Pakistan Journal of Life and Social Sciences

www.pjlss.edu.pk

https://doi.org/10.57239/PJLSS-2022-20.2.004

RESEARCH ARTICLE

The Development of Kluai Namwa (Musa Sapientum Linn.) Energy Gel: An Alternative Ergogenic Aid for Enhancing Endurance Running Performance

Chutinan Suksaard [1], Krittiya Kuenpetch [2], Nattiporn Nokkaew [3*]

[1,2] Faculty of Sports Science, Chulalongkorn University, Bangkok, Thailand

[3] Faculty of Science and Technology, Thammasat University, Pathumthani, Thailand

ARTICLE INFO

Received: May 23, 2022

Accepted: Oct 22, 2022

Keywords

Kluai Namwa (Musa Sapientum Linn.)

Endurance running

Blood potassium

Blood glucose

Blood lactate

Time to exhaustion

***Corresponding Author:**

nattiporn.N@chula.ac.th

ABSTRACT

Kluai Namwa (Musa Sapientum Linn.; Banana; BAN) is one of the most ancient species of banana well-grown in Thailand. BAN has a long history of use as a nutritional supplement and medical food due to its beneficial nutritional and therapeutic effects. Being an ergogenic aid, BAN has shown significant changes in the lipid profile, muscle and liver glycogen, enzyme activity, and Nitric Oxide (NO) activity inhibition, which results in prolonged exercise time. The objectives of this study were to develop a BAN energy gel and examine the effects of BAN energy gel on endurance running performance. The nutrition values of the developed BAN energy gel, glucose, sucrose, fructose, sodium, potassium, magnesium, protein, fat, ash, and total carbohydrate were assessed. The BAN energy gel nutrition values were 1.20±0.02 (g), 8.77±0.08 (g), 1.31±0.01 (g), 25.67±0.13 (mg), 184.83±0.54 (mg), 14.07±0.09 (mg), 0.43±0.08 (g), 0.14 ±0.02 (%), 1.23±0.19 (g), 0.55±0.01 (g), 15.95±0.21 (%) per 100 g sample, respectively. BAN energy gel had total energy of 66.75±0.84 Kcal/100 g of sample. For examining the effects of BAN energy gel, eleven Thai male runners (aged 27.36±8.89 years and VO_2 max 69.43±12.69 ml/kg/min) participated in this study to investigate Time To Exhaustion (TTE). TTE in subjects who consumed BAN energy gel was significantly longer than in subjects who consumed placebo (PLA) (55.23±10.32 min. vs. 46.13±9.87 min). The potassium level in the blood of subjects who consumed BAN energy gel was significantly higher than in subjects who consumed PLA (p<.05). This study found that BAN energy gel can prolong time to exhaustion. Therefore, BAN energy gel can be used as an ergogenic aid for runners, which is suitable to be consumed before and during the competition.

INTRODUCTION

Banana has a variety of cultivars (Miller, 2012, Murdoch et al., 1993). Kluai Namwa (Musa Sapientum Linn.; BAN) is one species of banana well-grown in Thailand. BAN contains 74 percent water, 53 percent carbohydrates, 1 percent proteins, 0.5 percent fat, and 2.6 percent fiber. In the ripening process, the starches in a BAN are converted to sugars. A fully ripe BAN has only 1-2 percent starch and 51 percent non-starch polysaccharides (Skidmore and Smith, 2005). Presently, the consumption of BAN has increased due to its nutritional and therapeutic value. The unripe BAN treats diarrhea, while the ripe BAN treats gastric ulcers, hypertension, diarrhea, dysentery, and diabetes (Dikshit et al., 2012). Many studies discovered that BAN has several benefits, such as providing anti-depression effects, preventing anemia, controlling blood pressure, and promoting the metabolic rate in conditions of stress (Kumar et al., 2012). As ergogenic aid, BAN has shown significant changes in the lipid profile, muscle and liver glycogen, enzyme activity, and inhibition of Nitric Oxide (NO) activity. Leelarungrayub et al. (2017) found that consuming two ripe BAN increased back and leg strength and prolonged exercise time under the antioxidant condition, in addition to possibly controlling the triglyceride and cholesterol levels and the pro-inflammatory IL-23 cytokine in healthy male subjects. Muchimapura et al. (2014) also observed that a single administration of BAN extract lengthened the swimming time in lab rats.

Running is one of the endurance sports that can improve mental and physiological health (Doyenart et al., 2020). Half-marathons are 21 Km long-distance running events. They are described as oxidative metabolism activities that use a lot of energy and involve rhythmic movements done by large muscle groups (Seepika et al., 2022). Oxidation of glycogen derived from muscle is highest during the early stages of endurance running and decreases as running duration is prolonged (Hargreaves and Spriet, 2020; Ravindra et al., 2022). During prolonged exercise, muscle glycogen breakdown can be reduced below the use of muscle glycogen, resulting in a depletion of muscle glycogen, leading to muscle fatigue and exhaustion (Seepika et al., 2022).

In endurance running, nutrients, both macronutrients and micronutrients play an important role in increasing and maintaining blood glucose concentration, slowing muscle glycogen breakdown, and reducing muscle fatigue, all of which help runners improve their endurance running performance (Nieman et al., 2015). If half-marathon runners don't get enough nutrients from food and supplements to meet their energy needs, it can tire their muscles, lower the amount of glucose in their blood, and make them run slower. Carbohydrate (CHO) is one of the most important energy sources for energy metabolism and also acts as a key energy source for runners (MacLaren and Morton, 2011). The Academy of Nutrition and Dietetics (AND), Dietitians of Canada (DC), and the American College of Sports Medicine (ACSM) all agree that moderate to high-intensity exercise (1-3 h/day) requires 6-10g per kilogram of body weight per day (g/kg/day) of CHO (Jäger et al., 2017), or the current ACSM guidelines of 30-60g CHO/hour for exercise lasting more than 1 hour. KarlCHO (as blood glucose and muscle glycogen) produces more ATP (Adenosine Triphosphate) per volume of Oxygen (O_2) than fat. Still, a lack of CHO in the liver and muscles can make you tired, less productive, and less able to focus (Vitale and Getzin, 2019).

The depletion of muscle glycogen and reduction of blood glucose concentrations can occur after 90 minutes of running, and they are associated with physical fatigue in runners during prolonged running (Jeukendrup, 2013). More than two-fifths of marathon runners experience severe, and performance-limiting depletion of physiologic carbohydrate reserves (a phenomenon known as "hitting the wall"); moreover, approximately 1–2% of runners drop out before reaching the finish lines (Rapoport, 2010). Therefore, the intake of ergogenic aids containing CHO has been one of the widespread strategies used in endurance running to ensure that runners will have enough energy throughout the prolonged event.

Several ergogenic aids containing CHO, including drinks, bars, and gels, are available as energy sources for runners during endurance training and competition (Naderi et al., 2016, Nieman et al., 2015). Recently, the CHO supplement market has diversified from beverages containing CHO to highly concentrated energy gels (Kozlowski et al., 2021).

An energy gel is a gel-based concentrated-CHO supplement developed to be ingested with water. An energy gel is considered by athletes to be a convenient ergogenic aid to carry during an endurance exercise. Most energy gels provide high CHO and other electrolytes suitable for endurance runners (Fleming et al., 2018). The major ingredients of energy gel are

CHO, electrolytes, and several juices. Athletes can consume energy gels before, during, and after training or competition to increase or maintain blood glucose and slow down muscle fatigue (Castell et al., 2010; Coyle, 2004; Saunders et al., 2007).

Endurance performance improvements have been observed during a 3-hour endurance trial performed at 70% $\dot{V}O_2max$ after consuming slurried or solid bananas vs. ingesting an artificially sweetened placebo (Murdoch et al., 1993). Kozlowski et al. (2021) have found that ingestion of energy gels during prolonged cycling elevates blood glucose levels and enhances subsequent performance, whereas more frequent ingestion elicits additional performance benefits.

Given the popularity of energy gel consumption among endurance athletes, little research exists analyzing the effects of energy gel on long-distance runners, BAN contains 53% CHO (Skidmore and Smith, 2005), and BAN consumption would be able to prolong exercise time (Leelarungrayub et al., 2017). It was hypothesized that half-marathon runners would be receptive to consuming Kluai Namwa (Musa Sapientum Linn.) energy gel and that endurance running performance would be significantly improved after ingestion of Kluai Namwa (Musa Sapientum Linn.) energy gel compared to the control group. However, no BAN energy gel is currently on the market.

MATERIAL & METHODS

Energy gel consumption behavior among the Thai runners

To provide a frame of reference for the development of BAN Energy Gel, a consumption of energy gel behavior questionnaire was developed to examine the consumption behavior of energy gel among Thai runners (the validity score (IOC score) was 0.95, and reliability (Cronbach's alpha coefficient) was 0.76). The questionnaire consisted of demographic information (age and running distance), reasons for consuming energy gel, the running duration at which runners start consuming energy gel, and the flavor of the energy gel that runners prefer to consume. The data was collected among 404 randomly chosen Thai runners through Yamane's formula sampling technique. The questionnaire took approximately two minutes to complete. The data were analyzed to interpret the energy gel consumption behavior.

Kluai Namwa (Musa Sapientum Linn.) Energy Gel Development

The fresh BAN has seven ripening stages. (1–7: completely unripe to completely ripe). The fruit in the 6th stage of ripening was collected from a local farm in Thailand.

Figure 1: The 6th stage of ripening of the fresh Kluai Namwa (Musa Sapientum Linn.)

The bananas in the 6th stage of ripening were cleaned, then simmered at 80 °C for 10 minutes in a water bath. The simmered BAN was cooled using an ice bath for 5 minutes, then peeled and cut into small pieces. The small pieces of BAN were blended with water in a food processor. The BAN seeds were removed by sieving. Blended BAN was simmered at 80 °C in a water bath, then carrageenan, salt, citric acid, maltitol, and sucralose were added. All ingredients were steadily stirred at 80 °C until all ingredients were dissolved. The samples were removed from the water bath and cooled using an ice bath for 5 minutes. The BAN energy gel sample was filled into single-use packets.

Proximate analysis of the Kluai Namwa (Musa Sapientum Linn.) energy gel

For proximate analysis of the BAN energy gel, glucose, sucrose, and fructose quantities were determined using High-Performance Liquid Chromatography (Agilent Technologies, Germany) (AOAC, 2019). Protein was determined using the digestion and distillation units (Gerhardt, Germany) (AOAC 991.20, 2016). Moisture was determined using a hot air oven (Binder, Germany) (AOAC 925.10, 2019). Ash was determined using a muffle furnace (Cabolite, UK)

(AOAC 923.03, 2019). Fat was determined using the Soxtec 8000 extraction unit and the hydrotic 8000 (Foss, Denmark) (AOAC (2003, 05, 2019). Kcal/100 g=% fat was multiplied by 9 to calculate fat energy. Total carbohydrate contents were determined by calculated, based on Total carbohydrate, g/100 g. = 100 - (% Moisture + % Ash + & Protein +% Total fat). Total energy was determined by calculated, based on kcal/100 g. = [(%Total fat x 9) + (% Protein x 4) + (% Carbohydrate x 4)].

Mineral analysis of the Kluai Namwa (Musa Sapientum Linn.) energy gel

For mineral analysis of BAN energy gel, sodium, potassium, and magnesium were determined using an Inductively Coupled Plasma Emission Spectrometer (PerkinElmer, USA) and block digestion system (Seal analytical, UK) (Latimer, 2016).

Sensory analysis the Kluai Namwa (Musa Sapientum Linn.) energy gel

Sensory analysis was carried out by a panel of 40 non-trained assessors recruited from Thai runners. Assessors evaluated the BAN energy gel using a hedonic scale. Assessors were asked to sort the BAN energy gel from the least preferred (score 1) to the most preferred (score 7), considering appearance, color, odor, taste, and viscosity. For this test, the BAN energy gel was presented in single-use packets.

Placebo gel development

The Placebo energy gel (PLA) was developed using the same methods and ingredients as the BAN energy gel, except maltodextrin was used instead of BAN.

Subjects

Eleven healthy male half-marathon runners (mean ± S.D.: age of 27.36 ± 8.89 years; Body Mass (BM) of 63.79 ± 11.28 kg; the height of 171.36 ± 5.73 cm; maximal oxygen consumption ($\dot{V}O2max$) of 69.43 ± 12.69 mL•kg−1•min−1; average running time for half marathon distance was 106.50 ± 29.58 minutes) have participated in this study. All participants must have a VO_2 max greater than 45 ml/kg/min and perform exercise 3-5 days/ week for at least 1 hr./day. They must pass the Physical Activity Readiness Questionnaire test (PAR-Q test). Furthermore, they had to report no food allergies, especially banana or gel ingredients, free from heart conditions and/or did not recently experience shortness of breath, chest pain, bone, or joint problems, had no symptom of Gastro Intestinal (GI) discomfort and had the approval of attending physician. All participants must refrain from participating in any experimentation and/or endurance road race for at least two weeks before the start of the study and during the data collection period in this study. Moreover, they had no alcohol use or smoking.

Experimental design

This study used a double-blind, placebo-controlled, and repeated measures crossover design to determine the effect of BAN energy gel on endurance running performance tests in male half-marathon runners. The experiments occurred at the sports and health science laboratory, MFU sports complex, Mae Fah Luang university, Thailand. The participants were informed of any associated risks and discomforts and provided written informed consent before the study. The Mae Fah Luang university ethics committee on human research, Thailand, has approved the study, and the analysis was performed in accordance with the Cunniff and Washington (1997), the Declaration of Helsinki (2013), the Council for International Organizations of Medical Science (CIOM) (2016), the Standards of Research Ethics Committee (SREC) (2017), and the National Policy and Guidelines for Human Research (2015) (EC 21144-18).

Preliminary testing

Anthropometric characteristics were measured during the first visit. All participants completed an exhaustive graded exercise on a treadmill (Nautilus T916, Canada) to determine the maximal oxygen uptake (VO_2 max), first Ventilatory Threshold (VT_1), and second Ventilatory Threshold (VT_2). Heart Rate (HR) was recorded in Beats Per Minute (BPM) with a heart rate monitor (Polar H10, USA). The test started with a 3-minute warm-up at 3 km/h and gradually increased to 1 km/h every minute, with the treadmill inclination increasing from 0° to 0.4% every 1 minute until voluntary exhaustion. The criteria for determining fatigue were as follows: 1) a Heart Rate (HR) ≤10 bpm below the age-predicted maximum (220), 2) a Respiratory Exchange Ratio (RER) greater than 1.10, and 3) a Rating of Perceived Exertion (RPE) based on the 6-20 Borg scale of 18 (extremely hard). The initial velocities corresponding to VT_1 were obtained to determine the exercise intensity of the experimental trial (Chuychai et al., 2022). The data were collected for the baseline of this study.

Experimental procedure

All participants completed 3 visits. The first visit was to perform a VO_2 max test. The second and third visits were for endurance running performance testing. They were asked to record their food and beverage intake and their physical activity throughout the three days before the first laboratory visit, abstain from vigorous physical activity, and replicate this before the next visit. Participants came to the laboratory for each visit early in the morning following an overnight fast (only water was permitted). All trials were conducted simultaneously (mornings) under stable environmental conditions (~20–21 °C, ~60% relative humidity) with a 7-day washout period between sessions. Each participant was randomly assigned in a double-blind crossover design to consume either 100 g of BAN energy gel or PLA energy gel, followed by 250 ml of water 30 minutes before exercise.

After the treatment of energy gel ingestion for 30 minutes, the participants performed the TTE test on a motorized treadmill to determine their endurance running performance. After a warm-up at a self-selected running speed for 5 minutes, the running speed increased to the initial velocity corresponding to VT_1. The participant ran at VT_1 for 30 minutes before switching to V_2 until voluntary exhaustion.

Performance measurements

The TTE was recorded at the end of the test. The heart rate was collected 10 minutes before ingesting energy gel, immediately before exercise, and 15 and 30 minutes during and immediately after exercise.

Biochemical measurements

Blood glucose and blood lactate were collected from the arterialized fingertip blood sample 10 minutes before ingesting gel, immediately before exercise, 15 and 30 minutes during exercise, and immediately after exercise using a Blood Glucose Analyzer (Accutrend Performa, Germany) and Blood Lactate Analyzer (Accutrend Plus Lactate, Germany), respectively. Blood samples for potassium, sodium, magnesium, and phosphorus were collected in serum separation glass vacutainer tubes 3mg from the vein 10 minutes before ingesting gel and immediately after exercise. Urine-specific gravity was collected via a urine sample and placed in the sterile cup until it was half full, 10 minutes before consuming the gel, and immediately after exercise.

Psychological measurements

RPE was assessed during the TTE test using the RPE 6–20 scale, and GI symptoms were assessed immediately before ingestion, immediately before exercise, 30 minutes during exercise, post-exercise, and every 30 min during the TTE test using the Visual Analog Scale (VAS) score for GI symptoms.

STATISTICAL ANALYSIS

All data are presented as the mean ± standard deviation (S.D.). Statistical analysis was performed using IBM SPSS Statistics software, version 22.0 (SPSS, IBM Statistics, New York, US). All measurements were performed in triplicates. The data for endurance running performance were expressed as the mean±standard deviation. A One-Way Analysis of Variance (ANOVA) with repeated measures was used to analyze the differences between subjects on performance, biochemical, and psychological variables. To differentiate between subjects, an independent *t*-test was used. To investigate differences among subjects, a dependent *t*-test was used. For all tests, statistical significance was accepted at $p<.05$.

Results

Energy Gel Consumption Behavior among the Thai Runners Thai runners typically consume energy gels before and during running because they give them rapid energy and fullness and are convenient to carry (Table 1). Factors influencing Thai runners to purchase and consume energy gels are their nutritional value, flavor, and convenience to consume and carry while running (Table 2).

Table 1: Energy gel consumption behavior among the Thai runners (n = 404)

		Sample	%
Running distance			
	Less than 10 km.	96	18.86
	Minimarathon 10 km.	201	39.49
	Half marathon 21 km	132	25.93
	Full marathon 42 km.	51	10.02
	Others	29	5.70
Reasons for choosing energy gel			
	Fullness	207	22.09
	Long shelf life	46	4.91
	Deliciousness	92	9.82
	Convenient	189	20.17
	Rapid energy	247	26.36
	Light weight, portable	147	15.69
	Others	9	0.96
Energy gel consumption in marathon running			
	Before running	278	49.47
	During running	242	43.06
	After running	42	7.47
Energy gel flavor			
	Fruit flavor	355	59.97
	Cola flavor	83	14.02
	Chocolate flavor	72	12.16
	Vanilla flavor	42	7.09
	Caramel flavor	31	5.24
	Others	9	1.52
Energy gel fruit flavor			
	Banana	215	23.24
	Lemon	153	16.54
	Passion fruit	79	8.54
	Orange	161	17.41
	Strawberry	131	14.16
	Apple	109	11.78
	Watermelon	67	7.24
	Others	10	1.08

The proximate content of BAN energy gel

Table 2: Factors that influence Thai runners' purchases of energy gel (n = 408)

Factor	Average	Degree of Importance
Color	3.17 ± 1.03	Neutral
Odor	3.94 ± 0.82	Important
Flavor	4.50 ± 0.69	Very important
Texture	3.77 ± 0.78	Important
Packaging	3.98 ± 0.73	Important
Amount	3.97 ± 0.64	Important
Nutrition value	4.53 ± 0.60	Very important
Price	3.91 ± 0.75	Important
Place to buy	3.90 ± 0.76	Important
Long shelf life	3.94 ± 0.73	Important
Convenient	4.38 ± 0.61	Very important

Table 3: Proximate content of BAN energy gel (serving size 1 packet = 100g)

Proximate Characteristics	Contents
Energy (Kcal)	66.75 ± 0.84
Glucose (g)	1.20 ± 0.02
Sucrose (g)	8.77 ± 0.08
Fructose (g)	1.31± 0.01
Protein (g)	0.43 ± 0.08
Fat (%)	0.14 ± 0.02
Energy from fat (Kcal)	1.23 ± 0.19
Ash (g)	0.55 ± 0.01
Total carbohydrate (%)	15.95 ± 0.21

The mineral content of the BAN energy gel

BAN energy gel had 66.75 ± 0.84 kcal and contained a high amount of carbohydrates with natural sugars: glucose (1.20 ± 0.02 g), sucrose (8.77 ± 0.08 g), and fructose (1.31± 0.01 g) (Table 3). BAN energy gel contains essential minerals such as sodium, magnesium, and potassium, which help muscle contraction during exercise and reduce muscle cramps (Knechtle et al., 2007; Nieman et al., 2015). From the results, the BAN energy gel contained 25.67 ± 0.13 mg of sodium, 14.07 ± 0.09 mg of magnesium, and 184.83 ± 0.5 mg of potassium (Table 4).

Table 4: Mineral (serving size 1 packet = 100g)

Mineral Characteristics	Contents
Sodium (mg)	25.67 ± 0.13
Potassium (mg)	184.83 ± 0.54
Magnesium (mg)	14.07 ± 0.09

Sensory analysis of BAN energy gel

When BAN energy gel was compared to PLA energy gel and commercial energy gel (mixed-fruit flavor), the flavor and odor acceptance scores of BAN energy gel were significantly higher than those of PLA energy gel and commercial energy gel (mixed-fruit flavor) (Table 5).

Table 5: Acceptance sensory evaluation (n=40)

Characteristics	Type of energy gel		
	BAN energy gel (n=40)	PLA energy gel (n=40)	Commercial energy gel with mixed-fruit flavor (n=40)
	$\bar{X}$ ± S.D.	$\bar{X}$ ±S.D.	$\bar{X}$ ± S.D.
Appearance	4.70 ± 0.80	5.68 ± 0.83	5.93 ± 1.07*
Color	4.60 ± 1.00	5.50 ± 1.00*	5.00 ± 1.20
Odor	5.90 ± 0.80*	5.83 ± 1.01	5.20 ± 1.40
Flavor	5.88 ± 0.85*	4.95 ± 0.90	5.28 ± 1.43
Viscosity	5.00 ± 1.00	5.05 ± 1.11	4.70 ± 1.30
Overall	5.40 ± 0.80	5.35 ± 0.74	5.35 ± 1.19

* *p*- value < .05

Performance measurements

The result showed that the TTE in the group ingesting BAN energy gel (55.23 ± 10.32 min) was significantly longer than in the group ingesting PLA energy gel (46.13 ± 9.87 min) (P<.05) (Table 6).

Table 6: Average TTE (min ± S.D.) in BAN energy gel and PLA energy gel groups (n = 11)

Condition (n = 11)	Time to Exhaustion (min) $\bar{X}$ ± S.D.	*t*	*p*-value
BAN energy gel	55.23 ± 10.32	2.114	.047*
PLA energy gel	46.13 ± 9.87		

* *p*- value < .05

Biochemical measurements

Blood glucose and lactate concentrations between the BAN energy gel and PLA energy gel groups were not significantly different (Figure 2 and Table 7). After running, potassium concentration in blood in the BAN energy gel consumption group was significantly higher than in the PLA energy gel consumption group (Table 8).

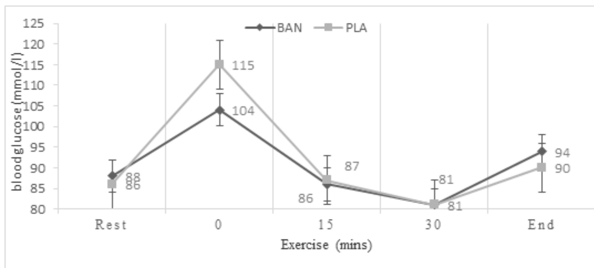

Figure 2: The blood glucose level at rest, during and immediately after exercise between 2 conditions (BAN and PLA)* *p*- value < .05

Table 7: Blood lactate concentration between BAN energy gel and PLA energy gel

Blood lactate (mg/dL)	Pretest (n=11) $\bar{X}$ ± S.D.	Posttest (n=11) $\bar{X}$ ± S.D.	*t*	*p*-value
BAN	1.89 ± 0.35	2.94 ± 1.89	-1.880	.089
PLA	1.86 ± 0.47	3.12 ± 1.58	-2.580	.027*

* *p*- value < .05

Table 8: Electrolyte concentrations in blood between BAN energy gel and PLA energy gel

Electrolyte	Type		*t*	*p*-value
	BAN (n=11) $\bar{X}$ ± S.D.	PLA (n=11) $\bar{X}$ ± S.D.		
Potassium (mmol/L)				
Pretest	4.22 ± 0.48	4.29 ± 0.36	.401	.693
Posttest	4.60 ± 0.25	4.25 ± 0.35	-2.651	.015*
Sodium (mmol/L)				
Pretest	142.27 ± 2.10	141.82 ± 1.60	-.571	.575
Posttest	143.73 ± 1.56	143.64 ± 2.20	-.112	.912
Magnesium in blood (mg/dL)				
Pretest	2.20 ± 0.13	2.12 ± 0.14	-1.437	.166
Posttest	2.11 ± 0.16	2.06 ± 0.09	-.801	.433
Phosphorus (mg/dL)				
Pretest	3.68 ± 0.63	3.67 ± 0.44	-.039	.969
Posttest	4.61 ± 0.65	4.21 ± 0.61	-1.487	.153

* *p*- value < .05

Psychological measurements

Thirsty, fullness, and RPE were not significantly different between the BAN and PLA energy gel groups. There were no reports of GI symptoms, nausea, vomiting, heartburn, bloating, and abdominal pain in the BAN and PLA energy gel group.

DISCUSSION

This study aimed to develop Banana (Musa Sapientum Linn.) as an energy gel and determine its effects on endurance running performance in Thai male runners. There were 11 participants in this study. The results of the study found that the TTE in the BAN energy gel group was longer than in the PLA energy gel group (55.23 ± 10.32 min vs. 46.13 ± 9.87 min, respectively, $p < .05$). BAN energy gel and PLA energy gel had the same caloric intake, but PLA energy gel contains maltodextrin as a main ingredient. After ingesting both gels for 30 minutes, there was a slightly higher blood glucose concentration level in the PLA group, but not at a significant level. As it is known, maltodextrin has a higher Glycemic Index (GI) than a banana, which has a medium GI and can provide rapid energy during exercise. Foods with a high GI index can be digested and absorbed faster than foods with a low GI. Banana is classified as having moderate GI, which affects slowing the release of glucose, according to the data we observed. The blood glucose concentration level at 15 and 30 minutes during exercise was rapidly dropped in both trials, which can be observed in most investigations, but not at hypoglycemia levels (below 65 mg/dL) (Costill et al., 1977; Foster et al., 1979). On the other hand, immediately post-exercise, BAN energy gel tended to increase blood glucose levels because of its nutrients, which included three natural sugars – glucose, sucrose, and fructose—and carbohydrates in the form of fiber (Bangash et al., 2021; Kumar et al., 2012). Our study supported Murdoch et al. (1993), which found that ingesting bananas before an exercise can improve blood glucose concentrations and TTE at cycling 70% VO_2 max until voluntary exhaustion compared with a placebo.

Our study's blood lactose level revealed no significant difference between the BAN group and the PLA group. In accordance with our findings, Chuychai et al. (2022) found no significant difference in blood lactate level on running to exhaustion when ingesting highly branched cyclic dextrin and glucose-containing beverages. Our study revealed that the blood lactate level was significantly higher in the PLA group but not in the BAN group than before and after exercise.

The study indicated that the potassium level in the BAN group was significantly higher than in the PLA group. (4.6 ± 0.25 vs. 4.25 ± 0.35 mmol/L, respectively). The results were also reported similarly in another study. Miller (2012) discovered that eating bananas can increase potassium concentration without causing hyperkalemia. This study suggests that if athletes want to increase blood potassium concentration during exercise to help contract muscles properly and reduce the risk of muscle cramps (Kumar et al., 2012; Mohan and Kumar, 2021), they should consume potassium at least 30 minutes before the competition. Our study observed that the level of potassium concentration in the PLA group decreased immediately post-exercise, which is in contrast with the level of potassium in the BAN group, which had significantly increased potassium concentrations.

RPE was recorded to observe endurance running performance. The results showed that ingesting the BAN group slightly increased RPE immediately before exercise, which was related to the level of blood glucose concentrations. On the other hand, immediately post-exercise, RPE in the PLA group was higher than in the BAN group. These were also related to the blood glucose concentrations that tend to decrease at the end of the exercise.

Neither the BAN nor the PLA group reported any GI side effects like nausea, vomiting, heartburn, bloating, or abdominal pain, but one participant in this study reported feeling slightly full 30 minutes into exercise and again immediately afterward after consuming the BAN energy gel, and another reported feeling slightly ill 15 minutes, 30 minutes, and again after consuming the PLA energy gel. A high intake of carbohydrates induces GI problems (De Oliveira and Burini, 2014). Therefore, athletes with a history of GI problems should avoid consuming high amounts of carbohydrates during exercise (Pfeiffer et al., 2012) .

CONCLUSION

This study was the first to develop a banana energy gel (Musa Sapientum Linn.). The results of this study provide data on the nutritional value of banana (Musa Sapientum Linn.) energy gel and the effects of banana (Musa Sapientum Linn.) energy gel on endurance, which improve potassium and glucose levels for runners. The energy gel of the banana (Musa Sapientum Linn.) contains various nutrients. Macronutrients are composed of carbohydrates such as sucrose, glucose, proteins, and fat. Micronutrients are sodium, potassium, and magnesium. As the gel forms, the energy gel of bananas (Musa Sapientum Linn.) can be an ergogenic aid that is convenient, easy to use, and lightweight. Banana (Musa Sapientum Linn.) energy gel is an important enhancement in endurance performance and can extend the period of exhaustion during running. The energy gels of bananas (Musa Sapientum Linn.) are a good alternative for running and are suitable to be consumed before and during competition. Further studies can be conducted on other endurance sports or on other levels, i.e., elite runners and amateur runners.

Conflicts of interest

There are no conflicts of interest to declare.

REFERENCES

Bangash JA, Khalil AW, Paracha GMU; 2021. Effect of various clarification techniques on the storage studies of carbonated sugarcane juice. Pakistan Journal of Life and Social Sciences, 19(1):23-26.

Castell L, Burke L, Stear S, McNaughton L, Harris R; 2010. BJSM reviews: A--Z of nutritional supplements: Dietary supplements, sports nutrition foods and ergogenic aids for health and performance Part 5. British Journal of Sports Medicine, 44(1):7-78.

Chuychai J, Srihirun K, Chinapong S, Sanpasitt C, Khaosanit P, Nokkaew N; 2022. Fluid containing highly branched cyclic dextrin: An alternative ergogenic aid to enhance endurance exercise performance in long-distance runners. Journal of Exercise Physiology Online, 25(4):1-13.

Costill DL, Coyle E, Dalsky G, Evans W, Fink W, Hoopes D; 1977. Effects of elevated plasma FFA and insulin on muscle glycogen usage during exercise. Journal of Applied Physiology, 43(4):695-699.

Coyle EF; 2004. Fluid and fuel intake during exercise. London, UK: Routledge.

Cunniff P, Washington D; 1997. Official methods of analysis of aoac international. Journal of AOAC International, 80(6):127-131.

De Oliveira EP, Burini RC; 2014. Carbohydrate-dependent, exercise-induced gastrointestinal distress. Nutrients, 6(10):4191-4199.

Dikshit P, Shukla K, Tyagi MK, Garg P, Gambhir JK, Shukla R; 2012. Antidiabetic and antihyperlipidemic effects of the stem of Musa sapientum Linn. in streptozotocin-induced diabetic rats. Journal of Diabetes, 4(4):378-385.

Doyenart R, Olímpio M, Boeira D, Sombrio F, Milhomes YP, Gomes K, et al.; 2020. Psycho-physiological changes after a half marathon in amateur runners. Journal of Physical Education and Sport, 20(4):1768-1774.

Fleming JA, Naughton RJ, Harper LD; 2018. Investigating the nutritional and recovery habits of tennis players. Nutrients, 10(4):1-12.

Foster C, Costill D, Fink W; 1979. Effects of preexercise feedings on endurance performance.. Medicine and Science in Sports, 11(1):1-5.

Hargreaves M, Spriet LL; 2020. Skeletal muscle energy metabolism during exercise. Nature Metabolism, 2(9):817-828.

Jäger R, Kerksick CM, Campbell BI, Cribb PJ, Wells SD, Skwiat TM, et al.; 2017. International society of sports nutrition position stand: Protein and exercise. Journal of the International Society of Sports Nutrition, 14(1-15):20.

Jeukendrup AE. Nutrition for endurance sports: marathon, triathlon, and road cycling. In: Food, Nutrition and Sports Performance III London, UK: Routledge; 2013. .

Knechtle B, Pitre J, Chandler C; 2007. Food habits and use of supplements in ultra-endurance cyclists-the Race Across AMerica (RAAM) 2006. Schweizerische Zeitschrift fur Sportmedizin und Sporttraumatologie, 55(3):102-117.

Kozlowski KF, Ferrentino-DePriest A, Cerny F; 2021. Effects of energy gel ingestion on blood glucose, lactate, and performance measures during prolonged cycling. Journal of Strength and Conditioning Research, 35(11):3111-3119.

Kumar KS, Bhowmik D, Duraivel S, Umadevi M; 2012. Traditional and medicinal uses of banana. Journal of Pharmacognosy and Phytochemistry, 1(3):51-63.

Latimer W, Official Methods of Analysis of AOAC International 20th Ed., 2016 Two-Volume Set. [online] AOAC International; 2016.

Leelarungrayub J, Parameyong A, Eungpinichpong W, Klaphajone J; 2017. Effects of Banana (Linn) Consumption for Physical Strength, Metabolic Response, Oxidative Stress, Lipid Profiles, and Interleukin-23 in Healthy Men: A Preliminary Study. The Open Sports Sciences Journal, 10(1-20).

MacLaren D, Morton J; 2011. Biochemistry for sport and exercise metabolism. New Jersey, NY: John Wiley & Sons.

Miller KC; 2012. Plasma potassium concentration and content changes after banana ingestion in exercised men. Journal of Athletic Training, 47(6):648-654.

Mohan C, Kumar V; 2021. Ion-selective electrodes based on PVC membranes for potentiometric sensor applications: A review. International Journal of Membrane Science and Technology, 8(2):76-84.

Muchimapura S, Wattanathorn J, Thukhammee W; 2014. Musa sapientum extract decreases fatigue and oxidative stress markers in rats. PharmaNutrition, 2(3):102-119.

Murdoch SD, Bazzarre TL, Snider IP, Goldfarb AH; 1993. Differences in the effects of carbohydrate food form on endurance performance to exhaustion. International Journal of Sport Nutrition and Exercise Metabolism, 3(1):41-54.

Naderi A, De Oliveira EP, Ziegenfuss TN, Willems ME; 2016. Timing, optimal dose and intake duration of dietary supplements with evidence-based use in sports nutrition. Journal of exercise nutrition & biochemistry, 20(4):1-21.

Nieman DC, Gillitt ND, Sha W, Meaney MP, John C, Pappan KL, et al.; 2015. Metabolomics-based analysis of banana and pear ingestion on exercise performance and recovery. Journal of Proteome Research, 14(12):5367-5377.

Pfeiffer B, Stellingwerff T, Hodgson AB, Randell R, Pöttgen K, Res P, et al.; 2012. Nutritional intake and gastrointestinal problems during competitive endurance events. Med Sci Sports Exerc, 44(2):344-51.

Rapoport BI; 2010. Metabolic factors limiting performance in marathon runners. PLoS computational biology, 6(10):1-13.

Ravindra P, Janhavi P, Divyashree S, Muthukumar S; 2022. Nutritional interventions for improving the endurance performance in athletes. Archives of physiology and biochemistry, 128(4):851-858.

Saunders MJ, Luden ND, Herrick JE; 2007. Consumption of an oral carbohydrate-protein gel improves cycling endurance and prevents postexercise muscle damage. Journal of Strength and Conditioning Research, 21(3):678-689.

Seepika N, Chinapong S, Piakaew N, Laiwattanapaisal W, Katelakha K, Larpant N, et al.; 2022. The effects of different dosing strategies of caffeine ingestion during an endurance performance event in male half marathon runners. Journal of Physical Education & Sport, 22(9):1-23.

Skidmore TE, Smith PH; 2005. Modern latin america. New York, NY: Oxford University Press.

Vitale K, Getzin A; 2019. Nutrition and supplement update for the endurance athlete: review and recommendations. Nutrients, 11(6):1289-1299.