Prev. Nutr. Food Sci. 2019;24(3):245-253
https://doi.org/10.3746/pnf.2019.24.3.245
pISSN 2287-1098 · eISSN 2287-8602

Acute Effects of Passion Fruit Juice Supplementation on Cardiac Autonomic Function and Blood Glucose in Healthy Subjects

Piyapong Prasertsri, Uraiporn Booranasuksakul, Kanoknuch Naravoratham, and Petcharat Trongtosak

Faculty of Allied Health Sciences and Exercise and Nutrition Sciences and Innovation Research Unit, Burapha University, Chonburi 20131, Thailand

ABSTRACT: Ascorbic acid supplementation provides beneficial effects on enhancing cardiac autonomic function in patients with heart failure. Ascorbic acid also reduces blood sugar levels and enhances insulin activity, and encourages cardiac autonomic function. Passion fruit is rich in ascorbic acid and potential antioxidants. This study aimed to evaluate the acute effects of passion fruit juice (PFJ) supplementation primarily on cardiac autonomic function and secondary on blood glucose in healthy subjects. A randomized cross-over trial was conducted in 14 healthy subjects aged 21.29±0.73 years. Subjects were supplemented with either 50% PFJ, or glucose and fructose solution as a placebo (PLA) at 3.5 mL/kg body mass with a 1-week washout between treatments in a single-dose design. Short-term heart rate variability and blood glucose levels were evaluated prior to supplementation (T0) and following supplementation for 30, 60, 90, and 120 min (T30, T60, T90, and T120, respectively). Indexes of cardiac autonomic function at T30, including high frequency power (P=0.03) and total power (P=0.01), were significantly higher and the ratio of low frequency/high frequency power was significantly lower (P=0.01) in the PFJ group compared to the PLA group. Blood glucose levels significantly increased at T30 in both PLA (P=0.00) and PFJ (P=0.00) groups. However, there were no significant differences between groups. A single administration of PFJ enhanced cardiac autonomic function through augmentation of parasympathetic activity, although it did not attenuate postprandial hyperglycemia. PFJ may be potentially recognized as beverage able to prevent cardiovascular disease.

Keywords: vitamin C, passion fruit, autonomic nervous system, cardiovascular disease, diabetes mellitus

INTRODUCTION

Large datasets provide insights into the epidemiology of cardiovascular disease (CVD) worldwide, which is the leading cause of disease burden and deaths (Hinton et al., 2018; India State-Level Disease Burden Initiative CVD Collaborators, 2018). Risk factors for CVD include aging, high blood pressure, hypercholesterolemia, and obesity, and are among the most essential contributors to disability-adjusted life years (Hinton et al., 2018). Dietary and nutritional approaches are the most paramount modifiable factors in the prevention and management of CVD. These factors can affect CVD directly by contributing to the accumulation of vascular plaques, and indirectly by regulating the rate of aging, the major risk factor for CVD (Brandhorst and Longo, 2019). Diet composition is one of the preeminent approache to improve human health, and which may be helpful in preventing development of CVD, such as through decreasing oxidative stress, inflammation, atherosclerosis, and insulin resistance (Casas et al., 2018). A high consumption of vegetables and fruits is widely recommended as an excellent source of dietary fiber, antioxidants, and polyphenols (Slavin and Lloyd, 2012).

Passion fruit is mostly grown in tropical and sub-tropical parts of the world (Zas and John, 2016). It is widely consumed due to its pleasant flavour and acidic aroma (Fernandes et al., 2011). Furthermore, passion fruit is considered an important source of minerals and vitamins, such as ascorbic acid, phyto-constituents, flavonoids, and phenolic compounds (Ramaiya et al., 2013; Zas and John, 2016). Ascorbic acid has been reported to improve cardiac autonomic nervous system in previous studies, which suggest that ascorbic acid supplementation enhances parasympathetic (vagal) nervous activity (Buttros et al., 2009; Monahan et al., 2004) and attenuates sympathetic nervous activity (Bruno et al., 2012; Leuenberger et al., 2012). Maintaining regular activities of these systems plays a

Received 7 May 2019; Accepted 20 August 2019; Published online 30 September 2019

Correspondence to Piyapong Prasertsri, Tel: +66-38-103-166, E-mail: piyapong@buu.ac.th
Author information: Piyapong Prasertsri (Professor), Uraiporn Booranasuksakul (Instructor), Kanoknuch Naravoratham (Professor), Petcharat Trongtosak (Professor)

crucial role in the prevention of cardiovascular pathology and dysfunction, including hypertension, ischemic heart disease, arrhythmias, and congestive heart failure (Bairey Merz et al., 2015). Previous studies have demonstrated that consuming yellow passion fruit for 5 days decreases systolic blood pressure and oxidative stress in spontaneously hypertensive rats (Zhao et al., 2017). In addition, intake of passion fruit seed extracts containing piceatannol for 16 weeks improves blood lipids, platelet aggregation, and cardiac function in CVD-induced rats (Ishihata et al., 2016). A clinical trial in type 2 diabetic subjects demonstrated a reduction in systolic blood pressure and blood glucose following administration of purple passion fruit for 16 weeks (Raju et al., 2013). Studies in diabetic rats have also revealed that passion fruit extract effectively reduces blood glucose, increases antioxidants, and improves lipid profiles (Barbalho et al., 2011; Kandandapani et al., 2015; Uchida-Maruki et al., 2015). These data demonstrate the feasibility of passion fruit to exhibit beneficial effects for enhancing cardiac autonomic function and preventing of diabetes mellitus. However, knowledge obtained in the aspect of medical nutrition therapy is limited and broader preventive strategies could reduce the burden of CVD. Accordingly, this study, aimed to explore the effects of a single-dose passion fruit juice (PFJ) supplementation primarily on cardiac autonomic function and secondary on blood glucose in healthy subjects.

MATERIALS AND METHODS

Study design and subjects

This was a randomized cross-over study conducted in Mueang, Chonburi, Thailand. Fourteen healthy male and female subjects aged between 20 to 22 years (21.29±0.73 years) with body mass index (BMI) 20.65±1.26 kg/m^2 were enrolled. Inclusion criteria included: (a) male or female; (b) aged between 20 to 30 years; (c) normal BMI (18.5～23.0 kg/m^2); and (d) healthy of body and mind. Exclusion criterion included regular smokers or drinkers. Withdrawal criteria were as follows: (a) presented abnormal symptoms including nausea, vomiting, dizziness, or syncope; (b) participation in another intervention; and (c) requested to cease participation from the study.

Power calculation

Sample size was calculated using a cross-over study formula generated by Machin and Campbell (2005). Basu and colleagues (2010) studied the effect of strawberry supplementation on decreases in atherosclerotic markers in subjects with metabolic syndrome. Accordingly, the authors reported a mean difference in decreasing serum glucose between treatment and control groups of 0.1 mmol/L [standard deviation (SD) 0.1]. Hence, with α error of 0.05 and β error of 0.10, the sample size in this study was 14 subjects including a 10% drop-out rate.

Ethics statement

All subjects signed a consent form prior to screening and enrollment in the study. Subjects were informed of the study protocols, details, risks, and their role in the study, both in writing and verbally before signing the consent form. This study was conducted under the approval of the Human Ethics Committee of Burapha University (approval no. 175/2560), and in accordance with the ethical standards of the Declaration of Helsinki. This study is registered with the Thai Clinical Trials Registry (identification no. TCTR20180223005).

Recruitment and screening of subjects

This study recruited 14 healthy subjects at Burapha University, Mueang, Chonburi, Thailand from January to February 2018. Placards containing the study details were posted in the main areas of the University, such as the library, cafeteria, and student dormitories. Subjects interested in participating in the study contacted a research assistant by phone. After making an appointment, subjects were screened through health questionnaires used to examine their general information, medical illness, exercise participation history, supplementation intake history, and mental health, in addition to a physical examination, which measured body mass (BM), height, BMI, blood pressure (BP), and heart rate (HR). During the week following screening, subjects who were selected based on the inclusion and exclusion criteria and provision of informed consent participated in the initial installment of the study.

Experimental protocol

During the first visit, anthropometric measurements were taken. Subjects were then randomly supplemented with either 50% PFJ, or glucose and fructose solution as a placebo (PLA) at 3.5 mL/kg BM in a single-dose design. Short-term HR variability (HRV), blood glucose levels, HR, and BP were evaluated before supplementation (T0) and following supplementation for 30, 60, 90, and 120 min (T30, T60, T90, and T120, respectively). Subjects participated in the second visit the following week during which they underwent additional treatment. A 1-week interval was established as a wash-out period between treatments. All measurements were carried out at the same time of day, and under similar environmental conditions.

Supplements

The PFJ used in this study was a commercially available PFJ produced from purple passion fruits at Doi Kham Food Products Co. Ltd., (Chiang Rai, Thailand). The concentration of PFJ was 50% (50 g/100 mL) according to a

previous study by de Souza Mda et al. (2012), which reported productive effects of PFJ supplementation at 1 g/kg on improving levels of plasma lipid and oxidative stress. One hundred mL of the juice provided 55 kcal, consisting of 12.5 g sugars, 1 g other carbohydrate, <0.5 g dietary fibers, and 10 g sodium. The PLA was prepared by dissolving 6.875 g glucose powder (Utopian Co., Ltd., Samut Prakan, Thailand) and 6.875 g fructose powder (Mission Health Food Co., Ltd., Bangkok, Thailand) (Arjona et al., 1991; Ramaiya et al., 2013) in 100 mL hot water. The PFJ and PLA were prepared according to subject's BM, i.e. 3.5 mL/kg BM.

Assessment of cardiac autonomic function

Short-term HRV was analyzed to assess cardiac autonomic function following HR and BP measurements. HRV data was generated from lead II electrocardiography (PowerLab 4/30, AD Instruments, Bella Vista, NSW, Australia). The subjects' HRV data were collected over 5 periods: 5-min before supplementation, and post-supplementation at 25～30 min, 55～60 min, 85～90 min, and 115～120 min. Analysis of HRV data accounted for the time domain and frequency domain. The time domain consisted of the SD of normal beat-to-beat (R-R) intervals (SDNN) and the root-mean-square of successive R-R (RMSSD). The frequency domain comprised of the values of total power (TP), very low frequency (VLF, DC to 0.04 Hz), low frequency (LF, 0.04 to 0.15 Hz), and high frequency powers (HF, 0.15 to 0.4 Hz), and the LF/HF ratio. HRV data reveal sympathetic and parasympathetic nervous activities as well as baroreceptor activity (Shaffer and Ginsberg, 2017).

Measurement of blood glucose

Blood glucose levels was measured using a Accu-Chek® Guide blood glucose monitoring system (Roche Diabetes Care Inc., Indianapolis, IN, USA) consisting of lancets, test strips, and a glucometer. Upon lancing a subject's fingertip, a drop of capillary blood (approximately 0.6 μL) was obtained and the test strip was inserted into the glucometer. Values were reported by the glucometer monitor as mg/dL.

Measurements of HR and BP

Subjects' HR, systolic BP (SBP), and diastolic BP (DBP) were measured after resting in the supine position for 15 min using a digital automatic BP monitor (Rossmax CF155f, Rossmax Swiss GmbH, Berneck, Switzerland).

Anthropometry

Subjects' height was measured using a stadiometer (Health o meter®, Chicago, IL, USA) in the standing position during inspiration. BM, BMI, fat distribution (waist and hip circumferences and their ratio), and body composition (body fat percentage, fat mass, fat-free mass, muscle mass, protein mass, mineral mass, water mass, and basal metabolic rate) were measured in the standing position, while subjects were wearing minimal clothing, using a body composition analyzer (InBody270, InBody Co., Ltd., Seoul, Korea).

Data analyses

Normality of data was analyzed and confirmed using Shapiro-Wilk tests. Differences in variables within each group at T0, T30, T60, T90, and T120 and between groups at T30, T60, T90, and T120 were analyzed using one-way repeated measures analysis of covariance (ANCOVA) by adding T0 as a covariate and using the Bonferroni post hoc test for multiple comparisons. Differences between groups at baseline (T0) were analyzed using paired *t*-test. All analyses were carried out using IBM SPSS Statistics for Windows (IBM Inc., Armonk, NY, USA). Data are presented as mean±SD. A *P*-value of <0.05 was considered statistically significant.

RESULTS

Physical and physiological characteristics

A total of 14 subjects were eligible, enrolled, and completed the study. Table 1 shows the physical and physiological characteristics of subjects during the study period. There were no significant differences in age, gender, height, BM, BMI, body fat percentage, fat mass, fat-free mass, muscle mass, protein mass, mineral mass, water mass, basal metabolic rate, waist and hip circumferences, and waist/hip ratio between subjects in the PLA and PFJ groups.

Cardiac autonomic nervous activity

Compared with the PLA group, SDNN (F=4.85, *P*=0.04, effect size=0.17), RMSSD (F=5.32, *P*=0.03, effect size=0.18), TP (F=7.19, *P*=0.01, effect size=0.23), HF power (F=5.23, *P*=0.03, effect size=0.18), and HF power in normalized unit (F=7.09, *P*=0.01, effect size=0.23) were significantly higher at T30 in the PFJ group [SDNN, 73.16±40.77 vs. 63.79±48.45 ms; RMSSD, 81.72±61.66 vs. 59.36±74.07 ms; TP, 7,346.33±8,464.80 vs. 4,678.06±7,430.06 ms^2, HF power, 3,752.29±5,138.10 vs. 1,849.10±4,002.78 ms^2; HF power (normalized unit): 61.31±14.24 vs. 48.16±16.99]. The LF/HF ratio value (F=7.74, *P*=0.01, effect size=0.24) was also significantly lower at T30 in the PFJ group compared with the PLA group (0.66±0.50 vs. 1.52±2.31). Moreover, the LF power in normalized unit (F=5.72, *P*=0.03, effect size=0.19) and LF/HF ratio (F=5.60, *P*=0.03, effect size=0.19) were significantly lower at T120 in the PFJ group compared with the PLA group [LF power (normalized unit), 34.18

Table 1. Physical and physiological characteristics of subjects in the two treatment groups

	Placebo group	PFJ group	*P*-value
Age (yrs)	21.29±0.73	21.29±0.73	1.00
Gender (M/F, %)	7/7 (50/50)	7/7 (50/50)	1.00
Height (m)	1.65±0.11	1.65±0.11	0.79
BM (kg)	56.16±9.31	58.48±9.10	0.34
BMI (kg/m^2)	20.64±1.30	20.70±1.35	0.88
Body fat (%)	22.54±7.07	22.31±6.92	0.85
Fat mass (kg)	12.16±2.53	12.14±2.57	0.93
Fat-free mass (kg)	44.01±10.80	44.33±10.45	0.78
Muscle mass (kg)	24.20±6.64	24.35±6.45	0.80
Protein mass (kg)	8.67±2.19	8.73±2.11	0.83
Mineral mass (kg)	3.09±0.69	3.11±0.65	0.81
Water mass (kg)	32.24±7.93	32.50±7.69	0.64
Waist circumference (cm)	68.93±4.20	68.93±4.34	0.73
Hip circumference (cm)	86.43±4.47	85.64±4.99	1.00
W/H ratio	0.79±0.05	0.79±0.05	0.53
BMR (kcal/d)	1,318.07±233.32	1,327.57±226.31	0.96

Data are mean±SD (n=14).
Differences between groups were analyzed using paired-*t*-test.
PFJ, passion fruit juice; BM, body mass; BMI, body mass index; W/H, waist to hip circumference ratio; BMR, basal metabolic rate.

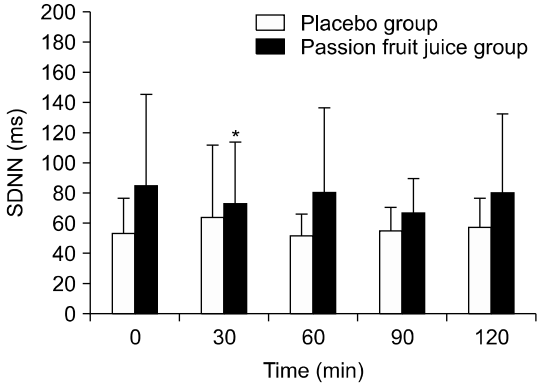

Fig. 1. Standard deviation of normal beat-to-beat intervals (SDNN) in passion fruit juice and placebo groups. Data are mean±SD (n=14). *Significantly different from placebo group (P<0.05).

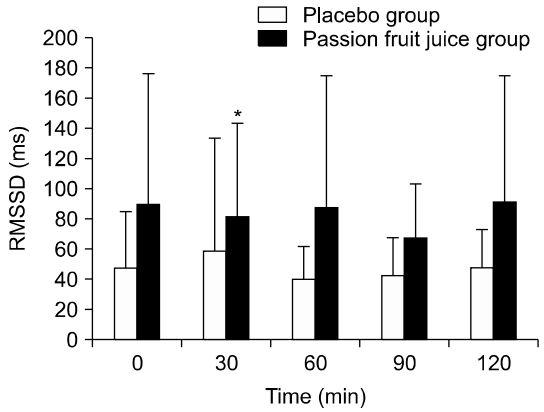

Fig. 2. Root-mean-square of successive beat-to-beat (RMSSD) in passion fruit juice and placebo groups. Data are mean±SD (n=14). *Significantly different from placebo group (P<0.05).

±19.07 vs. 51.96±24.53; LF/HF ratio, 0.81±0.73 vs. 2.98 ±3.93] (Fig. 1～4).

Analysis of HRV data did not indicate a significant change in HRV values between time points in either treatment group (Fig. 1～4 and Table 2).

Blood glucose level

Blood glucose levels at T0 were comparable between treatment groups, and were significantly elevated at T30 (both P=0.00). There were no significant differences in blood glucose levels at each time point between subjects in the PLA and PFJ groups (Fig. 5).

Moreover, the area under the curve showed that at T0-T30, T0-T60, T0-T90, and T0-T120 blood glucose levels in the PLA and PFJ groups did not significantly differ (Fig. 6).

Analysis of changes in blood glucose levels in the PLA

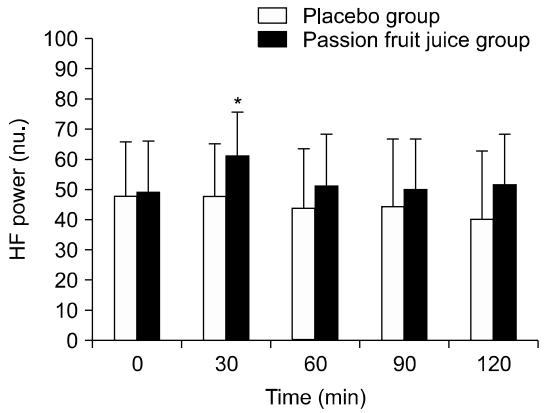

Fig. 3. High frequency (HF) power in normalized unit in passion fruit juice and placebo groups. Data are mean±SD (n=14). *Significantly different from placebo group (P<0.05).

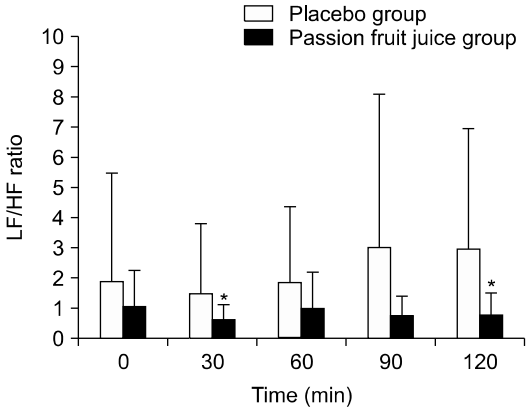

Fig. 4. Ratio of low frequency (LF) to high frequency (HF) power in passion fruit juice and placebo groups. Data are mean±SD (n=14). *Significantly different from placebo group (P<0.05).

Table 2. Heart rate variability of subjects in the two treatment groups (unit: ms^2)

	Placebo group	PFJ group	P-value
Total power			
T0	3,174.01±3,237.22	10,566.44±19,140.31	0.18
T30	4,678.06±7,430.06	7,346.33±8,464.80	0.01
T60	2,852.35±1,484.42	7,099.00±8,329.05	0.24
T90	2,959.20±1,670.50	4,958.96±3,336.26	0.51
T120	3,398.82±1,791.84	6,130.39±5,392.74	0.38
VLF power			
T0	1,021.29±803.60	2,501.52±3,152.49	0.12
T30	1,146.02±586.20	1,488.87±1,229.85	0.89
T60	1,225.34±1,155.67	1,581.16±1,088.19	0.15
T90	1,216.06±721.96	1,878.97±2,082.10	0.40
T120	1,427.02±1,281.06	1,544.59±1,423.43	0.91
LF power			
T0	832.39±765.98	2,433.17±4,199.59	0.18
T30	1,127.00±1,449.89	1,807.90±2,368.16	0.16
T60	805.87±720.25	2,003.31±2,781.03	0.34
T90	799.12±676.84	1,013.31±1,092.58	0.87
T120	980.48±705.59	1,246.73±1,310.39	0.97
HF power			
T0	1,110.77±1,736.86	4,806.91±10,776.95	0.22
T30	1,849.10±4,002.78	3,752.29±5,138.10	0.03
T60	741.32±635.35	2,762.18±4,003.99	0.12
T90	863.30±1,147.54	1,436.21±986.28	0.08
T120	880.02±903.31	2,406.57±2,585.70	0.49

Data are mean±SD (n=14).
Differences between groups were analyzed utilising one-way repeated measures ANCOVA.
PFJ, passion fruit juice; VLF, very low frequency; LF, low frequency; HF, high frequency; T0, before supplementation; T30, after supplementation for 30 min; T60, after supplementation for 60 min; T90, after supplementation for 90 min; T120, after supplementation for 120 min.

group demonstrated that blood glucose levels at T30 (P=0.00) and T60 (P=0.02) were significantly elevated from baseline; however, at T120 blood glucose levels were significantly decreased from baseline (P=0.04). In the PFJ group, changes in blood glucose levels observed at T30 (P=0.00) and T60 (P=0.01) were significantly elevated

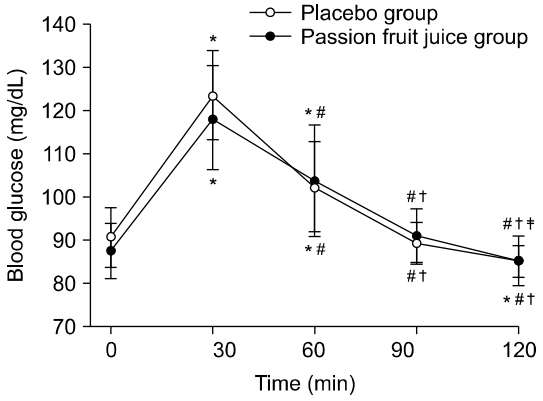

Fig. 5. Blood glucose level in passion fruit juice and placebo groups. Data are mean±SD (n=14). Significantly different from *T0, #T30, †T60, and ‡T90 (P<0.05).

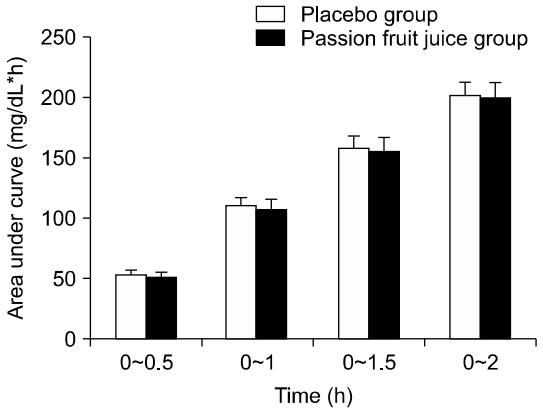

Fig. 6. Blood glucose area under the curve in passion fruit juice and placebo groups. Data are mean±SD (n=14).

from those at baseline (Fig. 5).

Heart rate and blood pressure

One-way repeated measures ANCOVA revealed that HR and BP were not significant differences between interventions at any time point (Table 3).

There were no significant alterations in HR and BP between time points in both the PLA and PFJ groups (Table 3).

DISCUSSION

CVDs are often accompanied by disparity of the sympathetic-vagal discharge to the heart, resulting in chronic adrenergic stimulation and decreased HRV (Kubota et al., 2017; La Rovere and Christensen, 2015). However, higher vagus nerve activity promotes greater HRV and favorable cardiovascular outcomes (Olshansky et al., 2008). This randomized cross-over study evaluated the effect of PFJ supplementation on enhancing cardiac autonomic function and attenuating postprandial blood glucose in healthy subjects. Our findings reveal beneficial effective-

Table 3. Heart rate and blood pressure of subjects in the two treatment groups

	Placebo group	PFJ group	*P*-value
Heart rate (beats/min)			
T0	69.37±10.51	68.16±10.57	0.49
T30	70.24±9.79	66.56±10.58	0.63
T60	70.91±9.66	68.37±10.00	0.73
T90	70.28±9.15	66.87±9.20	0.22
T120	68.98±8.59	66.92±10.94	0.35
Systolic BP (mmHg)			
T0	113.14±10.27	116.07±11.21	0.42
T30	112.79±11.66	115.07±10.45	0.97
T60	112.79±10.98	114.29±11.39	0.74
T90	115.64±11.86	114.86±10.73	0.11
T120	116.00±10.48	116.07±10.06	0.43
Diastolic BP (mmHg)			
T0	70.50±6.73	71.64±4.94	0.62
T30	68.00±7.16	71.07±8.97	0.42
T60	70.29±7.77	68.14±4.82	0.11
T90	71.57±8.81	68.71±5.78	0.13
T120	70.29±7.68	71.00±5.55	0.95

Data are mean±SD (n=14).
Differences between groups were analyzed utilising one-way repeated measures ANCOVA.
PFJ, passion fruit juice; BP, blood pressure; T0, before supplementation; T30, after supplementation for 30 min; T60, after supplementation for 60 min; T90, after supplementation for 90 min; T120, after supplementation for 120 min.

ness of acute PFJ supplementation on cardiac autonomic responses.

PFJ is the main product derived from passion fruit pulp (Laboissière et al., 2007). PFJ contains numerous essential nutrients, including amino acids, fiber, sugar (glucose, fructose, and sucrose), organic acids, phenolic compounds, flavonoids, antioxidants, ascorbic acid, vitamin A, minerals (calcium, phosphorus, sodium, potassium, and magnesium), and trace elements (ferrous, copper, manganese, zinc, and selenium) (Ramaiya et al., 2013; Ramaiya et al., 2014; Singh and Das, 2013; Zhu et al., 2017). Studies investigating the anti-inflammatory and antioxidant effects of passion fruit reported that patients with knee osteoarthritis, asthma, and hypertension experience improvements following supplementation with purple passion fruit peel extract (Farid et al., 2010; Watson et al., 2008; Zibadi et al., 2007). Significantly, our findings extended the advantageous effects of passion fruit on prevention of CVD.

Purple and yellow passion fruit varieties have been reported to yield high contents of ascorbic acid (0.20～0.32 g/kg and 0.16～0.20 g/kg of fresh fruit, respectively) (Ramaiya et al., 2013). In addition to decreasing blood glucose levels and increasing insulin sensitivity (Hurrle and Hsu, 2017; Shivavedi et al., 2019), several studies have shown ascorbic acid supplementation improves cardiac autonomic function by enhancing parasympathetic nervous activities and reducing sympathetic nervous activities (Ali-Hassan-Sayegh et al., 2014; Lewis et al., 2006; Schindler et al., 2003; Yasue et al., 2008). Piccirillo et al. (2003) suggested that ascorbic acid may improve the autonomic nervous system through 2 mechanisms: indirectly, by improving hemodynamics, and directly, by acting on subendothelial nerve endings at the baroreceptor level. Moreover, acute administration of ascorbic acid might improve local nitric oxide production, thus directly stimulating the vagal sinus. The present study showed increases in HF power and TP, and decreases in LF/HF ratios at T30, which is defined as postprandial period. HF power is an index of parasympathetic modulation of HR (Jandackova et al., 2016). Hence, increased HF power indicates an increase in parasympathetic nervous control of the heart. TP represents overall variability. Increased HF power therefore leads to increased TP. Meanwhile, LF power reflects baroreceptor activity (Shaffer and Ginsberg, 2017), which is a significant element of the mechanisms contributing to neural regulation of the cardiovascular system (La Rovere and Christensen, 2015). Nevertheless, the present results did not show a change in LF power value at postprandial state. However, there was a decrease in LF/HF power ratio, an index of parasympathetic and sympathetic balance (Low and McCraty, 2018). These data are suggestive of greater vagus nerve activity that could encourage satisfactory cardiovascular outcomes.

We also observed increased SDNN and RMSSD values at T30. SDNN reflects all the cyclic components responsible for variability and strongly correlates with TP of the frequency domain (Ernst et al., 2017). Meanwhile, RMSSD reflects the R-R variance in HR and is applied to estimate the vagally mediated changes reflected in HRV (Shaffer and Ginsberg, 2017). Rises in both SDNN and RMSSD values indicate a greater HRV (Low and McCraty, 2018). RMSSD values are also correlated with the HF power of the frequency domain; therefore, the increase in RMSSD is supportive of favorable effects of ascorbic acid amid the augmentation of parasympathetic nervous function. Consequently, these results could be employed to describe broad advantages presented by the ascorbic acid constituents in PFJ.

Previous literature have shown that 1,000 mg/d of supplementary ascorbic acid decreases blood glucose levels (Afkhami-Ardekani and Shojaoddiny-Ardekani, 2007; Christie-David et al., 2015; Dakhale et al., 2011; Kotb and Al Azzam, 2015) and serum insulin (Afkhami-Ardekani and Shojaoddiny-Ardekani, 2007; El-Aal et al., 2018) in type 2 diabetic patients. Oxidative stress can disturb glucose metabolism by damaging enzymes and cellular machinery, and by increasing insulin resistance (Asmat et al., 2016). Hence, antioxidant supplementation, such as with ascorbic acid, vitamin A, vitamin E, and glutathione, can be beneficial for reducing blood glucose and hyper-

glycemia (Khan et al., 2015; Li et al., 2017; Palekar and Ray; 2017). Kandandapani et al. (2015) reported a significant increase in superoxide dismutase and catalase, and a decrease in thiobarbituric acid reactive substances (TBARS) levels in the vital organs of diabetic rats treated with passion fruit *Passiflora edulis* extracts. Moreover, studies have shown supplementation of PFJ for 28 days significantly reduces plasma TBARS in normal Wistar rats (Kandandapani et al., 2015). In the present study, we did not observe an additional effect of PFJ on attenuating postprandial hyperglecemia. This may be due to an insufficient amount or duration of ascorbic acid. In the previous studies, rats were chronically administered high doses of ascorbic acid (i.e., 1,000 mg/d for 6 weeks to 3 months) (Afkhami-Ardekani and Shojaoddiny-Ardekani, 2007; Kotb and Al Azzam, 2015), whilst we used a single administration at a low dose. However, we showed that PFJ is beneficial for maintaining blood glucose levels. Moreover, at T120 blood glucose levels were significantly decreased from baseline in the PLA group compared with the PFJ group.

Our data did not reveal a significant change in either HR or BP. PFJ may have raised parasympathetic nervous activity resulting in reduced HR and BP, whereby a latter reduction leads to decreased baroreceptor activity (Gronda et al., 2017). Then, the inhibitory signal from the baroreceptor to the sympathetic nervous control at the vasomotor center is diminished (Kougias et al., 2010). Hence, the sympathetic nervous activity is stimulated to raise BP. Finally, a constant BP and HR is present during the experiment to maintain cell nourishment. These mechanisms are clearly observed, particularly in healthy subjects.

This study has some limitations. Firstly, it was designed to explore acute PFJ supplementation. Further investigation on chronic PFJ supplementation is needed to confirm the favorable effects of PFJ on cardiac autonomic function and blood glucose levels in the context of medical nutrition therapy. Secondly, we did not investigate insulin concentrations. Therefore, it is not possible to explain certain essential mechanisms involved in controlling blood glucose, such as changes in insulin levels or insulin sensitivity.

The present study suggests that single-dose PFJ supplementation enhances cardiac autonomic function, but does not attenuate postprandial hyperglycemia in healthy subjects. Accordingly, this study shows PFJ is advantageous for human health, and that PFJ may be employed as a potential beverage for prevention of CVD and to encourage a healthy heart.

ACKNOWLEDGEMENTS

This work was supported by the Faculty of Allied Health Sciences, Burapha University and Exercise and Nutrition Sciences and Innovation Research Unit, Burapha University, Thailand. We wish to especially thank Mr. Kadetawan Wattanayuenyong, Mr. Tinnapop Yingsangtrakul, and Ms. Anongnad Thinyoowong for recruiting and coordinating subjects.

AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest for all potential sources of bias, including affiliations, funding sources, and financial or management relationships.

REFERENCES

Afkhami-Ardekani M, Shojaoddiny-Ardekani A. Effect of vitamin C on blood glucose, serum lipids & serum insulin in type 2 diabetes patients. Indian J Med Res. 2007. 126:471-474.

Ali-Hassan-Sayegh S, Mirhosseini SJ, Rezaeisadrabadi M, Dehghan HR, Sedaghat-Hamedani F, Kayvanpour E, et al. Antioxidant supplementations for prevention of atrial fibrillation after cardiac surgery: an updated comprehensive systematic review and meta-analysis of 23 randomized controlled trials. Interact Cardiovasc Thorac Surg. 2014. 18:646-654.

Arjona HE, Matta FB, Garner JO Jr. Growth and composition of passion fruit (*Passiflora edulis*) and maypop (*P. incarnata*). HortScience. 1991. 26:921-923.

Asmat U, Abad K, Ismail K. Diabetes mellitus and oxidative stress —a concise review. Saudi Pharm J. 2016. 24:547-553.

Bairey Merz CN, Elboudwarej O, Mehta P. The autonomic nervous system and cardiovascular health and disease: a complex balancing act. JACC Heart Fail. 2015. 3:383-385.

Barbalho SM, Damasceno DC, Spada AP, Lima IE, Araújo AC, Guiguer EL, et al. Effects of *Passiflora edulis* on the metabolic profile of diabetic Wistar rat offspring. J Med Food. 2011. 14: 1490-1495.

Basu A, Fu DX, Wilkinson M, Simmons B, Wu M, Betts NM, et al. Strawberries decrease atherosclerotic markers in subjects with metabolic syndrome. Nutr Res. 2010. 30:462-469.

Brandhorst S, Longo VD. Dietary restrictions and nutrition in the prevention and treatment of cardiovascular disease. Circ Res. 2019. 124:952-965.

Bruno RM, Daghini E, Ghiadoni L, Sudano I, Rugani I, Varanini M, et al. Effect of acute administration of vitamin C on muscle sympathetic activity, cardiac sympathovagal balance, and baroreflex sensitivity in hypertensive patients. Am J Clin Nutr. 2012. 96:302-308.

Buttros JB, Bergamaschi CT, Ribeiro DA, Fracalossi AC, Campos RR. Cardioprotective actions of ascorbic acid during isoproterenol-induced acute myocardial infarction in rats. Pharmacology. 2009. 84:29-37.

Casas R, Castro-Barquero S, Estruch R, Sacanella E. Nutrition and cardiovascular health. Int J Mol Sci. 2018. 19:3988.

Christie-David D, Girgis C, Gunton J. Effects of vitamins C and D in type 2 diabetes mellitus. Nutr Diet Suppl. 2015. 2015:21-28.

Dakhale GN, Chaudhari HV, Shrivastava M. Supplementation of vitamin C reduces blood glucose and improves glycosylated hemoglobin in type 2 diabetes mellitus: a randomized, double-blind study. Adv Pharmacol Sci. 2011. 2011:195271.

de Souza Mda S, Barbalho SM, Damasceno DC, Rudge MV, de

Campos KE, Madi AC, et al. Effects of *Passiflora edulis* (yellow passion) on serum lipids and oxidative stress status of Wistar rats. J Med Food. 2012. 15:78-82.
El-Aal AA, El-Ghffar EAA, Ghali AA, Zughbur MR, Sirdah MM. The effect of vitamin C and/or E supplementations on type 2 diabetic adult males under metformin treatment: a single-blinded randomized controlled clinical trial. Diabetes Metab Syndr. 2018. 12:483-489.
Ernst G, Watne LO, Frihagen F, Wyller TB, Dominik A, Rostrup M. Decreases in heart rate variability are associated with postoperative complications in hip fracture patients. PLoS One. 2017. 12:e0180423.
Farid R, Rezaieyazdi Z, Mirfeizi Z, Hatef MR, Mirheidari M, Mansouri H, et al. Oral intake of purple passion fruit peel extract reduces pain and stiffness and improves physical function in adult patients with knee osteoarthritis. Nutr Res. 2010. 30: 601-606.
Fernandes AG, dos Santos GM, da Silva DS, de Sousa PHM, Maia GA, de Figueiredo RW. Chemical and physicochemical characteristics changes during passion fruit juice processing. Ciênc Tecnol Aliment. 2011. 31:747-751.
Gronda E, Francis D, Zannad F, Hamm C, Brugada J, Vanoli E. Baroreflex activation therapy: a new approach to the management of advanced heart failure with reduced ejection fraction. J Cardiovasc Med. 2017. 18:641-649.
Hinton W, McGovern A, Coyle R, Han TS, Sharma P, Correa A, et al. Incidence and prevalence of cardiovascular disease in English primary care: a cross-sectional and follow-up study of the Royal College of General Practitioners (RCGP) Research and Surveillance Centre (RSC). BMJ Open. 2018. 8:e020282.
Hurrle S, Hsu WH. The etiology of oxidative stress in insulin resistance. Biomed J. 2017. 40:257-262.
India State-Level Disease Burden Initiative CVD Collaborators. The changing patterns of cardiovascular diseases and their risk factors in the states of India: the Global Burden of Disease Study 1990-2016. Lancet Glob Health. 2018. 6:e1339-e1351.
Ishihata A, Maruki-Uchida H, Gotoh N, Kanno S, Aso Y, Togashi S, et al. Vascular- and hepato-protective effects of passion fruit seed extract containing piceatannol in chronic high-fat diet-fed rats. Food Funct. 2016. 7:4075-4081.
Jandackova VK, Scholes S, Britton A, Steptoe A. Are changes in heart rate variability in middle-aged and older people normative or caused by pathological conditions? Findings from a large population-based longitudinal cohort study. J Am Heart Assoc. 2016. 5:e002365.
Kandandapani S, Balaraman AK, Ahamed HN. Extracts of passion fruit peel and seed of *Passiflora edulis* (Passifloraceae) attenuate oxidative stress in diabetic rats. Chin J Nat Med. 2015. 13: 680-686.
Khan AN, Khan RA, Ahmad M, Mushtaq N. Role of antioxidant in oxidative stress and diabetes mellitus. J Pharmacogn Phytochem. 2015. 3:217-220.
Kotb A, Al Azzam KM. Effect of vitamin C on blood glucose and glycosylated hemoglobin in type II diabetes mellitus. World J Anal Chem. 2015. 3:6-8.
Kougias P, Weakley SM, Yao Q, Lin PH, Chen C. Arterial baroreceptors in the management of systemic hypertension. Med Sci Monit. 2010. 16:RA1-RA8.
Kubota Y, Chen LY, Whitsel EA, Folsom AR. Heart rate variability and lifetime risk of cardiovascular disease: the Atherosclerosis Risk in Communities Study. Ann Epidemiol. 2017. 27: 619-625.e2.
La Rovere MT, Christensen JH. The autonomic nervous system and cardiovascular disease: role of n-3 PUFAs. Vascul Pharmacol. 2015. 71:1-10.
Laboissière LH, Deliza R, Barros-Marcellini AM, Rosenthal A, Camargo LM, Junqueira R. Food processing innovation: a case study with pressurized passion fruit juice. J Technol Manag Innov. 2007. 2:108-123.
Leuenberger UA, Linton-Frazier L, Spilk S, Hogeman C. Ascorbic acid attenuates sympathetic activation and endothelial dysfunction induced by short-term intermittent hypoxia in humans. FASEB J. 2012. Available from: https://www.fasebj.org/doi/abs/10.1096/fasebj.26.1_supplement.898.6
Lewis MJ, Short AL, Lewis KE. Autonomic nervous system control of the cardiovascular and respiratory systems in asthma. Respir Med. 2006. 100:1688-1705.
Li C, Miao X, Li F, Wang S, Liu Q, Wang Y, et al. Oxidative stress-related mechanisms and antioxidant therapy in diabetic retinopathy. Oxid Med Cell Longev. 2017. 2017:9702820.
Low A, McCraty R. Heart rate variability: new perspectives on assessment of stress and health risk at the workplace. Heart Mind. 2018. 2:16-27.
Machin D, Campbell MJ. Cross-sectional and longitudinal studies. In: The Design of Studies for Medical Research. John Wiley & Sons, Ltd., Chichester, UK. 2005. p 89.
Monahan KD, Eskurza I, Seals DR. Ascorbic acid increases cardiovagal baroreflex sensitivity in healthy older men. Am J Physiol Heart Circ Physiol. 2004. 286:H2113-H2117.
Olshansky B, Sabbah HN, Hauptman PJ, Colucci WS. Parasympathetic nervous system and heart failure: pathophysiology and potential implications for therapy. Circulation. 2008. 118:863-871.
Palekar AV, Ray KS. Oxidative stress, antioxidative enzymes and dietary antioxidant intake in patients with diabetes mellitus with and without nephropathy. SM J Diabetes Metab. 2017. 2: 1006.
Piccirillo G, Nocco M, Moisè A, Lionetti M, Naso C, di Carlo S, et al. Influence of vitamin C on baroreflex sensitivity in chronic heart failure. Hypertension. 2003. 41:1240-1245.
Raju IN, Reddy KK, Kumari CK, Reddy EB, Rao SD, Reddy CD, et al. Efficacy of purple passion fruit peel extract in lowering cardiovascular risk factors in type 2 diabetic subjects. J Evid Based Complementary Altern Med. 2013. 18:183-190.
Ramaiya SD, Bujang JS, Zakaria MH, King WS, Shaffiq Sahrir MA. Sugars, ascorbic acid, total phenolic content and total antioxidant activity in passion fruit (*Passiflora*) cultivars. J Sci Food Agric. 2013. 93:1198-1205.
Ramaiya SD, Bujang JS, Zakaria MH. Assessment of total phenolic, antioxidant, and antibacterial activities of *Passiflora* species. Sci World J. 2014. 2014:167309.
Schindler TH, Nitzsche EU, Munzel T, Olschewski M, Brink I, Jeserich M, et al. Coronary vasoregulation in patients with various risk factors in response to cold pressor testing: contrasting myocardial blood flow responses to short- and long-term vitamin C administration. J Am Coll Cardiol. 2003. 42:814-822.
Shaffer F, Ginsberg JP. An overview of heart rate variability metrics and norms. Front Public Health. 2017. 5:258.
Shivavedi N, Charan Tej GNV, Neogi K, Nayak PK. Ascorbic acid therapy: a potential strategy against comorbid depression-like behavior in streptozotocin-nicotinamide-induced diabetic rats. Biomed Pharmacother. 2019. 109:351-359.
Singh SD, Das D. Passion fruit: a fetched passion for dentists. Int J Pharm Sci Res. 2013. 4:754-757.
Slavin JL, Lloyd B. Health benefits of fruits and vegetables. Adv Nutr. 2012. 3:506-516.
Uchida-Maruki H, Inagaki H, Ito R, Kurita I, Sai M, Ito T. Piceatannol lowers the blood glucose level in diabetic mice. Biol Pharm Bull. 2015. 38:629-633.
Watson RR, Zibadi S, Rafatpanah H, Jabbari F, Ghasemi R, Ghafari J, et al. Oral administration of the purple passion fruit peel extract reduces wheeze and cough and improves shortness of breath in adults with asthma. Nutr Res. 2008. 28:166-171.
Yasue H, Nakagawa H, Itoh T, Harada E, Mizuno Y. Coronary

artery spasm—clinical features, diagnosis, pathogenesis, and treatment. J Cardiol. 2008. 51:2-17.

Zas P, John S. Diabetes and medicinal benefits of *Passiflora edulis*. World J Pharm Res. 2016. 5:453-465.

Zhao CN, Meng X, Li Y, Li S, Liu Q, Tang GY, et al. Fruits for prevention and treatment of cardiovascular diseases. Nutrients. 2017. 9:E598.

Zhu XH, Duan ZH, Yang YX, Huang XH, Xu CL, Huang ZZ. Development of passion fruit juice beverage. Proceedings of the 1st International Global on Renewable Energy and Development. 2017 Dec 22-25. Singapore. Available from: https://doi.org/10.1088/1755-1315/100/1/012080

Zibadi S, Farid R, Moriguchi S, Lu Y, Foo LY, Tehrani PM, et al. Oral administration of purple passion fruit peel extract attenuates blood pressure in female spontaneously hypertensive rats and humans. Nutr Res. 2007. 27:408-416.