DEVELOPMENT OF *ZEA MAYS* JUICE AS AN ALTERNATIVE RECOVERY BEVERAGE FOR EXERCISING PEOPLE

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ABSTRACT

The purpose of this study was to develop the *Zea mays (ZM)* juice as an alternative recovery beverage for exercising people. The study consisted of descriptive formulation and assessment of *ZM* juice, followed by experimental study examining the effect of *ZM* juice on rehydration, sports performance and muscle recovery among recreational individuals. A total of 461 male and female participants were randomly selected with criteria of physically active, did not consume sports supplements and had no injuries. Data were analyzed using descriptive, paired t-test and two ways factorial ANOVA. *ZM* juice contained 9.8 g carbohydrate, 2.4 g protein and 64.3 mg sodium which met the recovery requirement. The beverage acceptance rate was 75% among the participants. Rehydration assessment showed that *ZM* juice (*M* = 48.0%, *SD* = 18.7) significantly retained fluid better than CE drink (*M* = 28.5%, *SD* = 21.7), $t(14) = -2.23$, $p = .042$ and produced less urine (*M* = 1022, *SD* = 415.18) than those in CE drink group (*M* = 418.7, *SD* = 425.9), $t(14) = 2.22$, $p = .043$. Meanwhile sports performance of 'CINDY' exercise significantly higher $F(1, 16) = 10.84$, $p=.005$, $\eta^2=.404$ in *ZM* juice group (*M* = 18.77, *SD* = 5.00) compared to CE drink (*M* = 14.88, *SD* = 5.88). Delayed Onset Muscle Soreness (DOMS) score was significantly lower $F(1, 16) = 9.145$, $p=.001$, $\eta^2=.364$ in *ZM* juice (*M* = 11.59, *SD* = 0.92) compared to CE drink (*M* = 12.02, *SD* = 1.39). The Short Form McGill Pain Questionnaire (SF-MPQ) maximum score feeling of pain decreased after 24 hours (score = 43) of exercise compared before exercise 2 (score = 45) in *ZM* juice. To conclude, *ZM* juice was capable to retain body fluid, promote exercise performance and reduce feeling of pain. In implication, *ZM* juice would be a good alternative recovery beverage for exercising people besides the readily available drinks in the market.

PENGHASILAN JUS *ZEA MAYS* SEBAGAI MINUMANAN PEMULIHAN ALTERNATIF KEPADA INDIVIDU YANG BERSENAM

ABSTRAK

Tujuan kajian ini adalah untuk menghasilkan jus *Zea mays* (*ZM*) sebagai minuman pemulihan alternatif untuk individu yang bersenam. Kajian ini terdiri daripada formulasi deskriptif dan penilaian jus *ZM*, diikuti dengan kajian eksperimental yang mengkaji pengaruh jus *ZM* terhadap rehidrasi, prestasi sukan dan pemulihan otot di kalangan individu rekreasi. Sebanyak 461 peserta lelaki dan wanita dipilih secara rawak dengan kriteria aktif secara fizikal, tidak mengambil makanan tambahan sukan dan tidak mengalami kecederaan. Data dianalisis menggunakan deskriptif, ujian t berpasangan dan ANOVA faktorial dua arah. Jus *ZM* mengandungi 9.8 g karbohidrat, 2.4 g protein dan 64.3 mg natrium yang memenuhi keperluan pemulihan. Kadar penerimaan minuman adalah 75% di kalangan peserta. Penilaian rehidrasi menunjukkan bahawa jus *ZM* (*M* = 48.0%, *SD* = 18.7) mengekalkan lebih banyak bendalir tubuh berbanding dengan minuman CE (*M* = 28.5%, *SD* = 21.7), t (14) = -2.23, p = .042 dan mengurangkan penghasilan urin (*M* = 1022, *SD* = 415.18) berbanding dengan kumpulan minuman CE (*M* = 418.7, *SD* = 425.9), t (14) = 2.22, p = .043. Sementara itu prestasi senaman 'CINDY' lebih baik secara signifikan F (1, 16) = 10.84, p = .005, η^2 = .404 dalam kumpulan jus *ZM* (*M* = 18.77, *SD* = 5.00) berbanding minuman CE (*M* = 14.88, *SD* = 5.88). Keputusan *Delayed Onset Muscle Soreness (DOMS)* jauh lebih rendah F (1, 16) = 9.145, p = .001, η^2 = .364 dalam jus *ZM* (*M* = 11.59, *SD* = 0.92) berbanding dengan minuman CE (*M* = 12.02, *SD* = 1.39). Keputusan *McGill Pain Short Form (SF-MPQ)* menunjukkan rasa sakit berkurangan selepas 24 jam (skor = 43) latihan berbanding sebelum latihan 2 (skor = 45) dalam kumpulan jus *ZM*. Kesimpulannya, jus *ZM* dapat mengekalkan bendalir tubuh, meningkatkan prestasi senaman dan mengurangkan rasa sakit. Secara implikasinya, jus *ZM* akan menjadi minuman pemulihan alternatif yang baik untuk individu yang bersenam selain minuman yang sedia ada di pasaran.

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LIST OF ABBREVIATIONS

%	percent
ACSM	The American College of Sports Medicine
ANOVA	Analysis of variance
BMI	Body mass index
BP Healthcare	Private Health Company that provided blood analysis services
CE	Carbohydrate-electrolyte
CK	Creatine kinase
cm	centimetre
DOMS	Delayed onset muscle soreness
EIMD	Exercise induced muscle damage
g	gram
kg	kilogram
KL	Kuala Lumpur
L	litre
LDH	Lactate dehydrogenase enzyme
m^2	meter squared
min	minute
ml	millilitre
mmol	milimols
N28	Specie of sweet corn used in the study
p	significant value
r	effect size
RPE	Rate of perceived exhaustion

Sdn Bhd	Sendirian Berhad (private limited company)
SF-MPQ	Short Form McGill Pain questionnaire
SME	Small and Medium Enterprises
std deviation	Standard deviation
T	Smaller number of the two sums of rank
U/L	Unit per litre
UPSI	Universiti Pendidikan Sultan Idris
US	United States
USA	United States of America
USDA	The United States Department of Agriculture
VO_2max	Maximum volume of oxygen consumption
yrs.	year old
ZM	*Zea mays*
η^2	partial eta square
χ^2	Friedman's ANOVA test statistic

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CHAPTER 1

INTRODUCTION

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1.1 Introduction

Human body water is actively regulated and overall hydration is normally maintained within a narrow range, between 1% hyperhydration to 3% hypohydration (Casa et al., 2008). Euhydration is defined as a state of optimal total body water content which is regulated by the brain such that physiologically body system functions are at their most efficient. Achieving a euhydration state has positive benefits especially when physical activity is performed in hot ambient temperature environments and/or for long periods of time (Sawka, Cheuvront, & Kenefick, 2015; Cheuvront & Kenefick, 2014; Sawka & Cheuvront, 2005). It is important for the body to be in a euhydration state for it’s normal physiological functions so that physical activity can be performed

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at the best level. Achieving balanced body water content can avoid negative health consequences. Hypohydration may result in heat syncope which is due to venous pooling and subsequent reduced blood flow to the brain (Carter, Cheuvront, Vernieuw, & Sawka, 2006) which can then progress to heat exhaustion which is characterised by central fatigue and hypotension (Sawka et al., 2015).

Physical activity increases metabolic heat production which is caused by muscle contraction activity. This metabolic heat production must be dissipated to the environment to prevent dangerous body temperature elevation within the human body. This heat loss occurs through cutaneous vasodilation and sweating that is induced by activation of the autonomic nervous system which thus facilitates an increase in dry heat exchange that is primarily through convection and radiation processes, and also further enhanced through evaporative heat loss from sweat activity. Evaporation of sweat is the main mechanism in reducing excess body heat. However, the production of sweat in abundance and over prolonged periods of time will result in a decrease in the total body fluid content. Prolonged sweat production and failure to replace it through adequate fluid intake will lead to a negative fluid balance which then results in a dehydrated state occurring. As a result, this dehydrated condition will cause a decrease in physical activity performance as well as have an effect on normal regulation of physiological activities.

Previous studies have shown that the presence of a prolonged negative fluid balance, even as low as 2% of body mass, will affect endurance capability (Cheuvront, Kenefick, Montain, & Sawka, 2010; Sawka et al., 2007; Carter & Sawka, 2003). Generally, endurance activity or aerobic exercise performance will be affected

in warm-hot environments as a result of hypohydration (Sawka et al., 2015). Furthermore, body fluid loss as much as 3% or more will attenuate anaerobic performance (Kephart, Mumford, McCloskey, et al., 2016; Kraft et al., 2012), cognition and mood (Masento, Golightly, Field, Butler, & van Reekum, 2014), and as well as motor coordination (Wittbrodt & Millard-Stafford, 2018). For all those reasons, body weight loss resulting from dehydration will decrease the body's capability to complete tasks in a timely manner and will result in performance deterioration.

Prolonged and repeated exercise bouts with short periods of rest time in between them require specific nutrients to promote recovery as well as to prepare the body for upcoming tasks. There are three objectives of recovery from exercise exertions, which are; to replenish energy storage, to replace fluid losses and to promote muscle synthesis (Beelen, Burke, Gibala, & Van Loon, 2010). Researchers have found that carbohydrates (Burke, Hawley, Wong, & Jeukendrup, 2011), proteins (James, Mattin, Aldiss, Adebishi, & Hobson, 2014), fluids (Shireffs & Maughan, 2000; Shirreffs, Taylor, Leiper, & Maughan, 1996) and sodium (Merson, Maughan, & Shirreffs, 2008; Shirreffs, Aragon-Vargas, Keil, Love, & Phillips, 2007) are among the required nutrients for recovery. The combination of these nutrients promotes muscle glycogen synthesis, enhances fluid uptake and increase muscle protein synthesis to meet the above-mentioned recovery objectives.

Physically active individuals such as athletes, military personnel and individuals who are have intense work schedules such as paramedics, firemen, and policemen need proper and adequate nutrients to support their ability to perform their

daily activities effectively. At the same time in these more recent times, more and more laypersons have become involved in competitive sports as part of their hobby activities and these activities include marathons and power man competitions. For instance, the Standard Charted KL Marathon was able to attract more than 38,000 participants in 2018 as was reported on February 22nd, 2019 (http://www.kl-marathon.com). These circumstances thus lead to situations that demonstrate a need to increase an individuals' nutrient consumption to get the right recovery nutrients to support their performance as well as to compensate and replace that consumed in their daily routines. The demand for the right nutrients at the right time has become a greater challenge as over time more and more claims and recommendations have been made regarding recovery to the public. Nutritional guidelines have been updated extensively and the idea of planning food intake following a sports periodization plan made in accordance to the activity performed has become a priority to meet specific requirements (Shirreffs & Sawka, 2011; Beelen et al., 2010; Sawka et al., 2007; Burke, Kiens, & Ivy, 2004; Casa et al., 2000). Nutrition intake has of late become specifically individualized where recommendations are planned critically according to an individual's personal body size and the type of activity they perform (Evans, James, Shirreffs, & Maughan, 2017; Burke et al., 2011) .

Within the field of nutritional industries, activity specific food products have become more competitive and creative in the development of food and supplement products designed to meet recovery requirements after exercise. There are many of these supplements available in the markets which are described as suitable for recovery purposes. Unfortunately repeated occurrences of product contamination, the presence of prohibited substances and the misuse or misdescription of products has

spoiled the sports industry and marred athlete achievements (Momaya, Fawal, & Estes, 2015), and thus has also had an effect on the health status of users (Birzniece, 2015). At the same time, supplement products are typically more expensive compared to real food. As a result, not all exercising individuals and athletes are able to make use of it or are able to afford it. Therefore, using natural food sources as one of the recovery choices is a better choice as it is both safe and nutritious while able to meet recovery requirements.

1.2 Background of the Study

Recovery plays a vital role for individuals involved in physically demanding activities and such athletes need to achieve fast recovery in between their daily training sessions especially those who have a training schedule involving more than one training session in a day (Burke, et al., 2011; Beelen et al., 2010). Theoretically, physiological adaptation and complete recovery involving fluid replacement, glycogen replenishment and muscle synthesis needs between 48 to 72 hours of complete rest to achieve. Competitive athletes specifically do not have the luxury of time to completely rest as they need to get to their subsequent training session on schedule which typically is usually less than 8 hours between these sessions (Burke et al., 2011). During a competition, athletes need to be well-prepared as there are typically only short recovery times available in between competition stages; which may comprise of a preliminary round followed by quarter final, semifinal and the final competitions. As these stages of competition are going on, athletes need to be able to perform at higher performance levels as the competition progresses and subsequently

becomes tougher. Therefore, failure to achieve optimum recovery after each training and/or competition session will result in a decrement of their sports performance in the approaching sessions (Alghannam et al., 2016).

As recovery consists of fluid replacement, glycogen refueling and muscle synthesis, this process requires nutrients that will promote recovery, these nutrients being carbohydrates, proteins, electrolytes, and water. For this reason, nutritional guidelines suggest that an athlete should immediately consume carbohydrate-electrolyte containing beverages for better fluid replacement compared to just plain fluids alone (Lee, Nio, Ang, Law, & Lim, 2011; Shirreffs & Sawka, 2011; Shirreffs, 2009). The addition of protein has been found to be of better benefit by promoting muscle glycogen replenishment and muscle synthesis which could enhance subsequent performance (Leser, 2011). A combination of carbohydrates with proteins in a recovery beverage is recommended especially as the palatability of the beverage and quantity to consume becomes more acceptable to the consumer (Beelen et al., 2010) compared to beverages or foods that only contain carbohydrates.

Recovery products that are commercially available in the market are typically protein powders and food supplements in the form of beverages. They are typically expensive and the possibility of contamination by prohibited compounds (namely performance enhancing compounds prohibited by the World Anti-Doping Agency – WADA) may be present (Nica Sousa, Teixeira, & Soares, 2014) which could affect an athlete's performance, and therefore the health of consumers in the long term. Researchers have discovered that there are food choices that could provide a similar effect towards rehydration and recovery such as that provided by food supplements

such as low fat milk and chocolate milk (Reid, 2016; Desbrow et al., 2014; James et al., 2011; Cockburn et al., 2010; Pritchett et al., 2009; Thomas et al., 2009; Watson et al., 2008; Shireff et al., 2007; Karp et al., 2006). Unfortunately, milk contains lactose that may result in gastrointestinal disturbance for lactose intolerant or hypolactasic individuals. This lactose intolerance could affect physical performance because of the gastrointestinal discomfort it causes. Therefore, lactose-free products are needed especially among Asian and especially Malaysian people as the prevalence of lactose intolerance and hypolactasia is high in these populations (Hegar & Widodo, 2015; Asmawi, Seppo, Vapaatalo, & Korpela, 2006; Densupsoontorn, Jirapinyo, Thamonsiri, Chantaratin, & Wongarn, 2004; Bolin et al., 1970).

Zea mays var saccharata or sweet corn is a natural food that contains carbohydrate, protein and electrolytes in proportions that could meet recovery requirements and be comparable to commercial recovery products that available in the market nowadays. *Zea may* is selected because it is a plant-based food source and in its original form has a good taste. In general, corn is the second type of food staple consumed by populations in the world, after rice (Saldivar & Perez-Carrillo, 2015). It is consumed widely as a side dish, salad, beverage, sweetener, and snack or as a base for a variety of food products such as flour and cereal. In addition, it is easy to find as *Zea mays* is one of the crops that easily can be planted locally in a tropical environment. The added value of *Zea mays* is that it contains phytochemical components that have been shown to lower the risks of developing chronic disease as well as being able to promote digestive health (Siyuan, Tong, & Liu, 2018). Foster-Powell, Holt, and Brand-Miller (2002) identified the Glycemic Index of sweet corn as 53 ± 4, and 17 for its Glycemic load. The classification of the Glycemic Index for

sweet corn is moderate and it is a carbohydrate–rich food which has a role in promoting glycogen synthesis through substrate availability (Burke et al., 2011).

1.3 Problem Statement

A negative fluid balance, muscle micro-tears, and soreness commonly happens after executing robust activities. A significant depletion of stored fuels, for example glycogen and amino acids, results after intense endurance and resistance training (Aragon & Schoenfeld, 2013). The physiological changes caused by the consequences of exercise promotes better adaptation to and enhances the body's ability to perform better (Betts & Williams, 2010). Coupled with that, nutritional intervention that involves appropriate nutrient intake before, during and after exercise promotes this adaptation and recovery process. Recently, a most important issue discussed is how to achieve optimal recovery after exercise or in between consequent exercise sessions particularly when there is only limited rest time (Burke et al., 2011). A study has shown that consuming the proper ratio of specific nutrients initiates glycogen replenishment, rebuilds or repairs tissue damage as well as enhances exercise performance (Burke & Mujika, 2014). It is well established that recovery consists of three processes, namely muscle glycogen replenishment, fluid loss replacement and muscle repair (Peake & Gandevia, 2017; Beelen et al., 2010).

A study showed that muscle glycogen could be replenished within 24 hours when a sufficient amount of carbohydrate is ingested (Burke et al., 2011) and immediate feeding will promote this glycogen replenishment (Burke & Mujika, 2014)

especially when there is only limited rest time available. Glycogen is a carbohydrate storage form in muscles and the liver that plays a role as the main energy source that is used for physical performance. Consumption of exogenous carbohydrate accelerates glycogen store replenishment that will then be available for subsequent exercise bouts (Bowtell et al., 2017). The addition of protein enhances the recovery process by promoting muscle synthesis (Phillips, Luc, Loon, & Van Loon, 2011; Burke et al., 2004), thus helping in a reduction of perceived muscle soreness (McBrier et al., 2010). Combinations of carbohydrate and protein have shown a better outcome in muscle protein synthesis and thereby promoting the muscle's glycogen replenishment (Beelen et al., 2010; Berardi, Price, Noreen, & Lemon, 2006).

The recovery beverage business is always on an uptrend worldwide due to the ever increasing demands from active individuals and athletes for these post exercise beverages. Due to existing recommendations and guidelines for better exercise performance outcome being easily available to the public, this has influenced the intake of recovery beverages among active individuals. For instance, the sales report for the Gatorade sports drink in the year 2015 amounted to 1.67 million US dollars in the United States alone (The Nielsen Co, Dr. Pepper Snapple Group Inc., 2016). In Malaysia, there are several types of commercial recovery drinks available such as Horleys high protein shake, PowerBar Recovery powder, Shaklee ESP Soy Protein, Nestle MILO chocolate malt beverage, Gatorade sport fuel protein shake and so on. All these products are milk-based except for Shaklee ESP Soy Protein which is plant-based. However, it lacks the necessary carbohydrate that is needed for muscle energy fuel. Recovery beverages that contain carbohydrate and protein have become established as better choices compared to beverages containing only carbohydrates.

Therefore, esearchers have suggested that milk and milk-based beverages are better recovery choices as they contain both carbohydrate and protein naturally (Watson, Love, Maughan, & Shirreffs, 2008; Shirreffs, Watson, & Maughan, 2007; Shirreffs & Maughan, 1998).

Many studies conducted on Caucasian athletes had proven that milk and milk-based beverages are effective post-exercise drinks for exhausting activities because they contain carbohydrate, protein, vitamins, and electrolytes (Watson, et al., 2008; Shirreffs et al., 2007). Unfortunately, milk and milk-based beverages are not the best choices for active individuals who may have a problem with lactase deficiency that can result in lactose intolerance where the body is unable to digest lactose. Lactose is a sugar that is abundant in mammalian milk that has an important role in the body (Scrimshaw & Murray, 1988). Lactose is the combination of glucose and galactose that could be directly used as energy source in the body. The indigestible lactose results in carbohydrate malabsorption due to an inadequate amount of the enzyme lactase needed to hydrolyze lactose in food (Tomar, 2014). This condition will produce symptoms such as bloating, nausea, diarrhea and vomiting which can affect sports performance.

A study on the prevalence of lactose maldigestion among Latin American populations was found to be above 45% (Scrimshaw & Murray, 1988). A review by Tomar (2014) revealed that in the United States, the prevalence is 15% among White-Americans, 53% among Mexican-Americans and 80% in the African-Americans. While in Australia and New Zealand, it has been found that the prevalence of lactose intolerance is 6% and 9%, respectively. In general, it can be assumed that about two-

thirds of the world's adult population is lactase deficient. A study done among an Asian population (Asmawi et al., 2006) showed that the prevalence of lactose intolerance or hypolactasia was high with a prevalence of 88% among Malays, 91% among Chinese and 83% among Indians. Similarly, the prevalence of lactose intolerance was found above 50% of the studied population in Thailand (Densupsoontorn et al., 2004), Singapore (Bolin et al., 1970) and among Indonesian children (Hegar & Widodo, 2015).

Indeed, Pelly & Burkhart, (2014) conducted a survey on the dietary regimens among athletes competing in the 2010 Commonwealth Games in Delhi which reported that 10% of the athletes from South East Asian countries were likely to follow a low or lactose-free diet to avoid the symptoms of lactose intolerance. A study by McCarthy and colleagues (2017) identified that one of the reasons why the consumption of milk and milk products among the United States population has declined was due to the preference of consumers for non-dairy products to avoid lactose maldigestion side effects. Therefore, the demand for lactose-free products especially for recovery purposes during and after exercise is of priority to avoid the negative effects of lactose intolerance (Szilagyi & Ishayek, 2018) that could affect sports performance and thus, the health status of consumers.

Consequently, this current study aims to develop and assess the feasibility of a beverage from sweet corn, *Zea mays*, as an alternative recovery drink for an active individual which will promote fluid replacement, performance enhancement, and muscle recovery among them. The current study suggests the plant-based sources due to their absence of the sugar lactose, still contains carbohydrates and other nutrients

which are as important for recovery purposes. *Zea mays* does not contain lactose sugar as compared to human milk and milk from domestic animals (Adam, Rubio-Texeira, & Polaina, 2005).

1.4 Research Objective

The main objective of this study was to purpose and develop a new alternative recovery beverage that is suitable and fulfills recovery requirements among exercising individuals. Even though there are many recovery drinks available on the market, there is still a lack of products suitable for those who are unable to consume lactose containing products. Generally, recovery products consist of milk and milk substitutes which contain the sugar lactose that could trigger lactose intolerance as well as would not be preferred by those who practice a vegan diet. Therefore, this new proposed product, based on a plant source, could provide an alternative to overcome lactose and milk consumption issues.

There are three specific objectives of this study that proposes *Zea mays* juice as a recovery beverage. The first objective is to investigate the effectiveness of *Zea mays* juice as a rehydration beverage for fluid replacement following exercise induced dehydration. The second objective is to examine the ability of *Zea mays* juice in promoting recovery consequent to repeated high-intensity exercise episodes with only short rest periods in between and the final objective is to assess the ability of *Zea mays* juice to reduce muscle damage effects, namely muscle soreness and pain sensation after high-intensity exercise among exercising and physically active

individuals. As such, this study consists of a total of two research questions and two research hypotheses to be answered.

1.5 Research Question

1.5.1 Will *Zea mays* nutritive values meet nutrient recommendations for recovery?

1.5.2 What will be the acceptance rate among exercising individuals towards *Zea mays* juice?

1.6 Research Hypothesis

Ho1: There is no significant difference between *Zea mays* juice and carbohydrate-electrolyte drinks as an effective rehydration beverage after exercise.

Ho2: There is no significant difference in performance and muscle recovery effect resulting from repeated bouts of CrossFit ‘CINDY' exercise following *Zea mays* juice and carbohydrate-electrolyte drink consumption.

1.7 Research Framework

The research framework of this study is based on exercise recovery theory as the backbone to the research conducted, and there are four stages involved which includes assessing the acceptance of the product, *Zea mays* juice, and the ability of the *Zea mays* juice as an alternative recovery beverage. Figure 1.1 shows the research framework of this study covering the theory, stages involved, and the variables involved regarding *Zea mays* juice as a recovery beverage. The theory of thermoregulation in the body and the recovery mechanism in maintaining homeostasis and achieving normal physiological responses when exercising was used as the main basis in suggesting *Zea mays* juice as an alternative recovery beverage. The details of thermoregulation theory are later discussed in the literature review.

There are four stages to this study that intends to develop and test the recovery ability of *Zea mays* juice. The study shall start with the formulation and analysis of *Zea mays* nutritive values in meeting the requirement as a recovery beverage, followed by assessment of the acceptance by untrained assessor panels and consumers of the proposed product. The study then continues with two experimental studies which look at the rehydration ability of *Zea mays* juice and finally, the *Zea mays* juice is tested for its effect on high intensity physical performance and muscle recovery.

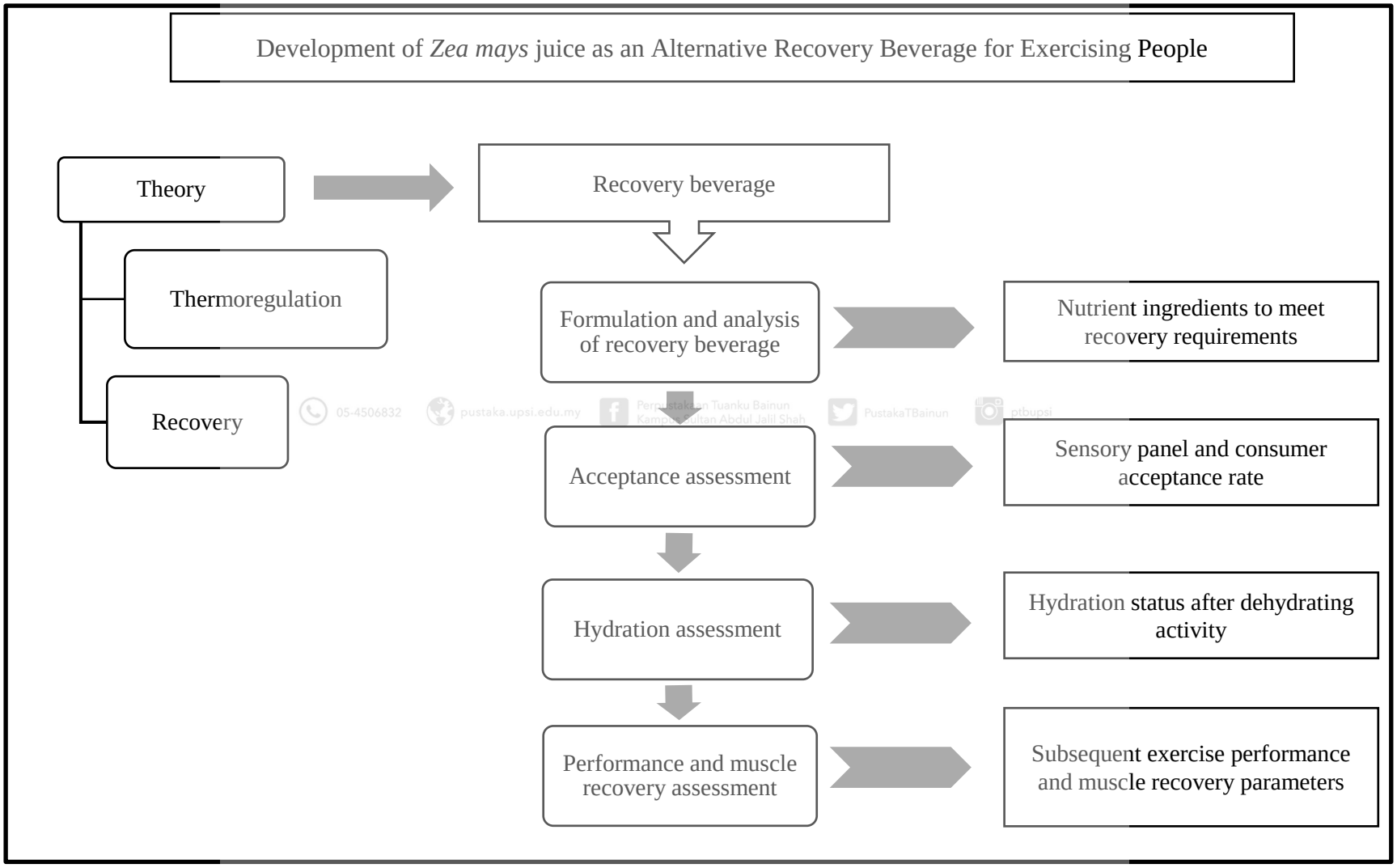

Figure 1.1. The research framework of the study

1.8 Importance of the Research

This current study aims to propose an alternative recovery drink for athletes and physically active individuals to promote fluid replacement, boost physical performance and accelerate muscle recovery after exercise. Consequently the formulation of this recovery drink would thus fulfill the nutrient requirements for physical demands resulting from intense workloads that are related to the work activities of military personnel, athletes, policemen, firemen, and paramedics. The development of this recovery beverage could contribute to the well-being of these populations thus allowing them to perform at their best in the nation interest. It would also provide a new recovery drink which is a lactose-free product that can be consumed by active individuals without worrying about the side effects of lactose maldigestion. At the same time, it is a plant-based beverage that could benefit those who are vegan diet practitioners and as well as being suitable for young athletes.

The rational of using sweet corn, *Zea mays*, as the main ingredient for this product can enhance the gross domestic product (GDP) of the country since the species used in this study is grown locally. Corn is one of the plants that grows throughout the year with a short harvest interval. It is one of the carbohydrate food sources that is widely consumed in daily life. There are many ways to consume corn and corn products such as in a salad, as a beverage, as a snack and as an ingredient in prepared food products, among which is corn flour. It is also the source of sugar in many processed beverages and food products namely as fructose syrup and is one of the major ingredients for breakfast cereals. The Ministry of Agriculture can make use of these findings and extend them to the relevant parties such as farmers and SME

corporations in promoting corn harvests and to encourage the production of corn-based products. As corn is widely consumed around the world, the invention of new corn products could become one of the export commodities for this country, thereby helping to boost the economy of our country.

1.9 Study Delimitations

The participants of this study were university students who are actively involved in sports and physical activity. Male and female students were invited to participate in the study during the pilot test, which was a sensory evaluation session and acceptance assessment of the product. During this sensory evaluation session, only individuals with experience of consuming sports drinks or recovery drinks previously were selected.

For the experimental study, only male participants were involved in the two experimental laboratory studies which were the rehydration assessment and subsequent repeated high intensity exercise performance together with muscle recovery assessment. The decision to select only one gender, namely male, during the experimental studies was due to body fluid regulation factors. Among female individuals, body fluids usually fluctuate following their menstrual cycle due to their normal physiological hormone responses occurring in this period. Because of this variability, the total body fluid content in females is expected to fluctuate and could influence the results of the experiment. At the same time, the objective of the study is only to look at the ability of a purposive recovery beverage on rehydration ability

without involving any hormonal response factors. As such, only male participants were involved in both experimental studies.

All of the studies were conducted in covered areas, i.e inside buildings except for the pilot test session. Data collection for the pilot test was undertaken in an outdoor environment following the participant's choice of training venue. Data was collected after the participants had completed their normal routine of individual choices of physical activity. The rest of the data collection activity was in a controlled set up and conducted either in the gymnasium or nutrition laboratory (lab) whereby the ambient temperature was controlled by adjustment of the air conditioning temperature. The acceptance assessment was conducted in a covered area within a building with tables and chairs provided when collecting responses from the participants. This was to ensure the participants were comfortable during the product assessment session.

There are three instruments used in this study. The first instrument was the Acceptance Test Questionnaire (ATQ) by Song and Aryana (2014). It was used to assess the participants' and panelists' feedback on the newly formulated recovery beverage which was *Zea mays* juice. The second instrument was the Delayed Onset Muscle Soreness (DOMS) score by Cleather (2005) and the third instrument was the Short-form McGill Pain Questionnaire (SF-MPQ) by Melzeck, (1987). All the instruments underwent a back to back translation process in Bahasa Melayu. The translation process was then reviewed and approved by field experts' for better participant understanding and to reduce any language bias when answering the questionnaire.

In the experimental study, cycling activity was used to dehydrate the participants for rehydration assessment. The participants were asked to cycle until they lost approximately 1.8% of their initial body weight at 70% to 80% of their predicted maximum heart rate using the formula "220 minus the individual's age". Following that, the CrossFit 'CINDY' exercise was chosen to determine the ability of the recovery beverage in supporting consequent repeated exercise performance with short rest periods in-between and muscle recovery. The CrossFit 'CINDY' exercise was chosen because of it being a high intensity exercise regime that could potentially result in micro-trauma wear and tear muscle damage (Kliszczewicz, Snarr, & Esco, 2014).

1.10 Study Limitations

The honesty of participants in following the instructions given is uncontrolled. The participants in the sensory evaluation and acceptance assessment were given instructions to provide their own opinion regarding the taste of *Zea mays* juice. They were asked to answer individually without any influence from their friends who also sat for the assessment or by the individual that conducted the assessment.

During both of the experimental studies, the participants were given instructions to avoid vigorous exercise and activity on the day before the assessment. They were also reminded to record their food and beverage intake for 24 hours prior to the experiment day and to repeat consuming similar types and quantities of foods and beverages throughout the assessment session. During the muscle recovery

assessment, participants need to record their food and beverage intakes on the assessment day as well as on the following day. Types of foods and the quantity consumed may influence the recovery rate thus cause an effect on the outcome of serum creatine kinase assay that was taken on the following day.

Both of the experimental studies were set up with a minimum of seven days in between the two assessment sessions. The activity of the participants during these two sessions was uncontrolled as they were active individuals who were involved with various types of physical activities in their normal daily routines at university. Some of the participants were either university or national athletes that needed to follow their pre-determined training periodization plans. The assessment date was chosen by the participants according to their availability to commit to the experimental procedures. During the final experimental study which was the repeated high intensity CrossFit 'CINDY' exercises and muscle recovery assessment, the participants needed to avoid vigorous activity prior to the assessment day and also on the day after the exercise session as they need to return on the following day for another blood sample to be drawn as the procedure of the assessment was repeated for two days to complete the assessment protocol.

1.11 Operational Definitions

Zea mays juice is a sweet corn juice from the species N28 (Nelson Franchise Sdn Bhd) that was used as a rehydration and recovery beverage for this present study. *Zea mays* juice is the extract from the corn kernels and has the addition of salt and water

to meet the recovery recommendations similar to that of established sports drinks (Shirreffs, 2003).

A recovery beverage is a beverage that consists of specific nutrients which include carbohydrates, proteins, electrolytes and fluids that needed to accelerate glycogen replenishment, promote muscle synthesis and fluid replacement after physical activity. (Beelen et al., 2010)

Exercising persons (people) refers to individuals who are involved in at least a total of 150 minutes of moderate intensity exercise or 75 minutes of vigorous physical activity in a week (WHO 2010).

A carbohydrate-electrolyte drink (CE drink) is a beverage that contains carbohydrates in sugar form which may be glucose, fructose or sucrose or combination of them and electrolytes which is predominantly sodium. It has been established that sports drink do promote fluid replacement and muscle recovery after exercise (Shirreffs, 2003). Gatorade was used as the CE drink in the present study as an example of a typical carbohydrate-electrolyte drink that is known for its ability to promote fluid replacement (Singh et al., 2011).

Muscle recovery is the activity covering both muscle synthesis and regeneration of new muscle cells after micro-damage resulting from the exercise performed in the presence of specific nutrients such as carbohydrates and proteins (Burke et al., 2011).

1.12 Summary

Nutritional applications have become one of the key elements in training programs for better physical performance adaptation as well as to fulfill daily energy and fluid requirements. A proper and individualized nutrition plan could help the body in meeting the demand for the right nutrients to sustain and promote exercise performance and daily routine activity expenditure. The high demand resulting from physical activity increases the requirement for nutrients for the body to recover faster and perform better. The idea behind this study is to develop and propose a new alternative recovery beverage that promotes effective recovery. A plant-based food product was chosen because it is naturally nutritious and free from prohibited substances that could affect the performance of competitive athletes and thus their health status in the long term. To date, it is also suitable to fill an empty space for lactose-free products that are unavailable or very limited in the market presently. Therefore, the proposed product in this study could provide an alternative choice for those with lactose intolerance or lactase deficiency, as well as for vegetarians and vegans.