1.

21CFR172.320. Revised as of April 1, 2007. Code of Federal Regulations. From U.S. Government Printing Office via GPO Access. Title 21, Volume 1.

21CFR182.3890. Revised as of April 1, 2007. Code of Federal Regulations. From U.S. Government Printing Office via GPO Access. Title 21, Volume 1.

21CFR182.3013. Revised as of April 1, 2007. Code of Federal Regulations. From U.S. Government Printing Office via GPO Access. Title 21, Volume 1.

APPENDIX A: STUDY 1

a. Homogenizer Model 300 DJF 4 2PS, Manton-Gaulin Mfg. Co. Inc, Everett, MA

b. Research Consent Form

I, ________________________, agree to participate in the research entitled "Consumer Acceptance Test of Pre-workout and Post-workout Sports Drinks," which is being conducted by Witoon Prinyawiwatkul of the Department of Food Science at Louisiana State University, phone number (225) 578-5188.

I understand that participation is entirely voluntary and whether or not I participate will not effect how I am treated on my job. I can withdraw my consent at any time without penalty or loss of benefits to which I am otherwise entitled and have the results of the participation returned to me, removed from the experimental records, or destroyed. 280 consumers will participate in this research. For this particular research, about 10-15 minutes of participation will be required for each consumer.

The following points have been explained to me:
1. In any case it is my responsibility to report prior participation to the investigator any allergies I may have.

2. The reason for the research is to gather information on consumer sensory acceptability of pre-workout and post-workout sports drinks. The benefit that I may expect from it is a satisfaction that I have contributed to the solution and evaluation of problems relating to such examinations.

3. The procedures are as follows: Four coded samples will be placed in front of me, and I will evaluated them by normal standard methods and indicate my evaluation on a score sheet. All procedures are standard methods as published by the American Society for Testing and Materials and the Sensory Evaluation Division of the Institute of Food Technologists.

4. Participation entails minimal risk: The only risk that can be envisioned is that of an allergic reaction to whey products, sugar, leucine, glutamine, creatine, or fruits such as citrus, berries, and tropical fruits.

5. The results of this study will not be released in any individual identifiable form without my prior consent unless required by law.

6. The investigator will answer any further questions about the research, either now or during the course of the project.

The study has been discussed with me, and all of my questions have been answered. I understand that additional questions regarding the study should be directed to the investigator listed above. In addition, I understand the research at Louisiana State University AgCenter that involves human participation is carried out under the oversight of the Institutional Review Board. Questions or problems regarding these activities should be addressed to Bill Richardson, the Chancellor of LSU AgCenter at 578-4161. I agree with the terms above.

______________________________ ______________________________
Signature of Investigator Signature of Participant

Witness: _______________________ Date: _________________________

c. Sample Questionnaire

1. Gender: Male______ Female______ **Sample X**

2. How would you rate the **COLOR** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely	
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

3. How would you rate the **AROMA** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely	
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

4. How would you rate the **VISUAL APPEARANCE** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely	
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

5. How would you rate the **CONSISTENCY** (Thickness) of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely	
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

6. How would you rate the **MOUTHFEEL** (Graininess/Sandiness) of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely	
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

7. How would you rate the **FLAVOR** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely	
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

8. How would you rate the **SWEETNESS** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely	
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

9. How would rate **OVERALL LIKING** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely	
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

10. Is this product **ACCEPTABLE**? **YES** [ ] **NO** [ ]

11. Would you **BUY** this product if it were commercially available? **YES** [ ] **NO** [ ]

12. Would you **BUY** this product if it contained nutrients and supplements that would help you <u>during</u> a workout? **YES** [ ] **NO** [ ]

13. Would you **BUY** this product if it contained nutrients and supplements that would help you recover <u>after</u> a workout? **YES** [ ] **NO** [ ]

d. SAS code (ANOVA, MANOVA, DDA, LRA)

```
dm 'log;clear;output;clear';
data one;
input consumer    $ sample $  gender $    color aroma appearance
consistency mouthfeel   flavor      sweet oliking     accept      buy
      buyPre      buyPost;
datalines;
proc sort; by sample;
proc freq;by sample;
tables accept     buy   buyPre;
proc freq; by sample;
EXACT AGREE;
TABLES buy*buyPre/ AGREE;
TEST  AGREE;
proc means mean std n maxdec=2;by sample;
var color   aroma appearance consistency   mouthfeel  flavor      sweet
      oliking ;
proc anova;
class sample;
model color aroma appearance consistency   mouthfeel  flavor      sweet
      oliking      = sample;
means sample/tukey lines;
proc candisc out=outcan mah;
class sample;
var color   aroma appearance consistency   mouthfeel  flavor      sweet
      oliking;
proc discrim crossvalidate pool=test posterr;
class accept;
var color aroma   appearance consistency   mouthfeel  flavor      sweet
      oliking;
proc discrim crossvalidate pool=test posterr;
class accept;
var color;
proc discrim crossvalidate pool=test posterr;
class accept;
var  aroma;
proc discrim crossvalidate pool=test posterr;
class accept;
var appearance;
proc discrim crossvalidate pool=test posterr;
class accept;
var consistency;
proc discrim crossvalidate pool=test posterr;
class accept;
var mouthfeel;
proc discrim crossvalidate pool=test posterr;
class accept;
var flavor;
proc discrim crossvalidate pool=test posterr;
class accept;
var sweet;
proc discrim crossvalidate pool=test posterr;
class accept;
var oliking;
proc discrim crossvalidate pool=test posterr;
```

```
class buy;
var color aroma   appearance consistency   mouthfeel   flavor      sweet
      oliking;
proc discrim crossvalidate pool=test posterr;
class buy;
var color;
proc discrim crossvalidate pool=test posterr;
class buy;
var  aroma;
proc discrim crossvalidate pool=test posterr;
class buy;
var appearance;
proc discrim crossvalidate pool=test posterr;
class buy;
var consistency;
proc discrim crossvalidate pool=test posterr;
class buy;
var mouthfeel;
proc discrim crossvalidate pool=test posterr;
class buy;
var flavor;
proc discrim crossvalidate pool=test posterr;
class buy;
var sweet;
proc discrim crossvalidate pool=test posterr;
class buy;
var oliking;
proc discrim crossvalidate pool=test posterr;
class buyPre;
var color aroma   appearance consistency   mouthfeel   flavor      sweet
      oliking;
proc discrim crossvalidate pool=test posterr;
class buyPre;
var color;
proc discrim crossvalidate pool=test posterr;
class buyPre;
var  aroma;
proc discrim crossvalidate pool=test posterr;
class buyPre;
var appearance;
proc discrim crossvalidate pool=test posterr;
class buyPre;
var consistency;
proc discrim crossvalidate pool=test posterr;
class buyPre;
var mouthfeel;
proc discrim crossvalidate pool=test posterr;
class buyPre;
var flavor;
proc discrim crossvalidate pool=test posterr;
class buyPre;
var sweet;
proc discrim crossvalidate pool=test posterr;
class buyPre;
var oliking;
proc logistic data = one;
```

```
model accept = color aroma    appearance consistency   mouthfeel  flavor
      sweet oliking/ ctable;
proc logistic data = one;
model buy = color aroma appearance consistency   mouthfeel  flavor      sweet
      oliking/ ctable;
proc logistic data = one;
model buyPre = color aroma    appearance consistency   mouthfeel  flavor
      sweet oliking/ ctable;
```

APPENDIX B: STUDY 2

a. Pasteurization Vat

b. Cooling Vat Post Pasteurization

c. Homogenizer Model 300 DJF 4 2PS, Manton-Gaulin Mfg. Co. Inc, Everett, MA

See Appendix A p. 157.

d. Research Consent Form

See Appendix A p. 158.

e. Sample Questionnaire

See Appendix A p. 159.

f. SAS Code (ANOVA, MANOVA, DDA, LRA)

See Appendix A p. 160.

g. SAS Code (ANOVA for Physicochemical Properties)

```
dm 'log;clear;output;clear';
data one;
input sample $ pH Viscosity L C h;
datalines;
proc sort;
by sample;
proc anova;
class sample;
model pH Viscosity L C h = sample;
means sample/tukey lines;
run;
proc means mean std n maxdec=2;
by sample;
var pH Viscosity L C h;
run;
```

h. SAS Code (PCA Analysis)

```
options nodate nonumber;
%Include "biplot.sas";
%Include "equate.sas";

Data one;
Input sample $    color aroma appearance
consistency mouthfeel   flavor      sweet oliking;
datalines;
ODS exclude SimpleStatistics Cov TotalVariance;
Proc princomp data=one cov out=comp1;
 var color--oliking;
 run;
Title1 font='arial' height=0.4 cm "PCA on Consumer Acceptance of Pre-workout
Sports Drinks";
Title2 font='arial' height=0.4 cm "Symmetric Biplot -- alpha = 0.5";
%Biplot (Data=one,var=color   aroma appearance
```

```
consistency mouthfeel   flavor      sweet oliking, Id=sample, factype=sym,
colors=black blue, symbols=dot none);run;
quit;
Proc gplot data=comp1;
      plot prin1*prin2=1 / Href=0 vref=0 vaxis=axis1 haxis=axis2;
      axis1 label=(a=90 "Principal Component 1")
            order=(-6 to 5 by 1);
      axis2 label=("Principal component 2")
            order=(-2 to 2 by 0.5);
symbol1 c=black v=dot h=0.7 I=none pointlabel=(C=black "#sample");
run;
data two;
Input sample $    Appearance  Aroma Color Consistency Mouthfeel   Flavor
      Sweetness   OLiking;
datalines;
ODS exclude SimpleStatistics Cov TotalVariance;
Proc princomp data=two cov out=comp1;
 var appearance--oliking;
 run;
Title1 font='arial' height=0.4 cm "PCA on Consumer Acceptance of Post-workout
Sports Drinks";
Title2 font='arial' height=0.4 cm "Symmetric Biplot -- alpha = 0.5";
%Biplot (Data=two,var=Appearance    Aroma Color Consistency Mouthfeel
      Flavor      Sweetness   OLiking, Id=sample, factype=sym, colors=black
blue, symbols=dot none);run;
quit;
```

APPENDIX C: STUDY 3

a. Pasteurization Vat

See Appendix B p. 163.

b. Cooling Vat Post Pasteurization

See Appendix B p. 163.

c. Homogenizer Model 300 DJF 4 2PS, Manton-Gaulin Mfg. Co. Inc, Everett, MA

See Appendix A p. 157.

d. Research Consent Form

See Appendix A p. 158.

e. Sample Questionnaire

See Appendix A p. 159.

f. Demographic Survey

1. Do you perform resistance exercises such as lifting weights? Yes [ ] No [ ]
(If No, then please proceed to the next page.)

2. What is your **GENDER**? Male [ ] Female [ ]

3. What is your **AGE**?

18-24 [ ] 25-34 [ ] 35-44 [ ] 45-54 [ ] Over 55 [ ]

4. What is you body weight (pounds)?

Under 100 [ ] 100-149 [ ] 150-199 [ ] 200-249 [ ] Over 250 [ ]

5. How frequently do you perform resistance exercises?

1-2 days/week [ ] 3-5 days/week [ ] Over 5 days/week [ ]

6. Do you consume sports drinks before and during exercise to aid in hydration and supply the body with energy? Yes [ ] No [ ]

7. If you answered YES to question 6, what is the most important quality you are looking for when purchasing a sports drink? (Choose one)

[ ] Flavor
[ ] Nutrients
[ ] Consistency
[ ] Odor
[ ] Color
[ ] Price

8. Do you consume sports drinks after exercise to aid in recovery? Yes [ ]   No [ ]

9. If you answered YES to question 8, what is the most important quality you are looking for when purchasing a sports drink? (Choose one)

[ ] Flavor
[ ] Nutrients
[ ] Consistency
[ ] Odor
[ ] Color
[ ] Price

g. SAS Code (ANOVA, MANOVA, DDA, LRA)

See Appendix A p. 158.

h. SAS Code (ANOVA for Physicochemical Properties)

See Appendix A p. 159.

i. SAS Code (Demographic Information)

```
dm 'log;clear;output;clear';
data one;
input consumer $ RT  Gender Age Weight  Frequency  DrinkPre
QualityPre   DrinkPost  QualityPost;
datalines;
proc freq data=one;
run;
```

VITA

Maria Christine Pfister was born in June 1984, in Baton Rouge, Louisiana. In 2002, she graduated from McKinley Senior High School also in Baton Rouge. She attended Louisiana State University where she was awarded with a Bachelor of Science degree in Food Science. She is a candidate for a Master of Science degree from the Department of Food Science at Louisiana State University and Agricultural and Mechanical College in August 2008.