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Immediate effects of passion fruit juice supplementation on working ability and attention in healthy participants

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ABSTRACT

This study investigated the effects of a single consumption of passion fruit juice (PFJ) on working ability and attention. It included 14 healthy participants aged 20–30 years. Participants randomly consumed either placebo or 50% PFJ at 3.5 mL/kg body mass. Each intervention was divided into two phases (before and after consumption). Before consumption, the participants underwent blood glucose, blood pressure, and heart rate examinations. Then, working ability and attention were evaluated. Thereafter, the blood glucose, blood pressure, and heart rate were repeatedly examined. Next, the participants completed consumption. After consumption, the participants underwent the same experiments performed before consumption. The total working ability scores after consumption were significantly high in both interventions ($P < 0.05$). However, PFJ intervention had a significantly higher working ability at 1, 2, 3, 4, and 5 min than placebo intervention ($P < 0.05$). Moreover, PFJ intervention had greater increases in attention than placebo intervention. There were no significant differences in attention between two interventions. The blood glucose levels were significantly lower in PFJ intervention than in placebo intervention both before the working ability test and after the attention test ($P < 0.05$). A single consumption of PFJ improved working ability in healthy participants. This may be enhanced by improving attentional focus and maintaining postprandial blood glucose.

1. Introduction

Reasoning, problem solving, and planning are essential skills for mental and physical health, school and in-life success, and cognitive, social, and psychological development (Diamond, 2013). They are considered as higher cognitive control, referred to as executive function, which has three domains (working memory, inhibition, and cognitive flexibility) (Zink et al., 2021). Attention is a cognitive function involved in regulating thoughts, emotions, responses, and distractions; problem solving; and switching between multiple pieces of information (Kumar and Singh, 2020). There is an interplay between executive functions and attention. That is, the former enables individuals to effectively manage attention that facilitates performance, such as in working (Chan et al., 2021).

Several techniques, such as physical activity, mental exercise, healthy diet and nutrition, social interaction, enough sleep and relaxation, and control of vascular risk factors, can improve brain health and function (Wang et al., 2020). Different nutrients, including omega-3 fatty acids, curcumin, flavonoids, saturated fat, vitamins B, D, and E, choline, calcium, zinc, selenium, copper, iron, and antioxidants, can enhance brain function (Gómez-Pinilla, 2008).

Passiflora edulis, also known as passion fruit, is widely planted in tropical and subtropical regions worldwide, including South America, Caribbean, south Florida, South Africa, and Asia (He et al., 2020). Among the genus *Passiflora*, the yellow and purple passion fruits are the two common varieties with substantial economic importance in several countries, including Thailand (Yu et al., 2021). Passion fruit is rich in different vitamins and minerals (such as vitamin C, A, B2, and B3, folic acid, calcium, magnesium, phosphorus, potassium, iron, and zinc), carbohydrate, and dietary fibers (Ramaiya et al., 2019). Moreover, previous studies have shown that passion fruit extracts, juice, and isolated compounds have different health effects and biological activities,

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including antioxidant, anti-hypertensive, anti-tumor, antidiabetic, and hypolipidemic activities (He et al., 2020; Kawakami et al., 2021).

A previous report revealed that passion fruit juice (PFJ) significantly increases antioxidant enzyme and lowers oxidative stress in hypercholesterolemic Wistar rats (Muntafiah et al., 2022). Paramita and Rahmah (2022) performed a similar study on atherogenic Wistar rats. Results showed that the total cholesterol level of the PFJ group decreased compared with that of the control group. Furthermore, another report has shown that PFJ consumption relieves pain and muscle soreness in athletes (Irawan, 2017). This finding can help increase our knowledge about PFJ.

Several *in vitro* and *in vivo* studies on the health benefits of PFJ were conducted. However, human studies are limited. According to current knowledge, PFJ is beneficial. Our previous study (Prasertsri et al., 2019) on healthy volunteers showed that a single supplementation of PFJ improved cardiac autonomic nervous system function by promoting parasympathetic nervous system activity and maintaining postprandial blood glucose (BG) levels. However, little is known about the effects of PFJ on human brain function. Importantly, a recent study on healthy participants revealed that the sensory characteristics of PFJ, including its extremely strong, acidic, and exotic flavor, may not only activate gustatory cortex activity but also mediate the function of other cortical areas, neural plasticity, and synaptic connections (von Atzingen et al., 2022). Hence, this study aimed to investigate the effects of PFJ consumption primarily on brain function, particularly working ability and attention, and secondarily on BG level in healthy participants. We hypothesized that compared with placebo, a single consumption of PFJ improves working ability and attention, and lowers BG level.

2. Materials and methods

2.1. Study design and participants

This was a randomized cross-over study conducted on 14 healthy male and female participants. The sample size was calculated using a cross-over study formula developed by Machin and Campbell (2005). According to a study on healthy older adults conducted by Bowtell et al. (2017), blueberry supplementation at 30 mL/day for 12 weeks improved executive function based on the Groton maze learning test. Moreover, improvement was significantly higher in the blueberry supplementation group than in the placebo supplementation group. The difference of mean values between the blueberry and placebo supplementation groups was 4.90, and the standard deviation of the blueberry group was 4.60. Accordingly, with an α error of 0.05, β error of 0.10, and power of test of 0.90, the current study included 14 participants, with consideration of a drop-out rate of 10%.

The inclusion criteria were as follows: (a) male or female participants aged between 20 and 30 years, (b) those with a normal body mass index (BMI) (18.5–22.9 kg/m^2 based on the Asia-Pacific classification), and (c) those with a healthy body and mind. The exclusion criterion included regular smokers or drinkers. The withdrawal criteria were as follows: (a) participants who received another intervention; (b) those with abnormal symptoms, including nausea, vomiting, dizziness, and syncope during the study; and (c) those who decided to stop participating in the study.

All eligible participants signed a consent form before screening and study enrollment. The participants were informed of the detailed information on procedures, risks, and their role and authority in the study, both in writing and verbally, before signing the consent form. This study was approved by the Human Ethics Committee of Burapha University (approval no. 163/2561), and was performed in accordance with the ethical standards of the Declaration of Helsinki. This study was registered with the Thai Clinical Trials Registry (identification no. TCTR20190321001).

2.2. Recruitment and screening of participants

Participants were recruited using placards containing the study details that were posted in the main areas around the university. Those who were interested in participating the study contacted the research assistant via phone. Thereafter, they were screened using health questionnaires to examine general information, exercise habits, and history of medical illness, supplementation intake, and mental health. Then, they underwent physical examination to evaluate BM, height, BMI, blood pressure (BP), heart rate (HR), and body temperature. During the week after screening, the participants who were selected based on the inclusion and exclusion criteria and who provided informed consent initiated the study.

2.3. Experimental protocol

This study was carried out using a single-dose design. During the first visit, anthropometric and body composition measurements were obtained. The participants were enrolled in the two phases (before and after consumption) of the experiment. Before consumption, the blood glucose (BG) level, BP, and HR of the participants were examined. Then, working ability was assessed for 15 min using the Uchida-Kraepelin test. Subsequently, attention was investigated using the Simon, Flanker, and Stroop tasks. Finally, BG level, BP, and HR were examined again. The participants were randomly supplemented with either 50% PFJ or a mixture of glucose and fructose solution (placebo) at 3.5 mL/kg BM within 5 min. They were instructed to rest in sitting position for 30 min. Thereafter, the same experiments performed before consumption were carried out.

A 1-week interval was set as the wash-out period between supplementation. The participants participated in the second visit on the following week, during which they received additional treatment. Explicitly, the participants who received PFJ supplementation were then treated with placebo, and the participants who received placebo were then supplemented with PFJ. All experiments and assessments were performed at the same time of day and under similar environmental and internal conditions (e.g., room temperature and humidity and sounds). The participants were advised to ensure they got enough sleep before the day of the experiments. They were also instructed to relax while practicing the experiments. Moreover, they were asked to maintain their regular daily routines, including dietary consumption and physical activity behaviors during participating in the two phases of the experiment.

2.4. Study supplements

This study used a commercially available PFJ produced from purple passion fruits at Doi Kham Food Products Co. Ltd., Chiang Rai, Thailand. The Doi Kham Food Products Co. Ltd. was founded under His Majesty, King Bhumibol Adulyadej's vision to eliminate poverty and enhance the quality of life of people living in the mountains in the North of Thailand. The concentration of PFJ was 50% (50 g/100 mL). Based on the nutrition facts, 100 mL of juice provided 55 kcal, comprising 12.5 g of sugars, 1 g of carbohydrate, $<$0.5 g of dietary fibers, and 10 g of sodium. Regarding total energy and sugar ratio in the PFJ (Devi Ramaiya et al., 2013), the placebo was prepared as described in a previous study by Prasertsri et al. (2019). The PFJ and placebo were offered to participants according to their BM (i.e., 3.5 mL/kg).

2.5. Assessments of working ability

Working ability was assessed using the Uchida-Kraepelin test, a serial addition test requiring participants to perform calculations as fast and accurately as possible within 15 min. The test was performed using printed paper containing 15 lines of random, single-digit, horizontally aligned numbers. For each minute in the test, the participants were instructed to start a new line regardless of their position on the recent line. Each line contained an excess of calculations such that the participants did not finish any line for a particular minute prior to being provoked to move on to the initiation of the next minute based on the researcher's motivation (Sugimoto et al., 2009). During each visit, the participants were assessed using this test for two times (before and after PFJ or placebo consumption).

2.6. Assessment of attention

To assess attention, the participants were assigned with the Simon, Flanker, and Stroop tasks after the Uchida-Kraepelin test. These tasks were freely available online (PsyToolkit at https://www.psytoolkit.org/experiment-library). In the Simon task, the participants were required to respond to the words LEFT and RIGHT with the A button and L button on the keyboard as quickly as possible. Compatible condition indicated that the participants responded to the word LEFT or RIGHT when it appears on the LEFT or RIGHT side of the screen. By contrast, incompatible condition suggested that the participants responded to the word LEFT or RIGHT when it appears on the RIGHT or LEFT side of the screen. In the Flanker task, the participants were shown five letters above the fixation point on the screen. However, they must only respond to the central letter. The letters X and C should be responded to with the A button on the keyboard. The letters V and B must be responded to with the L button on the keyboard. Incompatible condition indicated a mismatch between the flanking letters that the participants responded and the response required by the central letter. In the Stroop task, the participants were presented with colored words, including RED, GREEN, BLUE, and YELLOW, on the screen and were required to respond to the color of the words (not the meaning) by pressing the corresponding button (r, g, b, and y for the RED, GREEN, BLUE, and YELLOW stimuli). The average reaction time in correct trials were reported in milliseconds for all the tasks. During each visit, the participants were assessed two times (before and after PFJ or placebo consumption).

2.7. Measurement of BG levels

The capillary BG level was measured from the participant's fingertip using the Accu-Chek® Guide BG monitoring system (Roche Diabetes Care Inc., IN, the USA), as described in a previous study (Prasertsri et al., 2019). During each visit, the BG levels of the participants were evaluated four times before the Uchida-Kraepelin test and after the Stroop task.

2.8. Measurements of BP and HR

Systolic BP (SBP), diastolic BP (DBP), and HR were evaluated using a digital automatic BP monitor (Rossmax CF155f, Rossmax Swiss GmbH, Switzerland), as described in a previous study (Vierra et al., 2022). During each visit, the BP and HR levels of the participants were evaluated four times before the Uchida-Kraepelin test and after the Stroop task.

2.9. Data analyses

Data normality was analyzed and confirmed using the Shapiro-Wilk test and via visual histogram assessment. Differences in variables within each supplementation and between placebo and PFJ supplementation were analyzed using two-way repeated measures analysis of variance with the Bonferroni post hoc test for multiple comparisons and were confirmed using the paired-t test. All analyses were performed with the Statistical Package for the Social Sciences software (IBM Corp., Armonk, NY, the USA). Data were presented as mean ± standard deviation. A P value of <0.05 was considered statistically significant.

3. Results

3.1. Physical and physiological characteristics

In total, 14 participants (4 male, 10 female) were eligible for the study. They enrolled and completed both experiments (Fig. 1). Participants' average age was 21.07 ± 1.00 years. There were no significant differences in terms of the physical and physiological characteristics of the participants before the placebo and PFJ interventions including body fat percentage, fat mass, fat-free mass percentage, fat-free mass, muscle mass, protein mass, mineral mass, water mass, waist and hip circumference, waist-to-hip ratio, and basal metabolic rate. However, before PFJ intervention the participants had a significantly lower BM ($P = 0.004$) and BMI ($P = 0.012$) than before placebo intervention.

3.2. Working ability

There were no significant differences in terms of the Uchida-Kraepelin test scores between the placebo and PFJ experiments before consumption. After consumption, time-series analysis showed no significant changes in the Uchida-Kraepelin test scores between each experiment. However, the Uchida-Kraepelin test scores of the PFJ experiment were significantly higher at 1, 2, 3, 4, and 5 min than those of the placebo experiment ($P < 0.05$) (Fig. 2A). Moreover, the total scores significantly increased in both experiments ($P < 0.001$). Nevertheless, there was no significant difference between experiments (Fig. 2B).

3.3. Attention

The Simon, Flanker, and Stroop tasks before consumption were comparable between the placebo and PFJ experiments. There were no significant differences between the two experiments after consumption. According to changes in the placebo experiment after consumption, the Flanker task significantly improved for both compatible ($P = 0.026$) and incompatible ($P = 0.011$) conditions. In addition, the Stroop task significantly improved for the incompatible condition ($P = 0.018$). In the PFJ experiment, attention was greatly increased than the placebo experiment after consumption. There were significant improvements in the Simon task for the compatible condition ($P = 0.039$) and the Flanker and Stroop tasks for both compatible ($P = 0.002$ and $P = 0.004$) and incompatible ($P = 0.046$ and $P = 0.001$) conditions (Table 1).

3.4. BG levels

The BG levels before consumption were similar between the placebo and PFJ experiments before the Uchida-Kraepelin test and after the Stroop task. After consumption, the BG levels of the placebo experiment significantly increased, and they were significantly higher than before consumption both before ($P < 0.001$) and after ($P = 0.037$) the tests. Similarly, the BG levels of the PFJ experiment significantly increased, and they were significantly higher than before consumption both before ($P < 0.001$) and after ($P < 0.001$) the tests. However, the BG levels of the PFJ experiment after consumption were significantly lower than those of the placebo experiment both before ($P < 0.001$) and after ($P < 0.001$) the tests (Fig. 3).

3.5. BP and HR levels

The BP and HR before consumption did not differ between two experiments. However, after consumption, the SBP level of the PFJ experiment was significantly lower than that of the placebo experiment ($P = 0.048$). The HR levels of the placebo experiment were significantly higher than before consumption both before ($P = 0.003$) and after ($P = 0.002$) the tests. No significant changes in HR level were observed at any time period in the PFJ experiment (Table 2).

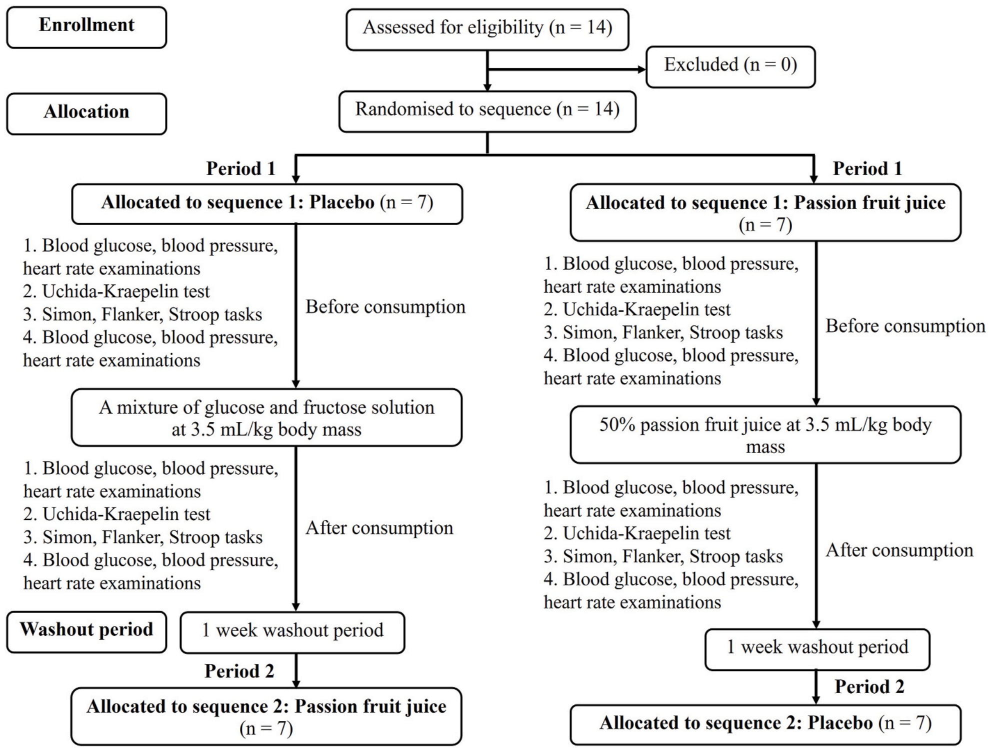

Fig. 1. CONSORT flow digram for this study.

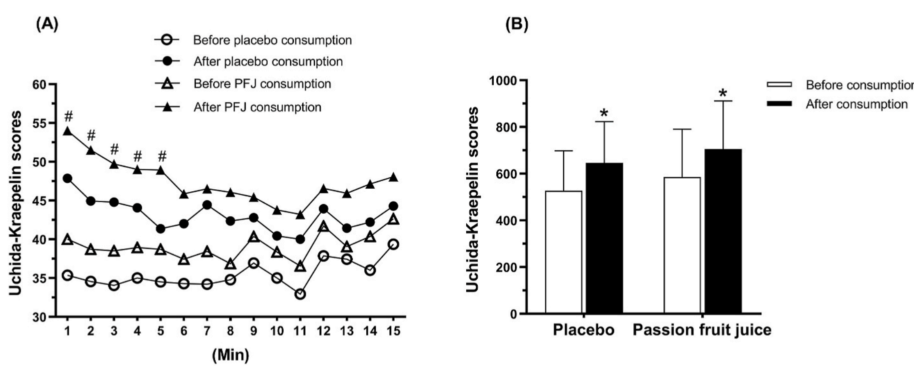

Fig. 2. Uchida-Kraepelin scores at 1–15 min (A) and total Uchida-Kraepelin scores (B) between the placebo and passion fruit juice (PFJ) experiments before and after consumption Data were presented as mean ± standard deviation, n = 14. * Significantly different from before consumption at $P < 0.05$. # Significantly different from placebo experiment at $P < 0.05$.

4. Discussion

To date, no study has comprehensively evaluated the brain function improvement properties of passion fruit in humans. Passion fruit is used in traditional medicine as a sedative and an agent for treating or preventing neurological disorders, such as anxiety and insomnia (Sena et al., 2009). Previous studies have reported that passion fruit has neuroprotective effects (Dos Santos et al., 2021; Sato et al., 2022; Tal et al., 2016). For example, a report evaluated the neuroprotective effect and antioxidant activity of PFJ and pulp and peel extracts in rats with aluminum chloride-induced Alzheimer's disease. Results showed that PFJ significantly reduced oxidative stress and inflammation, and the antioxidant enzymes significantly increased in the plasma, brain, hippocampus, and liver after supplementation with PFJ and pulp and peel extracts. Further, treatment with passion fruit improved brain function and modified acetylcholinesterase as confirmed based on the assessment of histological changes and the Morris water maze (Doungue et al., 2018).

In the brain, BG is the only source of cellular energy. Under normal conditions, it is tightly regulated due to its importance in physiological brain function (Mergenthaler et al., 2013). Animal and human studies have shown that increased BG levels are associated with better memory and attention (Benton et al., 1994). Benton et al. (1994) found that glucose supplementation enhanced brain performance based on the rapid information processing task and the Stroop task. Further, Birnie et al. (2015) showed that glucose drinks improved attention in healthy adults by promoting internal thought processes. Moreover, Ogawa et al. (2018) revealed that supplementation with sucrose improved the working ability of young female participants. Results showed that this finding is possibly due to not only the transport of glucose into the brain but also the increased activity of brain hedonic sites via the stimulation of sweet receptors (T1R 23). Brandt et al. (2013) provided more knowledge on glucose ingestion. That is, they showed that cognitively demanding tasks were enhanced in the medial temporal and frontal lobes. In this study, PFJ supplementation significantly lowered BG levels compared with placebo supplementation. Moreover, participants who

Table 1
Attention between the placebo and PFJ experiments.

	Placebo	PFJ	*P* value
Simon task (ms)			
Before consumption			
Compatible	625.14 ± 110.33	677.43 ± 141.49	0.236
Incompatible	640.50 ± 124.55	658.71 ± 143.06	0.651
After consumption			
Compatible	615.43 ± 86.53	605.29 ± 102.42*	0.763
Incompatible	587.50 ± 65.65	601.86 ± 88.15	0.485
Flanker task (ms)			
Before consumption			
Compatible	667.79 ± 66.65	714.43 ± 95.32	0.162
Incompatible	707.50 ± 85.91	750.86 ± 146.61	0.343
After consumption			
Compatible	627.57 ± 66.50*	656.5 ± 77.02*	0.145
Incompatible	640.50 ± 86.22*	686.14 ± 98.71*	0.127
Stroop task (ms)			
Before consumption			
Compatible	785.36 ± 171.46	848.36 ± 155.34	0.339
Incompatible	873.43 ± 189.55	970.21 ± 131.42	0.139
After consumption			
Compatible	730.14 ± 134.06	718.29 ± 100.65*	0.723
Incompatible	783.29 ± 145.36*	820.50 ± 113.94*	0.281

Data were presented as mean ± standard deviation, n = 14. PFJ, passion fruit juice.
[*] Significantly different from before consumption at $P < 0.05$.

Table 2
Blood pressure and heart rate between the placebo and PFJ experiments.

	Placebo	PFJ	*P* value
SBP (mmHg)			
Before consumption			
Before the tests	99.57 ± 9.16	100.29 ± 8.67	0.458
After the tests	98.93 ± 6.96	99.64 ± 8.07	0.681
After consumption			
Before the tests	100.79 ± 5.75	97.00 ± 5.33**	0.048
After the tests	101.64 ± 5.65	99.00 ± 7.02	0.062
DBP (mmHg)			
Before consumption			
Before the tests	64.50 ± 6.24	62.79 ± 6.04	0.246
After the tests	62.64 ± 5.17	64.07 ± 6.26	0.132
After consumption			
Before the tests	62.50 ± 6.30	59.71 ± 3.20	0.075
After the tests	61.79 ± 5.45	62.50 ± 4.74	0.583
HR (beats/min)			
Before consumption			
Before the tests	74.79 ± 15.83	75.86 ± 18.08	0.845
After the tests	75.43 ± 13.66	73.71 ± 14.69	0.717
After consumption			
Before the tests	80.43 ± 14.62*	75.29 ± 13.15	0.264
After the tests	80.43 ± 12.28*	75.93 ± 11.50	0.270

Data were presented as mean ± standard deviation, n = 14. DBP, diastolic blood pressure; HR, heart rate; PFJ, passion fruit juice; SBP, systolic blood pressure.
*Significantly different from before consumption at $P < 0.05$.
**Signifactly different from the placebo experiment at $P < 0.05$.

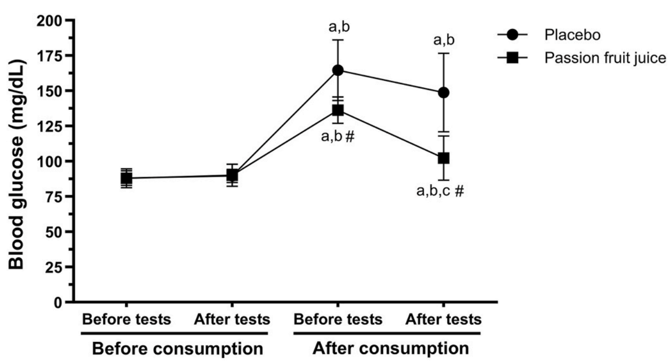

Fig. 3. Blood glucose between the placebo and passion fruit juice experiments before and after consumption. Data were presented as mean ± standard deviation, n = 14. [a]Significantly different from before consumption before the tests at $P < 0.05$. [b]Significantly different from before consumption after the tests at $P < 0.05$. [c]Significantly different from after consumption before the tests at $P < 0.05$. [#]Significantly different from placebo experiment at $P < 0.05$.

received PFJ supplementation had a significantly higher working ability at 1, 2, 3, 4, and 5 min. Although there were no significant differences in terms of attention between the placebo and PFJ interventions, however, significant improvements were detected in the PFJ intervention based on most tasks.

Based on the properties of passion fruit and the sensory characteristics of its juice with extremely strong, acidic, and exotic flavor, von Atzingen et al. (2022) showed that passion fruit may not only activate gustatory cortex activity but also mediate the function of other cortical areas, neural plasticity, and synaptic connections. PFJ is rich in vitamin C, which is the substance that provides stringent and acidulous taste. Based on the laboratory analysis, thus, vitamin C is assumed to be the important active ingredient in PFJ which offering several effects in this study including BG levels. Our previous study showed that PFJ intervention is beneficial for maintaining BG levels over 120 min compared with the placebo intervention (Prasertsri et al., 2019). Further, previous studies have found that supplementation with vitamin C reduces fasting BG and glycosylated hemoglobin levels in patients with type 2 diabetes mellitus (Afkhami-Ardekani and Shojaoddiny-Ardekani, 2007; Dakhale et al., 2011; Kotb and Al Azzam, 2015). An explanation proposed for reduced BG levels is that vitamin C improves nonoxidative glucose metabolism and then increases insulin action (Dakhale et al., 2011). In addition, vitamin C plays an important role in modulating brain neurotransmitter synthesis and release. For example, it acts as a co-factor for the conversion of dopamine to noradrenaline by dopamine-β-hydroxylase, which has an important role in regulating mood, dopaminergic and glutamatergic neurotransmission, and catecholamine and acetylcholine release from synaptic vesicles (Plevin and Galletly, 2020). Further, vitamin C is essential for converting tryptophan into serotonin, which is a major brain neurotransmitter (Gupta et al., 2014). Among these neurotransmitters, serotonin and noradrenaline are involved in cognitive function and learning (Chamberlain et al., 2006). Sim et al. (2022) found that vitamin C supplementation significantly improved attention and work absorption, with predisposition to improve fatigue and comprehensive work engagement, in healthy young adults. In addition, the performance of the vitamin C group based on the Stroop color–word test was better than that of the placebo group. In this study, collectively, improvements in working ability and also attention after PFJ supplementation could be explained by the fact that the vitamin C content in PFJ has modulating effects on brain neurotransmitters and hormones. For example, it interacts with the dopaminergic system by mediating the catalysis of dopamine-β-hydroxylase (Sim et al., 2022). Most importantly, dopaminergic signaling is significantly involved in successful executive control (e.g., attention and cognitive flexibility) and emotional arousal (e.g., motivation, goal seeking, and self-control) (Sim et al., 2022).

Furthermore, esters, terpenes, aldehydes, and alcohol components in PFJ primarily contribute to its characteristic fruity, floral, sweety, green, and citrus aroma (Janzantti and Monteiro, 2017). Aroma has beneficial effects on psychological characteristics (including working capacity, memory, thoughts, and moods) and physiological factors (such as BP, HR, muscle tension, skin temperature, pupil dilation, and brain activity) (Ko et al., 2021; Sowndhararajan and Kim, 2016). Several studies have shown that aroma inhalation significant affects brain function since its compounds can cross the blood–brain barrier and bind to receptors in the central nervous system (Sowndhararajan and Kim, 2016). Mechanisms and effects are distinct and specific to aroma constituents that bind to specific olfactory receptors and then trigger distinct neural network activities (Chamine and Oken, 2016). For example, effects on the processing speed task emerged commonly from a psychological mechanism (expectancy-increasing prime), and changes in physiology and cognition (working memory performance) were affected by aroma hedonics (Chamine and Oken, 2016).

Further, based on the analysis, PFJ also contains several micronutrients, including potassium, magnesium, phosphorus, calcium, and iron (mostly containing potassium), which may have an exotic flavor and beneficial effects on cardiovascular function (Chiu et al., 2021; Elliott et al., 2008; Lawless et al., 2003). This study showed that the SBP level was significantly lower after PFJ consumption than after placebo consumption. We assumed that the aforementioned micronutrients in PFJ, especially potassium, may act synergistically to decrease BP. Currently, several epidemiologic studies have shown that increased potassium and magnesium intake is a dietary therapy that plays an important role in lowering BP (Houston, 2011a, 2011b). The proposed mechanisms by which potassium can reduce BP include increased vasodilation, natriuresis, changes in intracellular sodium and tonicity, modulation of baroreceptor sensitivity, and decreased vasoconstrictive sensitivity to norepinephrine and angiotensin II (Houston, 2011b). Magnesium lowers BP via several mechanisms. These include acting like a natural calcium channel blocker, competing with sodium for binding sites on vascular smooth muscle cells, increasing prostaglandin E, binding to potassium in a cooperative manner, inducing endothelial-dependent vasodilation, and improving endothelial dysfunction (Houston, 2011a). Importantly, magnesium is more effective in reducing BP when consumed in combination with potassium and calcium (Houston, 2011a).

In terms of limitations, this study lacked a long-term consumption period. Therefore, PFJ consumption at longer durations may help evaluate long-term effects and other statistically significant outcomes. Moreover, further studies on electroencephalogram should be evaluated to assess the real-time changes and underlying mechanisms by which PFJ can be beneficial on brain functions.

In conclusion, a single consumption of PFJ at 3.5 mL/kg BM improves working ability in healthy participants. This may be enhanced by improving attentional focus and maintaining postprandial BG. Further, PFJ can be an alternative treatment for improving brain function and delaying the development of cognitive dysfunction.

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CRediT authorship contribution statement

Piyapong Prasertsri: Conceptualization, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Supervision, Funding acquisition. **Kittiya Sinnitithavorn:** Investigation, Writing – original draft, Funding acquisition. **Chonlakan Raroengjai:** Investigation, Writing – original draft, Funding acquisition. **Rujirat Phichayaworawit:** Investigation, Writing – original draft, Funding acquisition. **Pimonpan Taweekarn:** Writing – original draft, Writing – review & editing. **Kunavut Vannajak:** Writing – original draft, Writing – review & editing. **Uraiporn Booranasuksakul:** Writing – original draft, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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