

## Physical, Psychological, and Biochemical Effects of Palm Fruit Bioactive complex (PFBC) (*Elaeis guineensis*)

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### Abstract

Palm Fruit Bioactive complex (PFBC) has demonstrated antioxidant and anti-inflammatory properties. Therefore, it was the purpose of this pilot, exploratory randomized, double-blind, placebo-controlled study to investigate the effects of three doses of PFBC (0 mg/Placebo, 250 mg, 500 mg and 1,000 mg/day) taken for 30 days on measures of physiology, mood state, cellular damage, and gut microbiome status in healthy physically active adults. PFBC enhanced antioxidant capacity (cORP) at rest for all three doses tested over the initial 30 days, (250 mg: from 0.36 to 1.85; (p = .026), 500 mg from 0.27 to 1.09 (p = 0.010) and 1000 mg from 0.49 to 1.67 (p = 0.005), while there was no effect of placebo at rest. Two doses of the PFB trended towards enhancing antioxidant capacity after stressful exercise (500 mg from 1.1 to 2.8 (p = 0.64) and 1000 mg 1.67 to 2.91 (p = 0.058), while there was no effect for placebo (p = 0.320) or for the 250 mg PFB (p = 0.928). There were no other statistically significant results. All doses were safe and well-tolerated. PFBC has antioxidant and other physiologic impacts that are apparent at rest and after physical stress, continued research and development are warranted.

**Keywords:** Palm Fruit Bioactive Complex; Antioxidant; Anti-inflammatory; Polyphenols; *Elaeis guineensis*

### Introduction

Life expectancy has increased across the globe over the last 100 years as has the associated increased prevalence of age-related illnesses such as Alzheimer's disease. By 2050 it is anticipated that 1 in 85 people will be diagnosed with the disease [1]. Since there has been no identified successful treatment, research has focused on the etiology and progress of the disease in hopes to identify mechanisms and therefore prevention strategies. This focus is logical considering the increased prevalence, potentially long and unpredictable progression, as well as the significant costs both financially and emotionally, at all stages of cognitive impairment (CI) [2]. Mild Cognitive Impairment (MCI) is a clinical term that denotes a stage of CI that is considered more severe than normal aging but not yet indicative of dementia. MCI is characterized by self-reported impairment in cognition that maintains independence and activities of daily living [3]. There are no effective treatments for cognitive impairment, despite various pharmacological options [2]. However, research has made great progress in identifying potential mechanisms such as oxidative stress and inflammation [4] in the etiology of CI in the hopes that interventions may attempt to interfere with these processes. For example, the role of chronic oxidative stress as common pathogenesis of age-related neurodegenerative diseases and antioxidant therapy to offset oxidative stress in an attempt to prevent these diseases has been well documented in the literature [5]. This combined with the increased understanding of how lifestyle behaviors influence these mechanisms, has supported a potential role for nutrition in the prevention of CI. The identification of the role dietary intake plays in neurological processes such as neurogenesis and neuro connectivity has further supported the idea that nutritional interventions may provide a logical preventive step [6].

Research suggests that a diet rich in antioxidants (such as fruits, nuts, vegetables and spices) and lower in calories (mainly from lowering sugar intake and low in alcohol consumption) may lower risk of age-related cognitive decline and therefore decrease the risk of developing neurodegenerative diseases [7-9]. In addition, research supports the role of B-vitamins (vitamin B12, vitamin B6 and riboflavin), vitamin D, folate, polyphenols and n-3 polyunsaturated fatty acids (PUFAs) - eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in neuroprotection and in reducing the risk of cognitive decline [10]. In support of the benefits of such a dietary pattern, recent systematic reviews have reported a strong association between the Mediterranean-style diet (MsD) and neurodegenerative conditions [11-13]. This association is thought to be due to the antioxidant and anti-inflammatory effects of the high fruit and vegetable intake of the MsD [14]. Similarly, when individual nutrients such as n-3 fatty acids, DHA and flavonoids show benefits for preventing cognitive decline the mechanism of action by which they exert their effect is thought to be via antioxidant and/or anti-inflammatory pathways [6,15]. The association between inflammation and aging is discussed in connection with aging related changes to multiple age-associated issues which all lead to inflammation marked by a chronic sub-clinical elevation of pro-inflammatory mediators [16]. This age-related inflammation is referred to in the literature as “inflamm-aging” [15,16]. Several studies have connected “inflamm-aging” with cognitive aging [17,18]. Oxidative stress plays a critical role in maintaining chronic inflammation [19]. The age related changes in oxidative stress and inflammation influence multiple physiological systems including vascular function and brain aging, all of which influence cognitive decline [16].

Therefore, nutritional interventions that target inflammation and oxidation have been investigated. While dietary patterns such as MsD appear to offer benefit, it is not always realistic to adhere to any given pattern. Therefore, identifying foods and/or nutrients for supplementation may be helpful to maintain consistent anti-inflammatory effects. One such product is Palm Fruit Bioactive complex (PFBC). PFBC is derived from the extraction process of palm oil from oil palm fruit (*Elaeis guineensis*) utilizing a process that yields the water soluble phytochemical rich liquid rich in protocatechuic acid and caffeic acids as well as catechins, isomers of caffeoyl shikimic acid, 4-hydroxybenzoate, soluble fibers, and shikimic acid. The Palm Fruit Bioactives Complex contains 5 unique Polyphenols: protocatechuic acid, p-hydroxybenzoic acid, 3-O-caffeoyl shikimic acid, 4-O-caffeoyl shikimic acid, 5-O-caffeoyl shikimic acid.

Research suggests that the crude and ethanol extracts of the oil palm fruit can scavenge free radicals by either hydrogen or electron-donating mechanisms and can therefore act as primary antioxidants [20,21]. Due to its high antioxidants capacity palm fruit extract is neuroprotective in mice [22]. Additionally, it has been shown to protect against the development of atherosclerosis by helping to offset LDL oxidation and its associated effects and has been shown to prevent vascular constriction [23]. Rodent models suggest that it may slow the rate of glucose absorption, reduce insulin resistance and/or enhance insulin secretion [24]. Though many studies have been done in rodent models, a dose of 200 mg/kg is reported to be safe in humans [25].

Therefore, it was the purpose of this pilot exploratory proof of concept oriented study to investigate the effects of three doses of PFBC (0 mg/Placebo, 250 mg, 500 mg and 1,000 mg/day) on measures of physiology, mood state, cellular damage, and gut microbiome status in healthy physically active adults.

## Materials and Methods

Using a randomized, double-blind, placebo-controlled design, this pilot exploratory study enrolled 13 male and 16 healthy female subjects 18 to 70 years of age (mean age 39 (21 - 56y), BMI of 29.1 kg/m<sup>2</sup> (25.1 to 34.6 kg/m<sup>2</sup>) able to undergo running exercise sessions as part of this study. Subjects were asked to maintain regular diet and exercise activities throughout the study. This study protocol and the associated Informed Consent was reviewed and approved by Aspire IRB (Santee, CA, USA) on September 12, 2018. The study was executed by GLH Nutrition (Shawn Talbott, PhD, Principal Investigator) at Treehouse Athletic Club in Draper, Utah. The specific ethic code number is 96218.

### Product testing

The study tested three different doses of PFBC (250 mg (n = 7), 500 mg (n = 7) and 1000 mg (n = 7)) as compared to placebo (0 mg (n = 8), matched for appearance, color, odor, etc.) (Phenolaeis, USA) taken daily for the 30-day testing period. To help promote healthy hydration, subjects were encouraged to aim for at least 80 ounces of non-alcoholic fluid (water) daily.

### Body composition testing

For evaluating body composition, body weight, body fat percentage and lean mass percentage an FDA 510-k cleared validated bioelectric impedance device was employed (Tanita Body Composition, Arlington Heights, Illinois, USA).

### Heart rate variability

To measure and monitor heart rate and heart rate variability, a CorSense® monitor was utilized (Elite HRV, Asheville, NC).

### Mood state testing

In order to measure mood states and changes in mood states, the Profile of Mood States (POMS) questionnaire was used (Educational and Industrial Testing Service, San Diego, CA.). The POMS measures six different dimensions of mood states over a period of time. These include Tension or Anxiety, Anger or Hostility, Vigor or Activity, Fatigue or Inertia, Depression or Dejection, Confusion or Bewilderment. A five-point scale ranging from “not at all” to “extremely” is administered by experimenters to subjects to assess their mood states. The POMS allows for a total mood states score as well as the domains which constitute the overall score [26].

### Blood tests

This study utilized the peripheral capillary method for collecting blood samples for analysis, specifically for lipids (total cholesterol, low-density lipoprotein, high-density lipoprotein and triglycerides) and Brain-derived neurotrophic factor (BDNF). Capillary glucose was also captured. Samples were analyzed by the CLIA-waived Cholestech LDX™ Analyzer (Abbott Diagnostics, Lake Forest, IL.) In addition, serum TNF $\alpha$ , IL-6, IL-1B, MCP-1, IL-8, uric acid and cardiac troponin were also obtained, processed and subsequently measured and analyzed by a contract analytical laboratory (Wasatch Scientific, Salt Lake City, UT).

Oxygen reduction potential (ORP) was analyzed by use of the RedoxSYS Diagnostic System (Aytu Biosciences, Englewood, CO) [27] at the research site by the principal investigator per standardized guidelines. In general, the ORP is an integrated measure of the balance between total oxidants (e.g. oxidized thiols, superoxide radical, hydroxyl radical, hydrogen peroxide, nitric oxide, peroxyxynitrite, and transition metal ions) and total reductants (e.g. free thiols, ascorbate,  $\alpha$ -tocopherol,  $\beta$ -carotene, and uric acid) [27]. Thus, ORP is an overall measure of the oxidative stress to which a biological system is subjected to. Static ORP (sORP) provides a composite measure of available oxidants and reductants whereas capacity ORP (cORP) measures the number of accessible reductants to combat oxidative stress. Low sORP values mean that the “sample” is in the normal range of oxidative stress, while higher than normal sORP values mean that the “sample” is in a higher state of oxidative stress. cORP is the measure of antioxidant reserve available in the body’s system; high capacity values mean that the biological sample has antioxidant reserves in the normal range; lower than normal cORP values mean that the biological sample has below normal antioxidant reserves [27]. The greater the ORP, the more oxidative stress induction is occurring, the lower the ORP, the less oxidative stress is occurring (greater oxidative reserve or cORP) [27,28].

Measurements were taken using the RedoxSYS® Diagnostic System according to the manufacturer’s instructions (Aytu BioSciences). “Prior to each ORP measurement, both analyzer platforms were measured for calibration; sensor chip side A was inserted into the device to ensure the device was within specification ( $100 \pm 1$  mV) and then side B was inserted to further ensure the device was working within specification ( $300 \pm 4$  mV). Following calibration, plasma samples (30  $\mu$ L) were pipetted onto the exposed filter paper reservoir of a disposable electrode strip containing three electrodes: working (silver), counter (silver), and reference (silver chloride 3 M KCl) (RedoxSYS® sensor) and then inserted in a galvanostat based reader (RedoxSYS® analyzer platform). A low oxidizing current (1 nA) is applied to the sample until the charge between working and reference electrodes changes, providing an ORP reading in mV and indicating that all potentially oxidizable molecules present in the sample are oxidized. The final reading provided the aggregate measurement of the electric conductivity of plasma as the balance between oxidized and reduced molecules” [28].

### Microbiome testing

Subjects in the study agreed to donate fecal samples at specific study time points in order to evaluate the gut microbiome and potential changes in the gut microbiome over the month of the study. Subjects were provided specific instructions along with the sample collection kit and a UN 3373 compliant home kit for fecal sample collection, packaging and shipping to the analytical microbiome laboratory (Wasatch Scientific, Salt Lake City, UT). Fecal samples were analyzed for the overall biome composite including, firmicutes, Bacteroides, Bifidobacterium, lactobacillus, butyrate kinase, *A. muciniphila* and *S. thermophilus*.

### Exercise stress

As a means of inducing exercise-related stress, all subjects engaged in a self-perceived vigorous 10-kilometer (10-km) hill run on a predetermined course at an average elevation 4,226 to 4,327 feet above sea level. During the 10-km run all subjects were verbally encour-

aged to complete the course as fast as they could at their self-selected pace. The purpose was to induce stress and an acute oxidative and inflammatory response and to evaluate if the interventions had any impact on physiological response to oxidative stress and inflammation when taken along with stressful exercise. TNF $\alpha$ , IL-6, IL-1B, MCP-1, IL-8, uric acid and cardiac troponin were utilized as the blood biomarkers for this evaluation.

### **Study procedures and flow**

After obtaining informed consent, the subjects underwent a standard and good clinical practice screening study visit to determine eligibility. After subjects were identified as meeting the study criteria, subjects underwent baseline study visit where pre-supplementation data was obtained. Tests included body weight, body composition, heart rate variability, POMS, blood sampling for lipids, glucose, ORP, along with serum TNF $\alpha$ , IL-6, IL-1B, MCP-1, IL-8, uric acid and cardiac troponin and fecal sample collection for microbiome analysis.

The study closeout visit was after 30-days of assigned product usage (double-blind format). At the study visit, all baseline tests were repeated, and an exercise-stress protocol was followed in order to determine the response to stressful exercise while on the assigned study product. Two days after the exercise intervention was performed, final repeat measures of heart rate variability, (sORP, cORP) ORP testing along with serum TNF $\alpha$ , IL-6, IL-1B, MCP-1, IL-8, uric acid and cardiac troponin were collected.

### **Statistical plan**

Statistical analysis was performed using SAS<sup>®</sup> v9.3 (SAS Institute Inc.) and Microsoft Excel (Microsoft Excel 2013). All analyses were conducted with descriptive statistics. Summary statistics including mean, median, standard deviation, minimum, and maximum were provided for continuous variables, such as age. Frequencies and proportions were used to summarize categorical data, such as gender. All subjects who received the study product were included in the population for demographics and baseline characteristics. All subjects who completed the study were utilized in a per-protocol (PP) analysis. The per protocol analysis was chosen as the analysis of choice for efficacy evaluation. This study was designed to be pilot and exploratory in nature, therefore, the PP population was deemed to be most correct for data analysis. The paired t test or Wilcoxon sign-rank test was used to compare the change from baseline within each group. For comparisons over time and for between group analysis for significance, the repeated measures analysis of variance was employed (RM-ANOVA). A non-hierarchical statistical approach was utilized to treat each endpoint of interest separately as an independent endpoint of interest

## **Results**

### **Anthropometrics and body composition**

There was no within-group or between-group effect on body composition for the PFBC at any of the doses tested ( $p > 0.05$ ). This was true for each dose tested as well as for placebo, no effect of 0 to 1000 mg PFBC when taken orally within the context of this study design for affecting body weight or body composition.

### **Heart rate variability**

There were no statistically significant effects of the PFBC or placebo at any of the tested doses for impacting resting heart rate variability (HRV) over the ~30 days of product exposure ( $p > 0.05$ ). There was also no observed effect for HRV after the stressful run intervention ( $p > 0.05$ ).

### **Mood states**

There were no statistically significant effects observed within or between the groups for changes in total mood states score or in the POMS sub-domains over the course of the study. No effect on Total Mood Disturbance (the total POMS score), nor for the POMS confusion, fatigue, vigor, depression or anger subscores throughout the study period ( $p > 0.05$ ).

### **Blood tests - Metabolic**

There were no observed significant within or between-group effects observed for cholesterol, low-density lipoprotein, high-density

lipoprotein, triglycerides or for glucose over the course of the study ( $p > 0.05$ ).

**Blood tests - Inflammatory, immunity oriented**

There were no observed statistical within group or between groups effects over the study period. More specifically, there was no effect of any dose or placebo on TNFa ( $p > 0.05$ ), IL-6 ( $p > 0.05$ ), IL-1 beta ( $p > 0.05$ ), MCP-1 ( $p > 0.05$ ), uric acid ( $p > 0.05$ ) or on cardiac troponin ( $p > 0.05$ ).

**Oxidative stress/antioxidant markers**

Over the initial course of the study, the placebo group experienced a significant reduction in sORP at rest (baseline 122.7 to 30d score of 95.7;  $p = 0.02$ ), while there were no statistically significant changes for any of the PFBC tested doses at rest. Therefore neither group experienced an increase in oxidative stress. Interestingly enough, the antioxidant capacity (cORP) was significantly improved over the course of the study at rest (~30 days) for all three tested doses of PFBC (250 mg: from 0.36 to 1.85;  $p = 0.026$ , 500 mg: from 0.27 to 1.09;  $p = 0.010$  and 1000 mg from 0.49 to 1.67;  $p = 0.005$ ), while there was no effect on cORP of placebo at rest (from 2.46 to 1.59;  $p = 0.377$ ), suggesting that the groups taking the supplement increased their antioxidant reserves.

In measuring the effects of the stressful run on oxidative markers and antioxidant capacity, two doses demonstrated statistical trends for enhancing antioxidant capacity (500 mg from 1.1 to 2.8;  $p = 0.064$  and 1000 mg 1.67 to 2.91;  $p = 0.058$ ), while there was no effect for placebo ( $p = 0.320$ ) or for the 250 mg PFBC ( $p = 0.928$ ).

Table 1 and 2 detail significant and trending data demonstrating enhancement of antioxidant activity and capacity (PFBC 500 mg,  $p =$

Biomarker	Dose of PFBC	Baseline Mean (SD)	30 Day Mean (SD)	% Change	Number of Responders	p value
sORP	0 mg (n = 8)	122.7 (23.0)	95.7 (4.0)	-22.00%	1	0.02
	250 mg (n = 7)	118.6 (18.5)	103.4 (16.5)	-12.80%	2	0.16
	500 mg (n = 7)	139.5 (25.2)	122.3 (32.8)	-12.30%	3	0.9
	1000 mg (n = 7)	110.1 (24.7)	109.1 (44.2)	-0.90%	3	0.96
cORP	0 mg (n = 8)	2.46 (2.11)	1.59 (.95)	-35.50%	2	0.377
	250 mg (n = 7)	0.36 (0.15)	1.85 (1.4)	416.70%	5	0.026
	500 mg (n = 7)	0.27 (0.21)	1.09 (0.67)	304.20%	7	0.01
	1000 mg (n = 7)	0.49 (0.35)	1.67 (0.85)	241.20%	7	0.005

**Table 1:** Signals and trending data of interest: Baseline to pre-run.

Biomarker	Dose of PFBC	Pre-Run Mean (SD)	Post-Run Mean (SD)	% Change	Number of Responders	p value
cORP	0 mg (n = 8)	1.60 (0.95)	1.03 (.90)	-35.63%	2	0.32
	250 mg (n = 7)	1.85 (1.40)	1.78 (1.15)	-3.78%	2	0.928
	500 mg (n = 7)	1.10 (0.67)	2.80 (2.07)	154.55%	7	0.064
	1000 mg (n = 7)	1.67 (0.85)	2.91 (1.32)	74.25%	6	0.058
IL-1beta	0 mg (n = 8)	6.2 (10.1)	5.9 (7.0)	-4.84%	4	0.96
	250 mg (n = 7)	3.3 (3.8)	3.3 (2.6)	0.00%	3	0.98
	500 mg (n = 7)	6.7 (6.2)	4.4 (3.5)	-34.33%	5	0.41
	1000 mg (n = 7)	3.9 (4.7)	2.1 (1.8)	-46.15%	3	0.37
IL-6	0 mg (n = 8)	1.8 (1.8)	2.6 (1.7)	44.44%	3	0.4
	250 mg (n = 7)	4.5 (5.6)	3.9 (3.5)	-13.33%	2	0.81
	500 mg (n = 7)	7.5 (11.2)	3.0 (1.8)	-60.00%	3	0.33
	1000 mg (n = 7)	4.7 (9.9)	3.9 (5.5)	-17.02%	4	0.84

**Table 2:** Signals and trending data of interest: Pre-run to post-run.

0.010, 1000mg,  $p = 0.005$ ) of the PFBC, while the placebo group experienced a negative impact ( $p = 0.02$ ).

### Brain biomarkers

There were no statistically significant effects of the placebo or any dose tested of the PFBC ( $p > 0.05$  for all) on BDNF during either of the study periods (over the initial 30 days or during the exercise intervention).

### POMS

There were no statistically significant effects of placebo or any of the PFBC doses tested on the total POMS score ( $p > 0.05$  for all), nor for any of the POMS-subset categories (Tension or Anxiety, Anger or Hostility, Vigor or Activity, Fatigue or Inertia, Depression or Dejection,

Biomarker	Dose of PFBC	Pre-Run Mean (SD)	Post-Run Mean (SD)	% Change	p value
POMS	0 mg (n = 8)	5.0 (4.4)	5.0 (4.2)	0.00%	1
Fatigue	250 mg (n = 7)	9.3 (3.4)	7.3 (3.7)	-21.51%	0.31
	500 mg (n = 7)	8.9 (5.9)	7.1 (6.4)	-20.22%	0.61
	1000 mg (n = 7)	6.7 (5.8)	3.9 (3.7)	-41.79%	0.3
POMS VIGOR	0 mg (n = 8)	23.0 (5.2)	24.0 (5.6)	4.35%	0.72
	250 mg (n = 7)	16.1 (7.1)	18.6 (5.7)	15.53%	0.49
	500 mg (n = 7)	16.7 (4.4)	18.0 (3.6)	7.78%	0.56
	1000 mg (n = 7)	18.6 (4.6)	22.7 (7.3)	22.04%	0.23

**Table 3:** Signals and trending data of interest- Baseline to end of study.

Confusion or Bewilderment categories). Profile of Mood States fatigue and vigor subsets were analyzed and results are noted in table 3.

### Microbiome

There were no statistically significant effects of placebo or any of the doses of PFBC tested on the microbiome over the course of the study ( $p > 0.05$ ) for the biome composite score as well as for *Bacterioidetes*, *Bifidobacterium*, *Lactobacillus*, butyrate kinase, *A. muciniphila* or *S. thermophilus*.

### Safety

Within the confines of this study, there were no observed safety concerns for any of the tested doses of PFBC. All doses of the PFBC tested appeared safe and tolerable.

### Discussion

The primary finding of this pilot exploratory study was that PFBC enhanced cORP at rest for all three doses tested over the initial 30 days, (250 mg: from 0.36 to 1.85;  $p = 0.026$ , 500 mg: from 0.27 to 1.09;  $p = 0.010$  and 1000 mg from 0.49 to 1.67;  $p = 0.005$ ), while there was no effect of placebo (from 2.46 to 1.59;  $p = 0.377$ ). This indicates enhanced overall antioxidant capacity or increased antioxidant reserves which would allow for a greater capacity to combat oxidative stress. Over the initial course of the study (30 days), the placebo group experienced a significant reduction in sORP (baseline 122.7 to 30d score of 95.7;  $p = 0.02$ ), while there were no statistically significant changes for any of the PFBC tested doses. This is challenging to interpret in the context of a small pilot study but it does show that neither group experienced an increase in oxidative stress at rest. This was an ideal scenario for the study design as it demonstrated that any change in oxidative stress after the run was due to the run and not present at rest or pre-run.

Two doses of the PFBC trended (statistical trend) towards enhancing antioxidant capacity after stressful exercise (500 mg from 1.1 to 2.8;  $p = 0.064$  and 1000 mg 1.67 to 2.91;  $p = 0.058$ ), while there was no effect for placebo ( $p = 0.320$ ) or for the 250 mg PFBC ( $p = 0.928$ ). The values may not have reached significance because of a small subject number. It is important to note that increased cORP indicates greater antioxidant reserve which would be beneficial when engaging in exercise that leads to oxidative stress. Therefore, future studies may provide more insight into this trend to explore the potential for PFBC to support the ability of the body to combat oxidative stress

such as would be induced by exercise.

Polyphenols are naturally occurring compounds found largely in the fruits, vegetables, cereals and beverages. They are secondary metabolites of plants and are generally involved in defense against ultraviolet radiation or aggression by pathogens. Fruits like grapes, apple, pear, cherries and berries, as well as the palm fruit can provide 200 mg or more polyphenols per serving [29]. The PFBC utilized in this study is comprised of protocatechuic and caffeic acids as well as catechins, 4-hydroxybenzoate, shikimic acid, and soluble fibers with many of these phytochemicals falling into the class of polyphenolic compounds [20,21]. Epidemiological studies have shown that the greater the polyphenol intake, the lower the incidence of chronic human diseases [30]. It is well established that polyphenol-rich foods and beverages may increase plasma antioxidant capacity. This increase in the antioxidative capacity of plasma following the consumption of polyphenol-rich food, or in the case here, after chronic ingestion of the PFBC, may be explained by several potential mechanisms. Potentially by the presence of reducing polyphenols and their metabolites in plasma, by their effects upon concentrations of other reducing agents which might spare the effects of polyphenols on other endogenous antioxidants, or by their effect on the absorption of pro-oxidative food components such as iron. In this study, the antioxidant capacity as well as the antioxidant potential was positively impacted by the PFBC, however the placebo group experienced a significant reduction ( $p = 0.02$ , table 1), demonstrating consistency with other studies on polyphenolic compounds [20,31,32]. Polyphenols are said to protect cell constituents against oxidative damage and, therefore, may also limit the risk of various degenerative diseases associated with oxidative stress over time [29]. The present study found evidence that PFBC from the palm fruit has antioxidant activity in healthy adults under free-living conditions and after stressful exercise. These findings deserve follow-up in future studies.

### Limitations of the Study

Limitations of this study include small number of subjects and lack of control for potential consumption of other antioxidants and overall diet and exercise habits. In addition, baseline fitness level was not accounted for which could impact the oxidative stress of the exercise bout whereby the less fit individuals might experience more oxidative stress. The exercise intensity was subjective and not controlled for this may have further impact on the results related to exercise stress. As this was a planned exploratory pilot proof of concept study, the limitations are noted. Future studies should consider addressing these issues.

### Conclusion

This study demonstrated that PFBC was safe and well-tolerated in the study population of healthy volunteers at doses up to 1000 mg/day for 30 days. PFBC supplementation at doses as low as 250 mg acted as an antioxidant in this population as demonstrated by its effects on sORP and cORP. Trends or signals towards improvement of outcomes of inflammation and other support the further study of PFBC as a dietary supplement that functions to promote the antioxidant defense system, impacts on immunity and inflammation for overall health.

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### Conflicts of Interest

The authors declare no conflict of interest. The authors received funding for writing the manuscript. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data, or in the writing of the manuscript.

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