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THE UTILISATION OF *OPUNTIA FICUS INDICA* AS FUNCTIONAL FOOD AND IMPROVEMENT OF ATHLETES' PERFORMANCES

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Abstract: *An increased consumer awareness about health and wellness has shifted the consumers' interest towards healthy eating, preventive care, and secondary source medication. These factors together have led to the exponential growth in the functional beverages market. The dietary intake of compounds aimed for human consumption from Prickly pear cactus (Opuntia ficus-indica) have been studied for decades because of their beneficial and protective effects on different chronic diseases such as cancer, diabetes mellitus and cardiovascular disease due to their antioxidant properties to reduce inflammation caused by oxidative stress. Exercise capacity is frequently reduced in people living with chronic diseases. Having a fundamental knowledge of how exercise affects insulin and blood glucose especially in athletes' performances and how to manage these patients is important. The findings of this review represent that Opuntia spp. products have tremendous reductions in serum glucose and insulin, indicating potential as a functional food candidate. This review also provides experimental evidences about the most important phytochemicals and antioxidants that contribute in order to give the basis of their use in the prevention and cure of some chronic diseases.*

Keywords: *Antioxidant, Cactus pear, Opuntia, Chronic diseases, Glucose, Insulin, Prickly pear*

INTRODUCTION

Presently, consumers are becoming increasingly interested in valuing functional food products that have good high-quality attributes (sensory appearance, flavour and texture) and a reassurance that the food has only had contact with safe natural product materials (Silva, A. M., Albuquerque G. T., Pereira, P., Ramalho, R., & Costa, S. H., 2019). Functional plant-derived components are secondary plant metabolite biomolecules that occur in food which possess the capacity to modulate one or more metabolic processes or pathways in the body, prevention of certain diseases and disorders, potentially resulting in the increased health benefits and promotion of well-being (Faustino, M., Veiga, M., Sousa, P., Costa, E. M., Silva, S., & Pintado, M., 2019). These relatively low-cost, plant–based foods with antioxidant activity to manage certain non-communicable diseases, such as diabetes mellitus (especially type 2 diabetes mellitus – T2DM), may show tremendously protective results for the human health (Gouws, C. A., Georgousopoulou, E. N., Mellor, D. D., McKune, A., & Naumovski, N., 2019; Lu, D., Che, J., Yarla, N.S., Zhu, H., Lu, T., Xu, B., & Putta, S., 2018).

The prickly pear (Opuntia ficus indica, belonging to the Cactaceae family) contains the juicy flesh and a number of small seeds. It has high fibre content, potentially indicating that its consumption might have health benefits such as in weight control, as well as lowering glucose and cholesterol levels (Belviranlı, B., Al-Juhaimi, F., Özcan, M. M., Ghafoor, K., Babiker, E. E., & Alsawmahi, O. N., 2019). The cladode can be used for treating patients with T2DM. It reduces postprandial blood glucose, serum insulin and plasma (gastric inhibitory polypeptide) GIP peaks, as well as increasing antioxidant activity in healthy people (López-Romero, P., Pichardo-Ontiveros, E., Avila-Nava, A., Vázquez-Manjarrez, N., Tovar, A. R., Pedraza-Chaverri, J., & Torres, N., 2014). Moreover, novel functional foods such as probiotic beverages are crucial for

enhancing athletes' physical and psychological health and wellbeing (Pumpa, K. L., McKune, A. J., & Harnett, J., 2019). Fortified food with creatine, proteins, electrolytes, carbohydrate solutions and ascorbic acid (Margaritis, 2019), suggest that it can have a positive impact on athletic performance. Some subjects tempted to use fortified foods or dietary supplements are increasing the intakes of vitamins or minerals involved in various physiological functions, such as "bone capital," "lean mass gain," "immunity," in a more general way with no resultant deficiency (Pumpa, K. L., McKune, A. J., & Harnett, J., (2019).

If the athletes with T2DM would be competing and exercise with similar intensity and duration to that of actual competition, they must consume functional food and on days of less activity or off-season, the athlete may need more insulin, less food or a combination of the two to achieve adequate control (Yurkewicz, M., Cordas, M., Zellers, A., & Sweger, M., 2017).

EXPOSITION

Functional components have been defined as non-conventional molecules that can be found or applied in food and have the ability to change numerous of metabolic pathways in the human body which results in improving the health condition (Liguori, G., Gentile, C., Gailo, R., Perrone, A., Guarcello, R., Francesca, N., Fretto, S., Inglese, P., & Settanni, L., 2019). Therefore, at various stages of some non-communicable diseases related to various progressive steps from the disease's initiation to its development, the functional components have health-promoting roles and can be effectively applied for the treatment and prevention of diseases (Abuajah, I. C., Ogbonna, C. A., & Osulj, M. C., 2015).

Functional foods are well known as traditional food or a food product that has been enriched and transformed in order to optimise its nutritional characteristics and increase the human health status (Venkatakrishnan, K., Chiu, F. H., & Wang, K. C., 2019). They present the fastest growing food sector because of the consumers' increasing demand for healthy food (Sanguansri, L., & Augustin, M. A., 2010). It has been proved that nutraceuticals (bioactive components from animal and plant origin) can be part of the food product, they are able to directly influence the promotion of health components and rise the nutritional value of the food (Daliu, P., Santini, A., & Novellino, E., 2019). The in vivo efficacy of functionalizing agents depends on the doses added to the foods and the food matrices might affect the stability and bioavailability of the bioactive compounds. In contrast, plant extracts could affect food sensory characteristics producing undesirable odours as well as negatively affecting the final sensory characteristics of the product (Liguori, G., Gentile, C., Gaglio, R., Perrone, A., Guarcello, R., Francesca, N., & Settanni, L., 2019).

Based on the literature, it has been proved a strong relationship between functional components in food, health and well-being (Gaglio, R., Gentile, C., Bonanno, A., Vintaloro, L., Perrone, A., Mazza, F., Barbaccia, P., Settanni, L., & Di Grigoli, A., 2019). Plethora of examinations revealed that functional foods have a crucial part for managing the T2DM in human trials (Alkhatib, A., Tsang, C., Tiss, A., Bahorun, T., Arefanian, H., Barake, R., Khadir, A., & Tuomilehto, J., 2017). Presently, on the market different types of functional beverages and foods can be found, including dairy-based beverages, vegetable and fruit-based beverages, sports drinks, energy drinks, tea and tea-based beverages, and whey and soy proteins-based beverages (Nazir, M., Arif, S., Khan, S. R., Nazir, W., Khalid, N., & Maqsood, S., 2019). According to Venkatakrishnan, K., Chiu, H. F., & Wang, C. K., (2019), the novel functional foods and beverages can be formulated and enhanced with antioxidant components from some plants (green tea, rosemary, resveratrol, essential oils) for instance, polyphenols as a result to their therapeutic potential against T2DM. Noteworthy, the polyphenols are not well-known only by their antioxidant activities. They can directly or indireclty influence the signal transduction pathways related to the disease process (Törrönen, R., McDougall, G. J., Dobson, G., Stewart, D., Hellström, J., Mattila, P., Karjalainen, R., 2012).

The daily intake of great amount of functional foods which are a great source of flavonoids and minerals (fruits, vegetables, whole grains, nuts and fruits) combined with some

lifestyle changes can control the body weight and effectively prevent from T2DM developing (Shastun, S., Chauhan, A. K., Singh, R. B., Singh, M., Singh, R. P., Itharat, A., De Meester, F., Wilson, D., & Halabi, G. 2016). In one randomized study (PREDIMED) conducted over a period of 4 years, with 418 nondiabetic participants it has been proven that only 11 % of the participants who were using Mediterranean diet, predominantly with olive oil and nuts, became diabetic, in comparison with those participants consuming only low-fat diet, where 17.9 % ot them developed diabetes. The Mediterranean diet had decerased the rise of T2DM by 52 % (Maheshwari, A., Saboo, B., Singh, R. B., Verma, N., Vargova, V., Pella, D., & Pella, D., 2019).

In this era of fast paced world, diabetes has become a widespread epidemic, primarily because of the increasing prevalence and incidence of type 2 diabetes mellitus (T2DM) (Papier, K., D'Este, C., Bain, C., Banwell, C., Seubsman, S., Sleigh, A., & Jordan, S., 2017). The prevalence of type 2 diabetes mellitus (T2DM) is rapidly amplifying, which has contributed to an incersed number of T2DM patients and predicted that the number will rise to almost 439 million worldwide by 2030 (Mortensen, S. P., Winding, K. M., Iepsen, U. W., Munch, G. W., Marcussen, N., Hellsten, Y., Pedersen, B., Baum, O., 2019). Due to dysfunction and failure of various organs, especially the heart and peripheral blood vessels, despite all non-communicable diseases only of diabetes around 1.6 million people are dead (López-Romero, P., Pichardo-Ontiveros, E., Avila-Nava, A., Vázquez-Manjarrez, N., Tovar, A. R., Pedraza-Chaverri, J., & Torres, N., 2014). Conseguently, insulin resistance and b cell dysfunction are contributing factors to the disease, which are environmentally influenced and depend of the genetic factors. Most importantly, the prevalence of obesity and inactive lifestyle are also key contributors to the rising prevalence of T2DM throughout the world (Hassan, A., Perveen, A., Bhardwaj, U., & Sana-Ur-Rehman., 2019).

Over the last decade, regarding the low costs, fewer side effects, acceptability, antioxidant/free radical pathways based on hyperglycemia being associated with mitochondria overproduction of free radicals, the plant-based medicines, herbs and anti-hyperglycemic functional foods have become incresinlgy popular (Chandalia, M., Garg, A., Lutjohann, D., Von Bergmann, K., Grundy, S. M., & Brinkley, L. J., 2000). Owing to the high fibre content (slowing the rate of digestion) of many of the functional foods, including *Opuntia ficus indica – cacti,* they showed a tremendous anti-hyperglycaemic effect and the resultant altered rate of glucose absorption (Gouws, C. A., Georgousopoulou, E. N., Mellor, D. D., McKune, A., & Naumovski, N., 2019).

*Opuntia ficus indic*a commonly known as prickly pear is a greatly utilized plant product from the *Plantae* kingdom and *Cactaceae* family which grows in different dry and semi-dry places such as Mexico, Morocco, Tunisia, Eritrea, Ethiopia, Argentina, Peru, Bolivia, Brazil, the United States, Spain, Italy, Israel, Iran, and South Africa (Nharingo, T., & Moyo, M., 2016). *Opuntia* has been represented with different names regarding the place or region where it has been cultivated (in Spain this plant is called *chumberra*, in Italy – fico d'Indica, in Australia, Africa and United States is renamed prickly pear), four parts including root, stem, fruit and flower, broad range of colour (yellow, orange, red, and purple) and is sweet and juicy, full of pulp and mucilage with diff erent skin thicknesses (Salehi, E., Emam-Djomeh, Z., Askari, G., & Fathi, M. 2019).

Opuntia ficus indica has been used for centuries as a food resource and in traditional folk medicine for its nutritional characteristics and healing benefits, particularly in diabetes. Therefore, its fruits and stems, were investigated in the prevention and cure of chronic diseases (López-Romero, P., Pichardo-Ontiveros, E., Avila-Nava, A., Vázquez-Manjarrez, N., Tovar, A. R., Pedraza-Chaverri, J., & Torres, N., 2014). Based on the chemical composition the *Opuntia Ficus Indica* clodode contains water, charbohydrates, fibre, proteins, with 90 %, 5 %, 2 %, 0.5%, respectively (Osuna-Martínez, U., Reyes-Esparza, J., & Rodríguez-Fragoso, L., 2014). The sugar moiety includes mucilaginous components containing polymers, such as chains of (1-4)-linked β-D-galacturonic acid and R(1-2)-linked L-rhamnose residues (Lee, E. H., Kim, H. J., Song, Y. S., Jin, C., Lee, K. T., Cho, J., & Lee, Y. S., 2003). Its physiological role is to manage the

cellular water content troughout prolonged drought and to regulate the calcium fluxes of the plant (Hernández-Urbiola, M. I., Pérez-Torrero, E., & Rodríguez-García, M. E., 2011). The ascorbic acid, fibres, free amino acids (glutamine, taurine, and proline), betalain (natural colourant in the food industry), represent the nutritional value of the cactus pear fruit (Jimenez-Aguilar, D., Mujica-Paz, H., & Welti-Chanes, J., 2014).

In addition, *Opuntia ficus indic*a has been recognized as a great source of (poly)phenols, predominating flavonoids as isorhamnetin, kaempferol and quercetin derivatives, as well as phenolic acids like piscidic and eucomic acids, mainly in young cladodes, which are the preferred ones for human consumption and that have higher amount of (poly)phenolic compounds and therefore a higher antioxidant activity than the old cladodes (De Santiago, E., Gill, C. I. R., Carafa, I., Tuohy, K. M., De Peña, M. P., & Cid, C., 2019). The *Opuntia ficus indica* leaves - cladode and select *Opuntia ficus indica* products predominately demonstrated significant reductions in serum glucose and insulin, showing that they are potential functional food candidate (Gouws, C. A., Georgousopoulou, E. N., Mellor, D. D., McKune, A., & Naumovski, N., 2019).

As an exapmle, cladodes powder was proposed as ingredient for fortified milk-based drinks, cereals, and bakery products (Del Socorro Santos DIáz, M., Barba De La Rosa, A. P., Héliès-Toussaint, C., Guéraud, F., & Nègre-Salvayre, A., 2017). Additionally, bread enriched with *O. ficus-indica* cladodes, by substitution of wheat flour with 5% of the whole cladodes powder illustrated an acceptable sensorial attribute, and it also showed increased total phenolics content and antioxidant potential with respect to control bread (Liguori, G., Gentile, C., Gailo, R., Perrone, A., Guarcello, R., Francesca, N., Fretto, S., Inglese, P., & Settanni, L., 2019). There is still a confusion as to which component of the *Opuntia ficus indica* has demonstrated anti-hyperglycemic efects or anti-diabetic properties. It is important to clarify these health benefits due to the increasing need for prevention and treatment of chronic diseases (Gouws, C. A., Georgousopoulou, E. N., Mellor, D. D., McKune, A., & Naumovski, N., 2019). Based on the literature, *Opuntia ficus indic*a is usually acceptable and cannot cause side effects if consumed modestly, however, it has been investigated that it may may cause mild diarrhea, nausea, increased stool volume, increased stool frequency, abdominal fullness, and headache and low colonic obstruction (Osuna-Martínez, U., Reyes-Esparza, J., & Rodríguez-Fragoso, L., 2014). On behalf of heavy metals (lead, mercury, arsenic) and other undeclared pharmaceuticals, which are illegaly added, it can lead to contamination of the *Opuntia ficus indica*. Furthermore, factors that might also affect the content of active constituents in this product may include microorganisms, microbial toxins, and genetic factors (Gagnier, J. J., Boon, H., Rochon, P., Moher, D., Barnes, J., & Bombardier, C., 2006).

Improvement in the glycemic control in people with a T2DM has been made with an exercise training, however, only a little is known regarding the high-intensity interval training (Mortensen, S. P., Winding, K. M., Iepsen, U. W., Munch, G. W., Marcussen, N., Hellsten, Y., Pedersen, B., Baum, O., 2019). It has been proven that T2DM is associated with microvascular dysfunction, but little is known about how capillary ultrastructure is affected by exercise training. Therefore, combination of training and long-term insulin control and diet in insulin dependent diabetes over a period of 9 months has been found to reduce the pericapillary basement membrane thickening in individuals with type I diabetes8, and in elderly individuals with T2DM (Winding, K. M., Munch, G. W., Iepsen, U. W., Van Hall, G., Pedersen, B. K., & Mortensen, S. P., 2018).

On the contrary, regarding the athletes with the sport do constantly, the exercises guidelines will be taken into consideration, such as the frequency of exercise, the intensity of exercise and type of exercise (Shugart, C., Jackson, J., & Fields, K., 2009). Physical activity is directly related to the insulin resistance, inflammation and oxidative stress in diabetes mellitus (Vetrivel Venkatasamy, V., Pericherla, S., Manthuruthil, S., Mishra, S., & Hanno, R., 2013). It is well known that insulin resistance describes the inability of the quantity of exogenous or endogenous insulin to rise glucose uptake and usage in an individual as much as it does in a

normal population (Lebovitz, 2001). The increased glucose uptake at approximately 40 % was result of a single bout of moderate intensity exercise. Numerous studies presented a tremendous development in glucose tolerance and insulin sensitivity in response to exercises obtained from post-training measurements from 12 – 48 hours of the final exercise training (Holloszy, J. O., Schultz, J., Kusnierkiewicz, J., Hagberg, J. M., & Ehsani, A. A., 1986).

Moreover, after the physical activity as a result of increase in GLUT4 (Glucose Transporter type 4) the glucose uptake remains elevated for up to 120 minutes in plasma membranes and T-tubules. This was observed in healthy individuals and controls with T2DM (Borghouts, L. B., & Keizer, H. A., 2000). The crucial role in pathogenesis of T2DM plays the inflammation. Two essential and sensitive physiological markers of subclinical inflammation are interleukin (IL – 6) and C – Reactive Protein (CRP) (Teixeira De Lemos, E., Pinto, R., Oliveira, J., Garrido, P., Sereno, J., Mascarenhas-Melo, F., Reis, F., 2011).

According to Taddei, S., Galetta, F., Virdis, A., Ghiadoni, L., Salvetti, G., Franzoni, F., Salvetti, A., (2000) exercise reduces peripheral inflammatory markers of endothelial dysfunction. Physical activity plays an import role in regulating the balance between reactive species formation and antioxidant mechanisms thus reducing oxidative stress that leads to reduced risk of T2DM. Additionally, antioxidants improve insulin sensitivity, presented from the clinical trials which suggest that treatment with vitamin E, Vitamin C, or glutathione improves insulin sensitivity in insulin resistant individuals (Venditti, P., Masullo, P., & Di Meo, S., 1999). One examination made on 20 male controls (10 patients who were overweight with diabetes and 10 weight-matched healthy controls, both using metformin), proved that at rest and during exercise, the diabetes patients had greater values than the healthy controls for palmitate rate of appearance (Ra), rate of disappearance (Rd), accompanied by significantly higher fat oxidation rates at rest and during recovery in the diabetes patients (Boon, H., Blaak, E. E., Saris, W. H. M., Keizer, H. A., Wagenmakers, A. J. M., & Van Loon, L. J. C., 2007). Exercise significantly lowered blood glucose concentration in type 2 diabetes patients, observed before in the literature (Borghouts, L. B., & Keizer, H. A., 2000).

CONCLUSION

Consumers' increasing interest in healthy food has appeared in an accelerated growth of functional foods. The findings of this review presented the nutritonal value of *Opuntia ficus indica* and its possible effects on the glucose reduction and decreasing the prevalance of other non-communicable diseases. The potential anti-hyperglycemic effects of different plant parts of Opuntia Ficus indica requires further investigation. Future research should examine the serum glucose-insulin relationships within consumption of functional food enriched with bioactive functional ingredients. Moreover, *Opuntia ficus indica* could find applications in food packaging as edible films or coatings due to its high antioxidants capabilities. Lifestyle changes, including an increase in physical activity, can delay the appearance of the aging phenotype and associated comorbidities, preventing or delaying the onset of diseases such as cancer and certain cardiovascular, pulmonary, and metabolic disorders. Exercise has been considered as an essential component of T2DM treatment, and most athletes with T2DM with help of appropriate precautions can safely participate in sports at recreational and elite levels.

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