A SUMMARY OF THE USE OF MAIZE IN NUTRITIONAL PRODUCTS FOR SPORTSPEOPLE

Kinga Kostrakiewicz-Gierałt

University of Physical Education in Kraków, Faculty of Tourism and Recreation, Poland

Address for correspondence:
Kinga Kostrakiewicz-Gierałt
Jana Pawła II 78
31-571 Kraków, Poland
E-mail: kinga.kostrakiewicz@awf.krakow.pl

Abstract The aim of the investigation was to review experimental articles and patents referring to corn-based nutritional products for sportspeople published in the period 1970–2019. Publications were searched in the ISI Web of Science and Scopus databases, as well as the Google Scholar and Google Patents internet search engines. Factorial combinations of the keywords ("*Zea mays*" or "maize" or "corn") and ("athlete" or "sport") were applied. Most papers and patents were published in the period 2010–2019 by researchers affiliated to the USA and China – the two largest global producers of corn. Altogether, 65 patents and 16 articles were recorded. Inventors patented food supplements based on corn-derived saccharides and proteins. Empirical articles were devoted to the impact of corn-based food products on health of sportspeople, evaluation of the impact of length of consumption on the metabolism and performance of athletes, as well the frequency of use and acceptance of nutritional products based on corn by sportspeople.
Despite growing interest in the application of corn constituents in nutritional products for sportspeople, further investigations are strongly desirable.

Key words corn, dietary supplements, health, kernel, nutrition

Introduction

The recent decades have seen a growing interest in the impact of plant constituents on sporting health and performance. Maize or corn (*Zea mays* L.) ranks third after wheat and rice as a staple food for a large proportion of the population worldwide, particularly in Asian and African countries (Sandhu, Singh, Malhi, 2007; Chaudhary, Kumar, Yadav, 2014). Numerous authors (Nuss, Tanumihardjo, 2010; Wildman, Kerksick, Campbell, 2010; Shah, Prasad, Kumar, 2016) have argued that the corn kernel is an edible and nutritive part of the plant, reporting that it contains carbohydrates, proteins, fats, as well as minerals (i.e. phosphorus, sodium, sulphur, calcium, iron, potassium, magnesium, selenium, and copper) and vitamins (C, E, K, B1, B2, B3, B5, B6, B12). Moreover, it is an essential source of various phytochemicals, such as carotenoids, phenolic compounds, and phytosterols, providing human health benefits and reducing the risk of major chronic diseases (see e.g. Lopez-Martinez et al., 2009;

Yongfeng, Jaylin, 2016; Sheng, Li, Liu, 2018). In contrast, Q. Shao and K.V. Chin (2011) have noted disadvantages in eating corn, such as obesity.

Taking this into consideration, the application of products containing constituents from *Zea mays* for sportspeople seems to be a very interesting issue. A bibliographic study focusing on use of corn-derived products in a sporting diet was conducted by B.I. Sorin (2015). However, given the low state of knowledge, the aim of this study was to overview the literature on the application of corn-derived products in diet of sportspeople.

Material and methods

Study species

Maize or corn (*Zea mays* L.) is a tall monecious annual grass with overlapping sheaths and broad conspicuously distichous leaf blades. The plants have staminate spikelets in long spike-like racemes that form large spreading terminal panicles (tassels) and pistillate inflorescences in the leaf axils, in which the spikelets occur from 8 to 16 rows on a thickened, almost woody axis (cob). The whole structure (ear) is enclosed in numerous large foliaceous bracts and a mass of long styles (silks) protrude from the tip as a mass of silky threads (Hitchcock, Chase, 1971). Corn is wind pollinated with both self and cross pollination usually possible. The shed pollen usually remains viable for 10 to 30 minutes, or longer under favorable conditions (Coe, Nueffer, Hoisington, 1988). Following successful pollination, numerous rows of kernels appear along a rachis (cob); these mature kernels are the edible grains harvested for consumption and processing.

Although the exact origin of corn is unclear, most experts (e.g. Brown, Zuber, Darrah, Glover, 1985; Galinat, 1988; Benz, 2001; Piperno, 2011) agree that it emerged in Mesoamerica before 5000 BC. Cultivated corn derives from teosinte *Zea mexicana* (an ancient wild grass found in Mexico and Guatemala) and it was introduced into the Old World in the sixteenth century. During its domestication from teosinte, corn has gained many agronomically significant attributes, but it has lost the ability to survive in the wild. It has become so domesticated that seeds cannot be separated from the cob and disseminated without human intervention. Corn seeds show poor dormancy, especially in the northern ranges of the crop's distribution. Plants occasionally grow in uncultivated fields and by roadsides or occur as volunteers in cultivated crops in the year following cultivation of a corn crop.

Method of publication search

For this survey, a systematic approach was applied through a dedicated step-wise process for selecting available peer-reviewed literature sources. The authors searched for peer-reviewed original full-text articles, dissertations, and patents, about the application of soybean-derived products for sportspeople, using the ISI Web of Science (All Databases) and Scopus-indexed publications. These search engines were selected as they provide a comprehensive all-encompassing database for various interdisciplinary domains. The review focused on literature documenting the application of corn published from 1970 to 2019. More publications were sought by browsing the Google Scholar and Google Patents internet search engines. Factorial combinations of the following keywords in the searches: ("*Zea mays*" or "maize" or "corn") and ("athlete" or "sport") were used. The selection terms were examined from the title, abstract, and keywords of the articles. The results comprised 4104 hits from the ISI Web of Science (All Databases), 169 hits from Scopus, 5,978 from the Google Scholar internet search engine, and 2,308 hits from Google Patents on 7 September 2019. After the removal of grey literature (blog posts, reports, conference

proceedings, and notes) from the lists of searches, we selected publications from 54 records through the ISI Web of Science, 17 through Scopus, 22 from the Google Scholar, and 93 from the Google Patents internet search engine. The abstracts were then screened for relevance and eligibility. The sole inclusion criterion for patents was their usefulness for sportspeople. The other inclusion criteria for the articles were as follows: (i) investigations are relevant to the main subject of presented review, (ii) participants are people (clinical trials), (iii) no limits in age, weight, sex, nationality and number of participants, (iv) no limits in geographical location, as well as time period of investigations, and (v) abstract in English. The exclusion criteria of the articles were as follows: (i) studies irrelevant to the main subject, (ii) investigations conducted on non-human species, (iii) repetitive publications (different parts of a single study were presented in two or more papers or studies based on a population that was part of an earlier publication), (iv) abstract written in a language other than English. Finally, the author selected publications based on the scope which resulted in 42 records through the ISI Web of Science, 10 through Scopus, 12 from Google Scholar and 56 from the Google Patents internet search engines. Following the removal of duplicates (publications indexed in at least two databases) from all searches and an initial screening of full-texts, a final total of 114 records were selected to be reviewed. The inclusion criteria of the articles were as follows: (i) observational, descriptive studies (case report/ case series), (ii) observational, analytical studies (case-control studies, cross-sectional studies, cohort

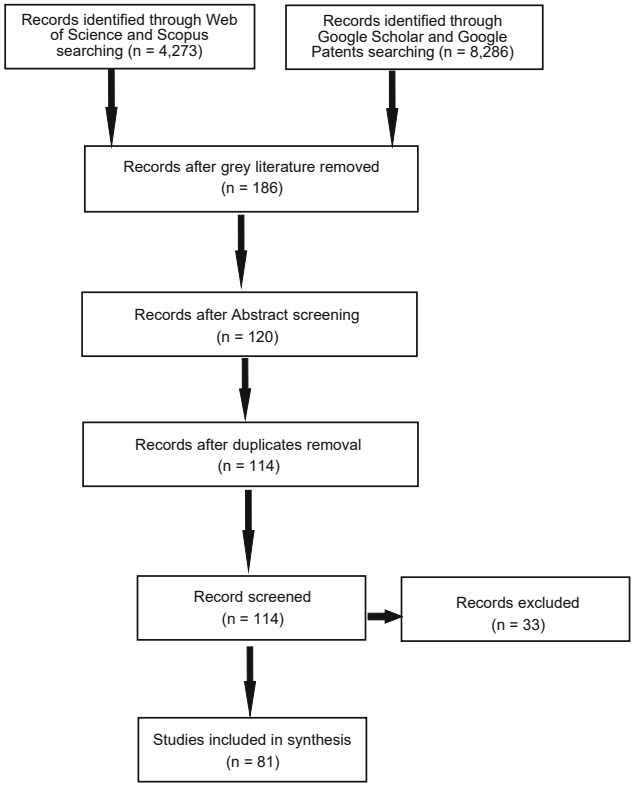

Figure 1. The simplified PRISMA flow chart detailing search results
Source: after Moher, Liberati, Tetzlaff, Altman (2009).

studies), (iii) experimental studies (randomized controlled trials). The exclusion criteria of the articles were as follows: (i) meta-analyses and (ii) systematic reviews, (iii) lack of full text, and (iv) lack of full text in English. Following the initial screening of abstracts from all the searches, a final total of 81 records were selected to be reviewed. A chart detailing the search results is presented in Figure 1. A statistical analysis based on non-parametric Kruskal-Wallis H test for multiple comparisons was used to check the statistical significance of differences among the numbers of records in particular decades.

Results

Most publications focusing on the application of corn-based products for sportspeople were published in the period 2010–2019 (Table 1). The authors of the majority of patents/publications are affiliated to the USA and China (Table 2). The inventors had patented food supplements (in the majority), sportswear, and devices enhancing sporting activities, while the empirical publications were devoted to nutritional products. The results of the literature survey are presented below.

Table 1. The number of experimental publications and patents connecting with application of corn products for sportspeople in particular time periods

Time period (years)	Mean number of publications per year (±SD)	The value of H Kruskal-Wallis test; p value*
1970–1979	0.10 (±0.32)[a]	H = 39.51, p < 0.001
1980–1989	0.20 (±0.42)[a]	
1990–1999	0.30 (±0.48)[a]	
2000–2009	2.70 (±1.91)[b]	
2010–2019	5.50 (±2.72)[b]	

The different letters (a and b) in superscripts mean that differences among time periods are statistically significant. The same letters in superscripts mean that differences among time periods are statistically insignificant.

Table 2. Geographic distribution of literature*

Author affiliation	Number of publications	Percentage
1	2	3
USA	31	38.2
China	13	16.2
Australia	4	5.0
Spain	4	5.0
Canada	2	2.5
Armenia	2	2.5
Austria	2	2.5
France	2	2.5
Great Britain	2	2.5
Japan	2	2.5
Netherlands	2	2.5
Russia	2	2.5
Argentina	1	1.2
Brasil	1	1.2
Chile	1	1.2

1	2	3
Denmark	1	1.2
Etiopia	1	1.2
Germany	1	1.2
India	1	1.2
Malaysia	1	1.2
New Zeland	1	1.2
Norway	1	1.2
Sweden	1	1.2
Switzerland	1	1.2
UK	1	1.2

* In case of multi-authored publications affiliation of the first author was considered.

Mono-, oligo- and polysaccharides

Several scientists had invented a recipe for carbohydrate blends comprising extracts from maize (corn syrup) that might be used as sweeteners in sport nutrition products, such as powders, pre-mixes, juices, energy bars, isotonic drinks and gelatine, and starch-based or pectin jellies (Table 3).

Table 3. The patented recipes for carbohydrate blends comprising extracts from corn

Patent	Patent number	Inventor(s)	Year
Use of novel carbohydrates and carbohydrate blends to provide a sports beverage with increased absorption	US20100129497A1	V. Rinaldi, J. Zachwieja, X. Shi, Z. Ali	2010
Natural sweetenter	US20150208703A1	R. Turner	2015
High carbohydrate food product	ES2603436-A1	M.B. Sorinas	2017
Sugar extracts	US9572852B2	L.L. Ilag, J. Smythe, T.P. Ellis, R.S. Weisinger	2017

Source: https://patents.google.com/patent.

Most patents were devoted to methods of producing nutrient products containing high fructose corn syrup as a sweetener. Such products are represented by beverages suitable for reducing fatigue, diminishing muscle soreness, maintaining blood sugar level during exercise, improving cardiovascular function, increasing athletic performance, enhancing vitamin absorption, as well as reducing calories. Other researchers had patented energy bars used forelieving tension and supplementing energy before running, nutritious puree compositions suitable for sportspeople, as well as energy gels suitable for increasing available energy during exercise and for replenishing electrolytes that are depleted during exercise. Moreover, corn glucose syrup might also serve as an important ingredient in foods suitable for sportspeople. Also, the process of acquiring steviol glycoside mixtures with other ingredients such as corn syrup to be used as sweeteners and flavours composition, among others, in sport drinks, was patented (Table 4).

Table 4. The patents of nutritive products for sportsman containing glucose corn syrup or high fructose corn syrup

Patent	Patent number	Inventor(s)	Year	Source
Beverages suitable for reducing fatigue	CN102845801-A; CN102845801-B	Y. Liu	2013	2
Beverage suitable for reducing fatigue	CN107874054-A	Y. Zhan, Y. Yang, Y. Luo, J. Li, D. Yang, B. Wang et al.	2018	2
Reducing muscle soreness with glucosamine compositions	US9089156B2	V. Rinaldi, W. Racicot, J.J. Zachwieja, R. Murray	2015	1
Beverage maintaining blood sugar level during exercise	CN105614612-A	X. Xia, Y. Yang, G. Zhang, X. Zhang	2016	2
Beverage improving cardiovascular function	CN103315347-A; CN103315347-B	Y. Chen, M. Fu, J. Li, S. Liao, D. Tang, J. Wen et al.	2013	2
Performance enhancing sports beverage and methods of use	US20120128815A1	S.P. Poulos, J. Boza, R.O. Scott	2012	1
Athletic performance enhancing beverage	US20150272196A1	J.Ch. Anthony, K.D. Kent, B.L. Winters, H.W. Yeom	2015	1
Beverages containing water-soluble vitamin E	US20070141203A1	P. Cook	2007	1
Use of erythritol and D-tagatose in diet or reduced-calorie beverages and food products	US20020160090A1	T. Lee, G. Olcese, Z. Bell, G. Roy, W. Mutilangi, R. Hirs et al.	2002	1
Energy bar as sweetener	CN107149142-A	X. Sun, J. Zhang, D. Mei	2017	2
Bite-size carbohydrate nutritional products and methods for using same	US20090239803A1	M.G. Feuvrier-Roy, D.J. Leonard, A. Mittal, A. Jeukendrup, A. Stellingwerff, E. Zaltas	2009	1
Puree compositions having specific carbohydrate ratios and methods for using same	US20130115329A1	V.D. Savant, T. Haile, F.C. Jimenez, C.M. Boice, K.R. Welsh, E.S. Zaltas et al.	2013	1
Electrolyte energy gel	US20050095271A1	M. Mathewson	2005	1
Encapsulated energy gel compositions	US20060280777A1	A. Schydlowsky	2006	1
Food composition enriched with babaçu coconut oil	BR102016026844-A2	F. Franca Silva, S.B. Do Desterro, M. Do Carmo Lacerda Barbosa, E. Bouskela, M.C. Pires Costa, R.M.T. Fernandes	2018	1
Sustained release of nutrients in vivo	WO2010080557A1	F. Sexton, S. Krishnan, V.K. Vendra	2010	1
Glucosyl stevia composition	US8911971-B2	A. Markosyan	2014	1
Stevia composition, production method and uses	WO2016049315-A1	A. Markosyan	2016	1

Source: https://patents.google.com/patent; https://apps.webofknowledge.com.

Corn starch as a main source of polysaccharides might be the basis of energy supplements, nutritive foods reducing the feeling of hunger, and overcoming the problems of rehydration after prolonged strenuous exertion. Other authors patented nutritive products balancing blood sugar levels and prebiotic combinations containing a high amylose corn starch suitable for sportspeople that diminishes the risk of gastrointestinal infection, and supports the uptake of important minerals such as calcium and magnesium (Table 5).

Table 5. The patents of products for sportspeople containing corn starch

Patent	Patent number	Inventor(s)	Year	Source
Carbohydrate and medium chain triglyceride gel as an energy suplement	WO1997007690A2	R. Jones	1997	1
High-protein pancake mix	JP2015142542-A	T. Kiyota, K. Suzuki, Y. Morimoto, K. Kondo, G. Masaoka, S. Nakano	2015	1
Corn starch and also corn flours and food comprising this corn starch	WO2008080630A1	C. Frohberg	2008	1
The nutritional food	CN103549412-A	H. Xu	2014	2
Nutritionally balanced food or beverage product	US20150017309A1	G.W.C. Pope-Mayell, R.D. Rotherham, J.P. Rogers	2015	1
Proficiency beverage	US7582324B2	A.G. Blank	2009	1
Food product with high viscosity	US7320810B2	P. Wuersch, O. Ballevre, H. Milon, B. Sievert	2008	1
Heat moisture treated starch for the treatment of hypoglycaemia	CA2544965C	X. Qi, R. Tester	2005	1
Compositions and uses thereof	US8507462B2	X. Qi, R. Tester	2013	1
Heat moisture treated carbohydrates and uses thereof	WO2010077635A2	S. Murali, P. Kaufman, J.S. Volek	2010	1
Prebiotic combination products	WO2005056023A1	J.Y. Piene	2005	1

Source: https://patents.google.com/patent; https://apps.webofknowledge.com.

Oligopeptides, polypeptides and proteins

Numerous researchers have patented methods of preparing protein hydrolysates, as well as a way of fractionating the nutritive proteins from plant material such as corn that could be useful in food products suitable for sportspeople during and after physical exercise (Table 6).

Table 6. The patented methods of preparing corn protein hydrolysates

Patent	Patent number	Inventor(s)	Year	Source
Protein hydrolysates	WO2002032232A2	V. Delest, L. Edens, J.G. Kortes, T.J-B. Naeye	2002	1
Protein hydrolysate rich in tripeptides	US20080220470A1	L. Edens, P.J.T. Dekker, De A.L. Roos	2008	1
Protein hydrolysate compositions stable under acidic conditions	EP2299839A2	T.M. Wong, P.S. Kerr, P.S. Ghosh, J.F. Lombardi, G.B. Lynglev, T. Hoff et al.	2011	1
The recipe for preparation of multi-nutrition active polypeptide	CN103168983-A	S. Wang	2013	2
Protein hydrolysate compositions having enhanced cck and glp-1 releasing activity	WO2012141795-A1	E.S. Krul, B. Tulk, M.K. Pawlik, J.F. Lombardi, E. Krul, M. Pawlik et al.	2012	1
The recipe for preparation high-value oligopeptide by hydrolyzing corn protein solution	CN107760750-A	Q. Cui, Y. Wang, X. Song, Y. Feng, Y. Liu, Y. Xiao	2018	2
Charged nutritive proteins and methods	US8809259B2	D.A. Berry, B.A. Boghigian, N.W. Silver, G. von Maltzahn, M. Hamill, R. Chillakuru	2013	1

Source: https://patents.google.com/patent; https://apps.webofknowledge.com.

Several researchers have invented recipes for nutritional drinks promoting recovery of fatigue and reducing the degree of injury, improving the athletic ability of teenagers, enhancing stress resistance, promoting growth of the brain and body, strengthening the physique and improving immunity, increasing bone calcium content and enhancing weight loss, supporting glucose uptake into the muscle and extending endurance during physical exercise, as well as optimizing muscle performance during exercise.

Simultaneously, other nutritional inventions worth noting are nutritive soups, chocolate for repairing body tissues, relieving physical fatigue, promoting digestion and preventing obesity, energy bars and food compositions provided in a ready-to-eat form or incorporated into a bar, chew, filling or paste suitable for sportspeople. Also, a dietary, prophylactic and functional food product suitable for sport alimentation and containing, among others, chapped grains of corn was patented. Furthermore, patents of sport nutritional supplements (provided in different forms) supporting lipolysis, promoting bone and muscle growth, as well as relieving sports fatigue, as well as enhancing recovery after physical exercise should be mentioned (Table 7). It should also be mentioned that S.A. Duvick, L.M. Pollak and P.J. White (2003) prepared a method of growing improved corn lines having high protein and/or oil content suitable for producing foods for sportspeople.

Table 7. The patents of nutritive products for sportspeople based on oligopeptides, polypeptides and proteins derived from corn

Patent	Patent number	Inventor(s)	Year	Source
1	2	3	4	5
Method for the formulation of a gel-format foodstuff for use as a nutritional foodstuff enriched with peptides and maltodextrins obtained from quinoa flour	WO2013091125A1	J.I. Cáceres, P. Enrione, D. Calderon, F.O. Lira	2013	1
The sport drink promoting recovery of fatigue and reducing injury degree	CN103704808-A	J. Hong, Z. Hu	2004	2
The sport drink improving the athletic ability of teenagers, enhancing stress resistance, promoting growth of the brain and body, strengthening physique and improving immunity	CN108094786-A	Anonymous	2018	2
The sports nutrition milk tea powder increasing bone calcium content and enhancing weight loss	CN103549015-A; CN103549015-B	W. Li	2014	2
Sports drink composition for enhancing glucose uptake into the muscle and extending endurance during physical exercise	US7740893B2	R. Portman	2010	1
Sports beverage and method of making	WO2009085928A2	W.L. Constantine, A.S.A. Dixon, S. Kramer, M.W. Varhol	2009	1
Method for manufacturing protein-containing drink	WO2019004271-A1	S. Hata, M. Banno, M. Takakura	2019	1
The chocolate used for repairing body tissue, relieving physical fatigue and removing redundant free radicals	CN103960436-A	J. Liu, M. Zhang, Y. Zhang, Y. Wang, H. Zhao	2014	2
The energy bars	CN106108027-A	J. Ma, K. Yu, X. Liu, Y. Sun, X. Yan	2016	2
The energy bars	IN201711014441-A	N. Yadav	2019	2
Composition based on quinoa and gofio, as well as other components such as cocoa and rice flour	ES2564739-A1	M. Gazmira, M. Toledo	2016	1
Dietary, prophylactic and functional food product for sport alimentation	RU2445797-C1; RU2458538-C1	A. Malyshev	2012	1
The sport nutritional supplements supporting lipolysis	CN108606269-A	B. Wang, X. Liu, G. Zheng, Y. Du, L. Zhang, R. Qian	2018	2

1	2	3	4	5
Composition comprising carbohydrate and peptide material and its use as an energy supplement after or during physical exercise or as a metabolic nutrient for oral consumption	US6713082B2	L.J.C. Van Loon, A.A.J. Wagenmakers, A.D. Siemensma, A. Kunst, M.J.J. Hakkaart, W.H.M. Saris	2004	1
Functional food paste	WO2010030944A2 EP2348891B1	W.C. Smith, J.A. Brown, S.K. Holt	2009	1
Altered fatty-acid, protein, oil, and starch corn lines and method for producing same	US6639132B1	S.A. Duvick, L.M. Pollak, P.J. White	2003	1

Source: https://patents.google.com/patent; https://apps.webofknowledge.com.

Other constituents

Many authors patented methods of processing the corn grain to obtain an oil for the production of food suitable in sporting nutrition, as well as recipes for nutritional products (Table 8). Also, the Table contains patented compositions enabling increased bioavailability of carotenoids derived from corn and anthocyanin, which can be directly incorporated into food products, and a method of obtaining ferulic acid.

Table 8. The patents of nutritive products for sportspeople based on oils derived from corn

Patent	Patent number	Inventor(s)	Year
Process for increasing throughput of corn for oil extraction	CA2562670A1	M. Van Houten, M.J. Beaver, A.M. Eyal, E.J. Fox, J. Ingvalson, N.T. Jakel et. al.	2005
Products comprising corn oil and corn meal obtained from high oil corn	WO2002014459A2	J.F. Ulrich, N.T. Jakel, T.T. Lohrmann, P.J. Mc Williams, M.J. Tupy, M.J. Beaver et al.	2002
Products comprising corn oil and corn meal obtained from high oil corn	US20040058052A1	J. Ulrich, N. Jakel, D. Kotowski, J. Ingvalson, B. Aufdembrink, M. Tupy et al.	2004
Compositions and methods to increase bioavailability of carotenoids	WO2009063333A2	T. Eidenberger	2009
Stabilized anthocyanin compositions	US8449927B2	T. Eidenberger	2008
Bioproduction of ferulic acid and uses thereof	WO2008116319A1	S. Parakash, J. Bhathena	2008

Source: https://patents.google.com/patent.

Investigations of products

Several authors focused on the frequency and acceptance of using corn-derived food. Investigations of the frequency of using nutritive corn products by sportspeople were conducted by M. Mamo, P. Singh (2018) and A.R. Pérez, A.J.C. Andújar, C.S. Muñoz, J.J.M. Molina and M.Z. Díaz (2012). In the study by M. Mamo and P. Singh (2018), on a group of 165 male and 135 female senior runners, they showed that the frequency of eating corn was rather low. The study by A.R. Pérez et al., (2012), on a group of 27 young international elite motorcyclists, showed that the majority of them ate corn cereals at least once a day. The study by D.L. Christensen, G. van Hall and L. Hambraeus (2002), on 12 adolescent male Kalenjin runners in Kenya during a 2-week field study, determined that their energy intake was mainly derived from the vegetable sources – with corn and kidney beans as the staple food. The results of the physico-chemical, functional, nutritional and sensorial tests by V.C. Del Castillo, M. Armada and J.C. Gottifredi (1999) showed a considerable preference of supplementary sporting foods based on corn in

comparison to commercial food. The study by Y. Carrera, R. Utrilla-Coello, A. Bello-Pérez, J. Alvarez-Ramirez and E.J. Vernon-Carter (2015) relate the extensive use of pinole (a traditional energy food based on flour obtained from toasted ground corn grains) by high performance ultra-runners, where the hydrolysis rate and *in vitro* digestibility of starch are greatly improved by the toasting process.

Other authors compared the metabolism and performance of sportspeople after consuming corn products and alternative nutritional foods. The investigation conducted in a group of 31 elite footballers from the Australian Football League (AFL) at the height of outdoor summer training demonstrated a better rehydration from a drink containing high amylose corn starch and glucose in comparison to other rehydration drinks (O'Connell et al. 2018). The study by A. Ahmad, N. Jusoh and R. Tengah (2019) on physiological responses and performance following subsequent repeated high intensity exercise with consumption of corn juice in a group of 17 hockey and football players, found that *Zea mays* juice containing carbohydrates (mainly glucose and fructose), proteins, and sodium has potential as an alternative recovery beverage to promote repeated exercise with a short rest time. The study by A.C. Snyder, L.O. Schulz and C. Foster (1989) found that the consumption of a carbohydrate supplement (made by the partial hydrolysis of corn starch) by elite speed skaters resulted in substantial increases in energy. The study by K.J. Cole, P.W. Grandjean, R.J. Sobszak and J.B. Mitchell (1993) examined the effects of incremental consumption of various carbohydrate solutions during prolonged exercise in 10 trained male cyclists, where the drinks with high fructose corn syrup provided a significantly higher level of carbohydrates in comparison to solutions containing glucose and sucrose. The study by G.A. Wallis, D.S. Rowlands, C. Shaw, R.L.P.G. Jentjens and A.E. Jeukendrup (2005) on a group of 8 trained cyclists showed that by drinking large amounts of maltodextrin and fructose during cycling exercise, exogenous carbohydrate oxidation can reach greater values than from ingesting maltodextrin alone. The study by J.B. Mitchell, W.A. Braun, F.X. Pizza and M. Forrest (2000) aimed at determining the influence of drinking solutions containing mixtures of carbohydrate types on pre-exercise glycemic response, exercise-induced hypoglycemia, metabolic responses, and 10-km treadmill running performance in a warm environment, on a group of 10 trained runners, found that the type of carbohydrate (high fructose corn syrup solution, glucose solution, sucrose and glucose mixture, banana with water) did not influence running performance or metabolic responses during exercise.

The study by M. Kern, N.D. Lagomarcino, L.M. Misell and V. Schuster (2000) focused on assessment of the blood lipid levels following consumption of a low-fat diet, medium-chain triacylglycerol or long-chain triacylglycerol in male endurance runners, where the long-chain triacylglycerol oil derived from corn has a positive impact on the blood profile of sportspeople. Further investigations by L.M. Misell, N.D. Lagomarcino, V. Schuster and M. Kern (2001) found that long-term consumption of medium-chain triacylglycerols (compared to corn-derived long-chain triacylglycerols) neither enhances endurance nor significantly alters performance-related metabolism in trained male runners.

Several investigations concentrated on the effect of the timing of ingestion of corn food products on the metabolism and performance of sportspeople. The study by M.D. Roberts, Ch. Lockwood, V.J. Dalbo, J. Volek and Ch.M. Kerksick (2011) on the impact of hydrothermally modified starch and maltodextrin on metabolic and hormonal responses in 9 male cyclists, found that ingestion of low-glycaemic hydrothermally modified starch before prolonged cycling exercise blunted the initial spike in serum glucose and insulin, and increased the breakdown in fat compared to maltodextrins. The study by R.B. Parks, H.F. Angus, D.S. King and R.L. Sharp (2018) aimed to characterize the metabolic response from consumption of modified amylomaize or dextrose before exercise,

showing that consumption in the hour before exercise of corn-derived starch modified by partial hydrolysis (compared to dextrose consumption) resulted in a more stable serum glucose concentration, but it did not offer a performance advantage in the high-intensity cycling trial. The study by M.G. Flynn et al. (1987) examined the influence of carbohydrate consumption on exercise performance and muscle glycogen use, in a group of 8 well-trained male cyclists, demonstrating a greater blood glucose level at 90 min after consumption of high fructose corn syrup compared to consumption of artificially sweetened water, maltodextrin and fructose.

Discussion

Most publications focusing on the use of corn-based products by sportspeople were published in the period 2010–2019, and mainly by researchers affiliated to the USA and China. Such a phenomenon might be linked to the largest global producers of corn as noted by the two specific countries (USDA, 2019). The investigated studies have shown that the numerous beneficial constituents of corn are widely applied in the production of nutritional food. At the same time, it should be noted that there is a discrepancy in the evaluation of the influence of high fructose corn syrup on people's health. Numerous researchers (see e.g. Bray, Nielsen, Popkin, 2004; Morrill, Chinn, 2004; Bocarsly, Powell, Avena, Hoebel, 2010) link the consumption of high fructose corn syrup with increased obesity and metabolic disorders, while many scientists (see e.g. Klurfeld, Foreyt, Angelopoulos, Rippe, 2013 and literature cited herein) have highlighted a lack of evidence of high fructose corn syrup as a cause of obesity. Additionally, J.J. Johnson and R. Murray (2010) argued that for sportspeople, a positive aspect of fructose metabolism is that in combination with other simple sugars, fructose stimulates rapid fluid and solute absorption in the small intestine and helps increase exogenous carbohydrate oxidation during exercise – an important response for improving exercise performance. The aforementioned authors observed that additional research is required to clarify the possible health-related implications of a long-term intake of large amounts of dietary fructose among sportspeople.

Conclusions

Most publications focusing on the application of corn-based products by sportspeople were published between 2010 and 2019, and mainly by researchers affiliated to research centers USA and China. Inventors have patented food supplements containing mostly corn derived saccharides and proteins. Despite a substantial number of empirical articles testing the quality and social acceptance of products, further investigations seem to be strongly desirable.

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