Potential Tropical Fruits to Aid Sports Performance and its Prospect to be Developed into Nano supplement

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Abstract. The competition in sports is getting tougher, and the drives to achieve better result has led the athletes to indiscriminately use dietary supplements, including herbal ones. Fruits relatively can acts as a support in health and exercise thanks to its rich content of macro- and micronutrients, fiber, minerals, vitamin and a number of bioactive phytochemical components. The aim of this study is to review and gather information on tropical fruits which is capable to improve athlete’s performance and its prospect to be developed into nano supplement. This review examined online literatures via PubMed, Sciendirect, and Google Scholar. Based on the literatures, the exercise performance can be improved by various compounds found in tropical fruits such as banana, cherry, grape, pomegranate, and watermelon. Overall, tropical fruits can aid sports performance by improving physical strength, increasing the recovery in injury, attenuate muscle soreness, and reducing fatigue. It is suggested that there is possibility to apply nanotechnology to formulate fruits based sport supplement in the form of nanoparticles.

1. Introduction
The competition in sports is getting tougher, and the drives to achieve better result has led the athletes to indiscriminately use dietary supplements, including herbal ones. In 2004, an investigation held by the US Olympic Committee reported that 90% of athletes take some form of supplementation [1-2]. Most herbal supplements in sports can be classified either as adaptogens, suggested to a plant that increases adaptation to exercise-induced stress through nonspecific effects, or as ergogenic aids, referred to substances with performance-enhancing effects [3].

In recent years, there has been shifting focus of nutrition supplement usage from macronutrient (carbohydrate, lipid, fat) to micronutrient made of plants or herbal in the forms of whole fruit or extract. Fruits relatively can acts as a support in health and exercise thanks to its rich content of macro- and micronutrients, fiber, minerals, vitamin and a number of bioactive phytochemical components, such as...
phenolic compounds (e.g. anthocyanins, ellagitannins, resveratrol, and quercetin) [4]. Nutrition and vitamins play an important role in maintaining health, endurance practice, improving physical strength as well as forming muscle mass of athletes [5-6]. It also helps to increase the recovery in injury, attenuate muscle soreness, and reduce fatigue. Moreover, appropriate nutrition strategies may allow greater adaptations to the training stimulus, or to allow the same training adaptation with less training [7].

The development of nanotechnology has been a major concentration in the development of pharmaceutical products in recent years. Nanotechnology usage is able to improve the solubility and bioavailability of natural ingredients or extracts which tend to be difficult to dissolve in water. It also has advantages being able to form a very small particle size so it can reach the target cell better and able to penetrate the blood brain barrier. This has become a new breakthrough in drug delivery systems, especially drugs made from herbal products [8]. The aim of this study is to review and gather information on tropical fruits which is capable to improve athlete’s performance and its prospect to be developed into nano supplement.

2. The tropical fruits that can improve exercise performance

2.1. Banana
Bananas are among the world’s leading fruit crops, and are an important source of carbohydrate energy for people around the world. It is a rich source of carbohydrate, magnesium, potassium and cultivar-dependent phenolic compounds (e.g. epicatechin, galloatechin, gallic acid, protocatechuic acid). On average, bananas contains ~7 mg gallic acid equivalents, high levels of vitamin A, vitamin C and a broad range of carotenoids (e.g. lutein, zeaxanthin α-carotene and β-carotene) [9-11]. It has been reported that bananas has health related benefits for cancer, metabolism of cholesterol and related markers of cardiovascular disease risk [12-16].

Study conducted by Murdoch et al. (1993) comparing the effect between different carbohydrate food form on endurance performance during exhaustive exercise bouts [17]. Eight highly trained male triathletes performed tests consisted of 90 min run followed by 90 min of cycling at 70% VO2max, which then gradually increased on the cycle, and continued to cycle until the subjects exhausted. They then rested for 20 min and ingested either one of sweetened placebo drink, slurried bananas, or solid bananas in equal portions relative to each subject’s body weight. The blood glucose concentration on both banana treatment increased significantly higher than placebo. It demonstrated that bananas are effective in maintaining plasma glucose, the predominant carbohydrate energy source, and that possibly enhancing endurance exercise performance because a decline in plasma glucose during exercise is associated with fatigue [17].

Other study by Nieman et al. (2015) examined the difference of consuming water, bananas, or pear, as much as 0.6 g carbohydrate/kg/hour, on 20 male athletes during 75 km cycling. The performance of those ingested bananas and pear increased by 5.0% and 3.3% faster vs. water with reductions in cortisol, IL-10, total leukocytes, and increases in blood glucose, insulin, and FRAP [18]. Further, Miller et al. (2012) examined the effect of ingesting 0 g, 150 g (1 serving), 300 g (2 servings) of bananas after 60 minutes of moderate to vigorous cycling in the heat on nine euhydrated man [19]. The results indicated a greater potassium level after 2 servings (4.6 ± 0.3 mmol/L) than those of 1 serving (4.5 ± 0.2 mmol/L) and 0 serving (4.4 ± 0.3 mmol/L) with a similar response for plasma glucose changes. The effect of banana ingestion on exercise-associated muscle cramps (EAMCs) is unknown, but the data suggested that bananas are unlikely to relieve EAMCs by increasing extracellular potassium or plasma glucose [19].
2.2. Cherry

Hundreds of different cherry species are categorized into two groups: Corymb (Prunus avium L. “sweet cherries” and Prunus cerasus L “tart cherries”) and Racemosa [20]. Sweet and tart cherries are characterized by their simple sugar content (e.g. fructose and glucose) and the presence of malic acid within tart cherries. Overall, cherries contain water and fat-soluble vitamins, β-carotene, calcium, magnesium, phosphorous, and potassium and despite flavor differences, both contain a variety of phenolic compounds that include various cyanidins, hydroxycinnamates, procyanidins, and flavonols [20]. Tart cherries are considered a great natural source of numerous phytochemicals (e.g. anthocyanidins and antocyanins) and other phenolic compound (e.g. catechins and quercetins) with high levels activity of antioxidant and anti-inflammation [21].

Howatson et al. (2010) conducted a study to investigate the influence of tart cherry juice on indices of recovery following marathon running. Twenty runners were given cherry juice or placebo 5 days prior, the day of and 48 hour after a marathon run. It was observed significantly faster recovery of isometric strength in cherry juice group as well as reduction of inflammation and greater total antioxidant status. It is appears that cherry juice provide means to aid recovery by increasing total antioxidative capacity, reducing inflammation, and lipid peroxidation [22]. Kuehl et al. (2010) held a randomized controlled trial on fifty-four healthy runners where the participants consumed 355 mL of tart cherry juice or placebo twice daily prior and on the day of the running event. Results reported a significantly lower pain in the cherry juice group vs. placebo [23]. Other finding also suggested a lower inflammation 24 hour and 48 hour post marathon in cherry juice group among twenty runners who consumed cherry juice or placebo [24].

A crossover trial was done on ten well-trained athletes performing knee extension maximum voluntary contractions (MVC). Participants consumed CherryActive supplement or iso-energetic fruit concentrate for 7 days before and 48 hour after exercise. It was reported that the cherry treatment group has significantly faster MVC force recovery than those of iso-energetic fruit concentrate [25].

2.3. Grape

Grapes are a good source of carbohydrate in the forms of fructose and glucose. It is also rich phenolic compounds, such catechin, epicatechin, quercetin, tannins, and resveratrol that possess high antioxidant, anti-inflammatory, and platelet inhibitory activities [26]. Consumption of grape also shown to improve blood pressure control, endothelial function, reduce LDL cholesterol oxidation [27].
Lafay et al. (2009) performed a study involving twenty elite sportsmen consisted of 10 handball, 5 basketball, 4 sprint and 1 volleyball players that were administered with 400 mg/day grape extract during competition period. After 30 days, the results showed a 9.5% increase in subject’s antioxidant capacity and improvement in physical performance during competitive season. It has also been noted, that grape extract administration after 30 days reduced plasma creatine phosphokinase concentration and increased haemoglobin levels, suggesting that grape extract administration might protect cell damage during exercise [28]. Study by Toscano et al. (2015) also reported a significant increase (15.3%) in running time-to-exhaustion as well as an increase in total antioxidant capacity (38.7%) on 15 runners who received 10 mL/kg/day grape juice for 28 days compared to 13 runners who received an isocaloric, isoglycemic, and isovolumetric control beverage [29]. It has also been reported that ingesting organic grape juice improved glucose homeostasis, antioxidant capacity, and microvascular function [30].

2.4. Pomegranate

Pomegranates has been used as a natural medicine in many cultures as it has several health benefits, due to its rich source of polyphenols and other biologically active compounds (e.g. flavanols, flavonoids, gallic acid, ellagic acid, quercetin, ellagittannins, and nitrate) [31]. Pomegranates can help prevent of treat various disease risk factors ranging from high blood pressure, high cholesterol, oxidative stress, hyperglycaemia, to inflammatory activities [32]. It is also shown to reduce free radicals, oxidative stress, and lipid peroxidation [33].

In 2010, Trombold et al. investigated the effects of ingesting pomegranate extract in a randomized crossover study on sixteen healthy active males. During 9 days testing period, participants were given either 650 mg pomegranate extract or placebo on each period with 14 days of washout period. Following resistance training consisted of two sets of 20 maximal eccentric elbow flexion exercises with one arm, it was found that strength recovery was significantly higher in pomegranate extract vs. placebo at 48 hour (85.4% ± 2.5% and 78.3% ± 2.6%, P = 0.01) and 72 h (88.9% ± 2.0% and 84.0% ± 2.0%, P = 0.009) [34]. In another randomized crossover study, seventeen resistance trained men were administered 250 ml of pomegranate juice or placebo twice daily at 12-hour intervals for 15 days. Participants then performed 3 sets of 20 unilateral eccentric elbow flexion and 6 sets of 10 unilateral eccentric knee extension. Results reported that participants with pomegranate juice had significantly higher strength and lower muscle soreness in the elbow flexion compared to placebo, although no significant difference were observed in the knee extensors. It is suggested that pomegranate juice promotes a mild, acute ergogenic effect [35].

Recent study on the effects of consuming pomegranate was conducted by Ammar et al. (2016) on nine weightlifters who performed Olympic style lifting following administration of either natural pomegranate juice or placebo. Participants who drank pomegranate juice shown higher performance (+8.30%) and lower RPE values (-4.37%), in addition to reducing the acute increase of systolic blood pressure, heart rate, creatine kinase and lactate dehydrogenase after 3 minutes of intense exercise [36]. Moreover, Ammar et al. (2017) have also reported that among nine elite weightlifters, who consumed pomegranate juice before performing two Olympic-Weightlifting sessions, shown to reduces the increase in malondialdehyde and improved the enzymatic reactions of catalase (+8.6%) and glutathione peroxidase (+6.8%), along with non-enzymatic of uric acid (+12.6%) and total bilirubin (+5.7%) shortly
3 minutes after training session compared to those consumed placebo. Further, pomegranate juice also promotes the acceleration recovery kinetics of the malondialdehyde (5.6%) and the enzymatic antioxidant defences compared to placebo [36].

![Figure 4. Pomegranate (Punica granatum)](image4)

2.5. Watermelon

Consumption of watermelon has been reported to be beneficial for health, such as a drop in blood pressure, cardiovascular disease, reduction in certain types of cancers, and some age-related degenerative pathologies [37-38]. Watermelon extract supplementation containing L-citrulline/L-arginine 6g daily for 6 weeks was reported to reduces ankle and brachial blood pressure and carotid wave reflection in obese middle-aged adults with pre- or stage 1 hypertension and normal ankle-brachial index, which can be expected to improved arterial function [37].

Watermelon is a fruit rich in natural L-citrulline, an amino acid which is great in helping to reduce physical soreness. A study by Tarazona-Diaz et al. (2013) reported that consuming 1.17 g L-citrulline contained in 500 mL watermelon juice can help reducing muscle pain 24 hour after exercise [39]. Another study by Martinez-Sanchez et al (2017) shown that there was a significant decrease of muscle pain on 21 male runners 24 hour after they consumed 500 ml watermelon juice 2 hour before performing two half-marathon races [40]. Shanely et al. conducted a study to compare the difference of consuming two weeks of watermelon puree (980 mL/day and 0.2g/kg carbohydrate with 1.47 g L-citrulline, 0.465 g L-arginine) vs. a 6% carbohydrate beverage during a 75 km cycling time trial. Results reported similar pattern of increase in blood glucose and blood lactate in either group, but there was a slight improvement of ratings of perceived exertion and greater perfection of fullness, followed by a greater increase in post-exercise plasma antioxidant capacity [41].

![Figure 5. Watermelon (Citrullus lanatus (Thunb.) var. lanatus)](image5)
3. The application of nanotechnology

The utilization of herbal as drugs tend to have a set of drawbacks, that is low solubility and low bioavailability substance, as well as requires higher amount or dose because of its conventional use. Those weakness can be overcome by applying nanotechnology and form it into a better herbal dosage form [42]. Preparations in the form of nanoparticles is able to increase the solubility, bioavailability, and stability of active substances. Nanoparticles size ranging from 20-200 nm, depending on the materials and method used in their manufacture. Smaller particle size will increase the surface area of the preparation, as well as facilitate easier transport of active substances into hard to reach action sites, such as blood brain barrier, and enable it to penetrate through cell and other cell membranes as its target of action. The application of nanotechnology has become a great innovation of a more sophisticated form of drug delivery system [43-46].

Study conducted by Liu et al. (2016) has formed Panax Notoginseng Saponin (PNS) into nanoemulsion dosage form with average particle size of 28.17 ± 0.39 nm. PNS has anti-inflammatory and anti-fatigue activity derived from Ginsenoside Rb1 and Rg1. Nanoemulsion has better oral bioavailability up to 2.58 fold and more optimal pharmacological effects compared to conventional dosage form. In an in vitro study, PNS nanoemulsion is reported to be able to extend drug delivery time, along with having better stability and longer storage period up to 6 months [47].

Another study by Hao et al. (2016) formed PNS into liposome dosage form. This drug delivery system has lipid bilayer vesicles which resembles human biological membrane. Liposome uses phospholipid as bases and enable it to bind active substances with low solubility in water. Moreover, liposome can improve active substances absorption in the body and also protects it from gastrointestinal fluid or enzyme to avoid first phase effects [48].

The results of the two studies suggested that it is possible to apply nanotechnology to formulate fruits based sport supplement in the form of nanoparticles. It is assumed that the tropical fruits reviewed in this article are also possible to be formulated as nano supplements.

4. Conclusion

There are many tropical fruits that can be used as sport nutrition such as banana, cherry, grape, pomegranate, and watermelon. Those fruits are assumed to have the possibility to be developed as sport supplement in the form of nanoparticles that possess many advantages to aids athletes in training or even competition.

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References

[1] Collins R and Kalman DS 2015 Nutritional Supplements in Sports and Exercise (pp. 3-21). Springer, Cham.
[2] Williams M, Anderson D, Rawson E, 2012 In: Nutrition for Health, Fitness & Sport, tenth ed. McGraw-Hill Education, New York, NY.
[3] Bailey S J, Vanhatalo A, Winyard P G and Jones A M 2012 Eur. J. Sport. Sci. 12 4 309-320
[4] Naderi A., Rezaei S, Moussa A, Levers K and Earnest CP 2018 Trends Food Sci. Technol 74 85-98.
[5] Rodriguez N R, Di N M and Langley S 2009 Med Sci Sports Exerc 3 41 19225360
[6] Phillips SM, Tang JE and Moore DR, 2009 J. Am. Coll. Nutr. 4 28.
[7] Maughan R 2014 Encyclopedia of Human Nutrition.
[8] Pandey A and Pandey G 2013 Plant Archives 2 13.
[9] Borges C V, de Oliveira Amorim V B, Ramlov F, da Silva Ledo C A, Donato M, Maraschin M and Amorim EP 2014 Food Chem 14 496-504.
[10] Mattila P, Hellström J and Törrönen R 2006 J. Agric. Food Chem 19 54
[11] Wall MM 2006 *J Food Compos Anal* **19** 5.
[12] Marangoni F and Poli A 2010. *Pharmacol. Res* **3** 61.
[13] Oliveira L, Evtuguin DV, Cordeiro N, Silvestre AJ, Silva AM and Torres IC *J. Agric. Food Chem* **7** 54.
[14] Ortega RM, Palencia A and López-Sobaler AM 2006 *Br. J. Nutr.* **1** 96.
[15] Quílez J, García-Lorda P and Salas-Salvado J 2003 *Clin Nutr* **4** 22.
[16] Villaverde JJ, Oliveira L, Vilela C, Domingues RM, Freitas N, Cordeiro N, Freire CS and Silvestre AJ 2013 *Ind Crop Prod* **42** 507-512.
[17] Murdoch SD, Bazzarre TL, Snider IP and Goldfarb AH 1993 *Int. J. Sport. Nutr. Exerc. Metab.* **1** 3
[18] Nieman DC, Gillitt ND, Sha W, Meaney MP, John C, Pappan KL and Kinchen JM 2015. *J Proteome Res* **12** 14.
[19] Miller KC 2012 *J. Athl. Train*, **47**(6), pp.648-654.
[20] Ballistreri G, Continella A, Gentile A, Amenta M, Fabroni S and Rapisarda P 2013 *Food Chem* **4** 630-638.
[21] McCune LM, Kubota C, Stendell-Hollis NR and Thomson CA 2010 *Crit. Rev. Food Sci. Nutr* **1** 51
[22] Howatson G, McHugh MP, Hill JA, Brouner J, Jewell AP, Van Someren KA, Shave RE and Howatson SA 2010 *Scand J Med Sci Spor.* **6** 20.
[23] Kuehl KS, Perrier ET, Elliott DL and Chesnutt JC 2010. *J Int Soc Sports Nutr.* **17**
[24] Dmitriou L, Hill JA, Jehnali A, Dunbar J, Brouner J, McHugh MP and Howatson G 2015 *J Int Soc Sport Nutr* **12** 22.
[25] Sumners DP, Dyer A, Fox P, Mileva KN and Bowtell J 2011 Montmorency cherry juice reduces muscle damage caused by intensive strength exercise.
[26] Burin VM, Ferreira-Lima NE, Panceri CP, Bordignon-Luiz MT 2014 Biochem. J. 114 155-163.
[27] Dávalos A, Fernández-Hernando C, Cerrato F, Martínez-Botas J, Gómez-Coronado D, Gómez-Cordovés C and Lasunción MA 2006. *Nutr. J.* **7** 136
[28] Lafay S, Jan C, Nardon K, Lemaire B, Ibarra A, Roller M, Houvenaeghel M, Juhel C and Cara L 2009 *J Sport Sci Med.* **3** 8
[29] Toscano LT, Tavares RL, Toscano LT, Silva CS, Almeida AE, Biasoto AC, Gonçalves Mda C and Silva AS 2015 *Appl Physiol Nutr Metab* **4** 899-906
[30] Gonçalves MC, Bezerra FF, Eleutherio E C, Bouskela E and Koury J *Clinics* **66** 1537-1541.
[31] Sreekumar S, Sithul H, Muraleedharan P, Azeez JM and Sreeharshan S 2014 *BioMed Res. Int.* **2014**.
[32] Zarfeshany A, Asgary S and Javanmard SH 2014 Adv. Biomed. Res. **3** 100.
[33] Kelawala NS and Ananthanarayan L 2004 *Int. J. Food Sci. Nutr.* **6** 55.
[34] Trombold JR, Barnes JN, Critchley L and Coyle EF 2010 *Med Sci Sports Exerc* **3** 42 493-498.
[35] Trombold JR, Reinfeld AS, Casler JR and Coyle EF 2011 *J. Strength Cond. Res.* **7** 25.
[36] Ammar A, Turki M, Chourou H, Hammouda O, Trabelsi K., Kallel C, Abdelkarim O, Hoekelmann A, Bouaziz M, Ayadi F and Driss T 2016 *PloS one* **10** 0160305.
[37] Figueroa A, Sanchez-Gonzalez MA, Wong A and Arjmandi BH 2012 *Am. J. Hypertens.* **6** 25.
[38] Tili I, Hidier C, Lenucci MS, Ilahy R, Jebri H and Dalessandro G 2011 *J. Food. Compos. Anal.* **7** 24 923-928.
[39] Tarazona-Díaz MP, Alacid F, Carrasco M, Martínez I and Aguayo E 2013 *J. Agric. Food Chem* **3** 61.
[40] Martínez-Sánchez A, Ramos-Campo DJ, Fernández-Lobato B, Rubio-Arias JA, Alacid F and Aguayo E 2017 *Food Nutr. Res.* **1** 61 1330098.
[41] Shanely R, Nieman D, Perkins-Weazie P, Henson D, Meaney M, Knab A and Cialdell-Kam L 2016 *Nutrients* **8** 8
[42] Mukherjee PK, Harwansh RK and Bhattacharyya S 2015 *Evidence-Based Validation of Herbal Medicine* (pp. 217-245). Elsevier.
[43] Alexander A, Patel RJ, Saraf S and Saraf S 2016 J. Control. Release 241 110-124.
[44] Harwansh RK, Patra KC and Pareta SK 2011 Int. J. Drug Deliv. 2 3
[45] Harwansh RK, Patra KC, Pareta SK, Singh J and Rahman MA 2011 Braz. J. Pharm. Sci 4 47
[46] Porter CJ, Pouton CW, Cuine JF and Charman WN 2008 Adv. Drug Deliv. Rev. 6 60.
[47] Liu Z, Zhang Q, Ding L, Li C, Yin Z, Yan G, Pi J, Li J, Li N and Qi D 2016 Curr. Drug Deliv. 4 13.
[48] Hao F, He Y, Sun Y, Zheng B, Liu Y, Wang X, Zhang Y, Lee RJ, Teng L and Xie J 2016. Saudi J. Biol. Sci 1 23