

Full Length Research Paper

***Morinda citrifolia* L. (noni) improves athlete endurance: Its mechanisms of action**

'Afa K. Palu^{1*}, R. D. Seifulla² and Brett J. West¹¹Tahitian Noni International Research Center, American Fork, Utah 84003 USA.²Moscow Scientific and Practical Center of Sports Medicine, 105120, Moscow, Zemlyanoy Val St., 53

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The ability of noni juice to improve endurance in athletes was evaluated clinically. A placebo-controlled clinical trial with TAHITIAN NONI® Juice (TNJ) was conducted in 40 highly-trained athletes. Drinking 100 mL of TNJ twice daily increased endurance (time-to-fatigue) by 21%, and improved antioxidant status as measured by a 25% decrease in blood chemiluminescence. Chemical analyses by multiple laboratories and drug-urine screening of human volunteers reveal that TNJ does not contain any illegal drugs or substances prohibited by the World Anti-doping Agency. The collective results indicate that TNJ improves endurance via potent antioxidant effects. The results warrant human clinical trials to assess the dosages and the feasibility of using TNJ by athletes participating in strenuous sports such as football, rugby, ice hockey, soccer and basketball.

Key words: Noni, *Morinda citrifolia*, antioxidant, free radicals, endurance.

INTRODUCTION

Morinda citrifolia L. commonly known as noni, from the family Rubiaceae, has been used in Polynesia for over 2000 years for food, medicine and dyeing of traditional clothes. Its medicinal usage has been purported to include the amelioration of diabetes (*suka*), gout (*kauti*), high blood pressure (*toto ma'olunga*), cancer (*kanis* or *kahi*), boils (*hangat maki*), and other skin and internal ailments (Wang et al., 2001; Palu, 2004; Palu et al., 2008).

Traditionally, noni fruit juice was also consumed after a long voyage to help strengthen and restore vigor to the body (Thaman, 1990, 1992). Interestingly, the numbers of athletes who use TNJ as part of their nutritional regimen are growing, and include reports of increases in recovery time and endurance. However the mechanisms responsible for these effects have not been elucidated.

MATERIALS AND METHODS

Noni samples

In these studies the commercial Brand TAHITIAN NONI® Juice (TNJ) was obtained from the manufacturer (Tahitian Noni International, 737 East 1180 South, American Fork, Utah 84003 USA).

Endurance clinical trial

Forty volunteers (32 males and 8 females), who were highly-trained, middle- to long- distance runners (1500 - 10000 m), were enrolled in the study. Each participant received a pre-experimental medical examination, including ECG, heart rate, blood pressure, and other measurements.

The volunteers were divided into 2 groups of 16 males and 4 females each: a TNJ group, ages 18 - 27; and a placebo group, ages 19 - 26. Athletes assigned to the TNJ group consumed 100 mL of TNJ twice daily, 30 min before meals, for 21 days. Those in the placebo group consumed blackberry juice, following the same dose and consumption schedule as the TNJ group.

The endurance of all athletes was measured by a treadmill run with increasing workload (stepwise every min), until muscle fatigue (time-to-fatigue). The time-to-fatigue was measured pre-study and at day 21. Total protein, urea, glucose, hemoglobin, lactate, and other blood measurements were made at the same intervals. Additionally, super- weak chemiluminescence (counts per min, relative to baseline data) of unsaturated fatty acids (spontaneous chemiluminescence) was determined with an LKB chemiluminometer (LKB Instruments, Sweden), using an established protocol (Rozhkova et al., 2003). The chemiluminescence method measures photons emitted after the excitation of fatty acids that occurs during electron transfer. The data were analyzed by multivariate statistical methods.

Drug screen test

TNJ was evaluated in a pilot study consisting of 6 healthy adult volunteers (5 males and 1 female), with no recent history of drug

*Corresponding author. E-mail: afap@tni.com. Fax: 1 (801) 234-1030; Tel: 1 (801) 234-3624.

Table 1. Treadmill run-time-to-fatigue in min (mean \pm standard deviation).

Group	Pre-study	Day 21
Placebo	11.4 \pm 0.6	11.5 \pm 0.7
TNJ	12.1 \pm 0.9	14.6 \pm 0.9

*P < 0.05

Table 2. Relative blood chemiluminescence (counts per min) superweak spontaneous chemiluminescence (mean \pm standard deviation).

Group	Pre-study	Day 21
Placebo	97.3 \pm 6.3	108.1 \pm 7.7
TNJ	101.2 \pm 7.2	75.4 \pm 6.2*

*P < 0.05

abuse, and who each consumed 125 mL of TNJ daily. Urine samples were collected from the volunteers within 24 h. Each sample was tested for the presence of THC, benzoylecgonine, phenylethylamine, opiates, methamphetamines, methadone, amphetamines, barbiturates, benzodiazepines, and tricyclic antidepressants, using a RapidCheck® 10 Panel Drug Test immunoassay, according to manufacturer's instructions without modifications (Craig Medical Distribution, Vista, CA).

TNJ antidoping screening

TNJ was evaluated by three different agencies (ConsumerLab.com in the US, China Doping Control Center, and Anti-doping Center Moscow). Tests were conducted for the presence of more than 170 chemicals and compounds which are banned under the guidelines of the World Anti-doping Agency.

RESULTS

Endurance, antioxidant, and exercise performance effects of TNJ

Endurance test results (time-to-fatigue) are shown in Table 1, blood chemiluminescence is compared in Table 2, and banned substances are listed in Table 3. Endurance in the TNJ group was increased by 21%, after 21 days of supplementation. There was no change in any blood measurements of the TNJ group. Blood lactate did not increase in this group, indicating that the improved endurance was not due to increased energy consumption. Conversely, chemiluminescence decreased by approximately 25%, suggesting that the increased time-to-fatigue was achieved due to significant antioxidant activity. No allergic responses, or other side effects, were observed in those who drank TNJ. No significant changes in any measurements were observed in the placebo group, with the exception of an increase in blood lactate. Even though the increase suggests an increase in energy expenditure, no improvement in endurance occurred in

the placebo group.

TNJ drug screen test

No drugs or their metabolites were found in any of the urine samples collected from both female and male volunteers that consumed 124 mL of TNJ daily.

TNJ antidoping screening

ConsumerLab.com (2005) reported that TNJ passed its antidoping screening and that no banned substances (beta-blockers, diuretics, narcotics, anabolic steroids, stimulants or masking agents) were detected. Similarly, reports from Moscow Anti-doping Centre and China Doping Control Center verified that TNJ does not contain any of the banned substances listed by the World Anti-doping Agency.

DISCUSSIONS

A stream of research shows that high-intensity exercise generates and increases oxygen-free radicals and other reactive-oxygen species (ROS) (Duarte et al., 1993; Heunks et al., 1999; Ji, 1999; Oba et al., 2002; McNulty et al., 2004). This type of exercise contributes to an imbalance of the body's ROS, and its antioxidant defense (Ji, 1999). Further, heavy exercise results in an increase of blood-glutathione oxidation, a marker of oxidative stress in healthy subjects (Sastre et al., 1992; Gomez-Caberera et al., 2003).

TNJ's antioxidant effect was first discovered and reported by Wang and Su (2001), from in-vitro studies. This discovery brought a new perspective into the health benefits of noni, especially regarding its effect on increasing energy, recovery time, and endurance in athletes, part of which is attributed to its antioxidant property.

TNJ ergogenic effect was evaluated in mice indicating that TNJ increased the swimming time of mice (36 to 45%) before becoming fatigued, and increased their endurance time (59 to 128%) on a rotarod test, compared to the control. Further, the older mice in the TNJ group performed similarly to the younger ones in the control group, with respect to swimming time and endurance (Ma et al., 2007).

There has been some interest and concern regarding the composition of herbal and dietary supplements, and their possible influence on drug or doping tests (Winek et al., 1993; Markowitz et al., 2004). As the use of herbal dietary supplements increases, this issue is of paramount importance. A pilot clinical study revealed that TNJ has the potential to increase the ability of post-menopausal women to perform more vigorous activities (Langford et al., 2004). With these ergogenic effects in mind, TNJ was evaluated for the presence of any prohibited substances. An alkaloid screen of the juice was negative. An HPLC

Table 3. Banned substances not detected in TNJ*.

Stimulants and Related Compounds	Narcotics and Related Substances	Anabolic Agents and Related Substances
Amineptine [†]	Alphaprodine	Androstenediol
Amfepramone	urphine	Androstenedione
Amphetamine	Codeine	Bambuterol
Bambuterol	Diamorphine (heroin)	Boldenone
Benzphetamine	Dihydrocodeine	Clenbuterol
Caffeine	Hydrocodone	Clostebol
Cathine/Norpseudoephedrine	Hydromorphone	Danazol
Cocaine	Levorphanol	Dehydrochloromethyltestosterone
Diethylpropion [†]	Meperidine [†]	Dehydroepiandrosterone (DHEA)
Dimethylamphetamine	Methadone [†]	Dihydrotestosterone
Ephedrine	Morphine	Drostanolone
Etilamphetamine	Nalbuphine	Fenoterol
Fencamfamin	Oxycodone (oxycotin)	Fluoxymesterone
Fenfluramine	morpho	Formebolone
Fenproporex	Pentazocine	Formoterol
p-hydroxyamphetamine	Propoxyphene [†]	Gestrinone
Morazone	Tetrahydrocannabinol (THC)	Mesterolone
Mefenorex		Metandienone
Methamphetamine		Metenolone
p-methoxyamphetamine		Methandriol
Methylenedioxyamphetamine		Methyltestosterone
Methylephedrine		Mibolerone
Methylphenidate		Nandrolone
Nikethamide [†]		19-norandrostenediol
Norfenfluramine		19-norandrostenedione
Pemoline		Norethandrolone
Phenmetrazine		Oxandrolone
Phendimetrazine		Oxymesterone
Phentermine		Oxymetholone
Phenylephrine		Reproterol
Phenylpropanolamine		Salbutamol
Pholedrine		Salmeterol
Pseudoephedrine		Stanozolol
Selegiline		Terbutaline
Strychnine		Testosterone
Terbutaline		Trenbolone

based screen was also performed and detected no alkaloids at or above the detection limits of 1 mg/L. Xanthine alkaloids were of particular interest, as noni belongs to the coffee (Rubiaceae) family. Another assay, specific to caffeine, found none at a detection limit of 50 mg/L (Blauch and Tarka, 1983).

TNJ does not appear likely to produce false-positive results in the immunoassay-based urine drug screens. Blood analysis of the athletes in this study revealed that improved endurance was not related to increased energy consumption, but rather to other mechanisms. The ergogenic properties of TNJ are likely due to the nutritional properties of the fruit, and not to any known performance-enhancing compounds. These results are in agreement

with the earlier cited mice-test results of Ma et al., (2007).

Chemiluminescence is the phenomenon of light emission (or photon emission) from excited lipid-oxidation products in biological matrices (Boveris et al., 1980). In the past decade, this phenomenon has been used extensively for clinical investigations (Lyamina et al., 2003), and an indicator of oxidative stress (Costa et al., 1997). It

has also been used as an indicator of lipid peroxidation associated with heavy exercise (Rozhkova et al., 2003; de Souza et al., 2005). To assess the antioxidant effect of TNJ, chemiluminescence was measured in this study for all participants at the beginning, and again at the 21-day conclusion. A decrease of 25% ($P < 0.05$) in the lipid peroxidation was observed in the TNJ group whereas

Table 3 (cont.)

Diuretics and related substances	Masking Agents and Related Substances	Beta Blockers and Related Substances
Amiloride	Diuretics	Acebutolo [†]
Acetazolamide	Epitestosterone	Alprenolol [†]
Bendroflumethiazide	Probenecid	Atenolo [†]
Benzthiazide		Bunitolol
Bumetanide		Labetalol
Canrenone		Metoprolol [†]
Chlorothiazide		Nadolol
Chlorthalidone		Oxprenolol [†]
Cyclothiazide		Pindolol
Dichlorphenamide		Propranolol
Ethacrynic acid		Sotalol
Furosemide		Timolol
Hydrochlorothiazide		
Metolazone		
Methyclothiazide		
Polythiazide		
Quinethazone		
Spironolactone		
Triamterene		
Trichlormethazide/ Trichloromethiazide		

* Banned substance list available through ConsumerLab.com (2005)

† Indicates metabolites screened in addition to parent drug.

none occurred in the placebo group. As such, TNJ increased the antioxidant level in TNJ group by 25%.

In conclusion, TNJ has been shown to improve physical endurance through increase in antioxidant activity. The results of our study warrant more clinical research among athletes from basketball, ice hockey, football, rugby and soccer to further explore the benefits of using TNJ as part of their daily regimens.

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