Food and Public Health 2014, 4(5): 229-241
DOI: 10.5923/j.fph.20140405.04

New Starches are the Trend for Industry Applications: A Review

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Abstract Starch is widely consumed by humans as an inexpensive and stable available carbohydrate source, and much work has been performed on the structure, functionality and applicability of starches. Although conventional sources of starch, such as corn and potato, other sources with improved properties are becoming significant to allow simpler and more robust processes. The feasibility of the use of new starches, i.e., legume, seed and palm, as renewable materials for commercial application may provide cost reduction of raw material in industries. Little information is available on the structure, properties and practical applicability of non-conventional sources of starch. Thus, it is necessary that these starches be studied to obtain and report their structural parameters, information that is required to gain competitiveness in an international-scale industry. A review of properties, applications, future trends and perspectives of some new starches is presented in this review.

Keywords New starches, Non-conventional starches, Turmeric, Annatto

1. Introduction

Most foods are multi-component systems that contain complex mixtures of water, carbohydrates, proteins, lipids and numerous minor constituents. Starch is a macro-constituent of many foods, and its properties and interactions with other constituents are of interest to the food industry and for human nutrition.

Sales of starches and derivatives were $51,2 billion in 2012 and are expected to reach $77,4 billion by 2018, a compound annual growth rate (CAGR) of 7,1% between 2012 and 2018 [1]. Indeed, the starch derivative market is expected to growth extensively at a rate of 6,2% from 2014 to 2019 because of the technological advancements occurring in the industry [2].

Starch application in industrial-related products dates back to ancient times [3]. For industrial uses, the selection of a starch is made by considering its availability and also its physicochemical characteristics, which vary depending on the source [4].

The inherent functional diversity of materials extracted from different biological sources adds to the range of applications. Currently, some uses of starch include the following: as a food additive to control the consistency and texture of sauces and soups, to resist the breakdown of gel during processing and to increase shelf life of an end product in the food industry; in the laundry sizing of fine fabrics and skin cosmetics in the textile and cosmetic industry; for enhancing paper strength and printing properties in the paper industry; as drug fillers in the pharmaceutical industry; as binders in the packaging industry [3].

Globally, intensive efforts have been channeled toward producing polysaccharide derivatives of different types of starch for diverse applications in different industries [5]. The widespread use of starch is justified because it is inexpensive and available in large quantities. In addition, it is relatively pure and does not require intense purification, as is often the case with other natural polymers such as cellulose and gums [6].

Commercial starches are obtained from cereals, such as corn, wheat and various types of rice, and from tubers or roots, such as potato and cassava (or tapioca) [7].

The main botanical source of starch is maize, accounting for about 80% of the world market. Maize starch is an important ingredient in the production of foodstuffs, and has been widely used as a thickener, stabiliser, colloidal gelling agent, water retention agent and as an adhesive [8].

The use of new starches, i.e., starches from non-conventional sources such as those isolated from roots and tubers could provide options for extending the spectrum of desired functional properties, which are needed for added-value food product development [7].

With the industry demand for new technological properties, several non-conventional starch sources, with different properties have been studied due to interest in using native starches for food production instead of using chemically modified starches [9]. Currently, these native

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starches are usually ignored and wasted during the isolation and separation of small molecule bioactive ingredients [10].

A large number of scientific investigations concerned with the use of starch have been published to date. Table 1 shows the literature searched in the "Scopus" and "Web of Knowledge" databases using the keywords "starch", "food" and "processing".

Table 1. Number and type of documents published in the Scopus and Web of Knowledge databases between 2010 and 2014

Year	Database	
	Scopus	Web of Science
2014	85	112
2013	153	185
2012	154	189
2011	154	205
2010	147	183
Document type		
Article	512	710
Review	72	108
Book chapter	44	3
Conference paper	32	75

A comprehensive study on the relationship between the structural characteristics and functional properties of starches from different sources could provide important information for optimizing industrial applications.

Much work was done for a better understanding of the new starches characteristics. This review summarises some of several non-conventional sources of starch, in terms of properties, applications, future trends and perspectives, to provide a greater range of options for increasing the use of these new starches.

2. Classification

Starch can be divided into three categories based on its nutritional classification: rapidly digestible starch, slowly digestible starch and resistant starch. Resistant starch is not digested in the small intestine and enters the colon for fermentation [11].

The starch molecule can be extracted and sold as such (native starch), but it can also undergo several processing operations to improve its proprieties and enlarge the range of its uses (modified and hydrolyzed starches).

Native starch is the starch chain extracted from raw material in its original form. Modified starches are starches that are modified by a chemical, physical or enzymatic process. Hydrolyzed starch is the starch chain broken into smaller glucose chains via a hydrolysis reaction.

Native starches has limited application in industry because it exhibits some disadvantages such as a low shear resistance, high retrogradation and syneresis, and it is often modified by physical, chemical or enzymatic processes or a combination thereof to provide desirable functional properties for determined uses.

Physically modified starch can be considered as a natural material and a highly safe ingredient [12]. Nevertheless, the commonly used ways of obtaining modified starch are complex, expensive and time consuming [13, 14] and frequently employ treatments with hazardous chemicals.

Many industrial applications require the modification of native starches, including oxidation, esterification, hydro-xymethylation, dextrinization and cross-linking. These modifications overcome the limitations of native starch properties (e.g., stabilizing the polymers against severe heating, shear, freezing or storage).

Such modified starches have innumerable applications in the food industry, particularly in confectionery and bakery processes for thickening and emulsification, and in non-food sectors as adhesive gums, biodegradable materials and sizing agents in the textile and paper industries [15].

3. Properties of Starch

Starch is composed of two different glucan chains, amylose (a linear polymer of a-D-glucose units linked by a-1,4 glycosidic linkages) and amylopectin (a branched polymer of a-D-glucose units linked by a-1,4 and a-1,6 glycosidic linkages), representing approximately 98–99% of the dry weight [16]. These polymers have the same basic structure but differ in their length and degree of branching, which ultimately affects their physicochemical properties [13].

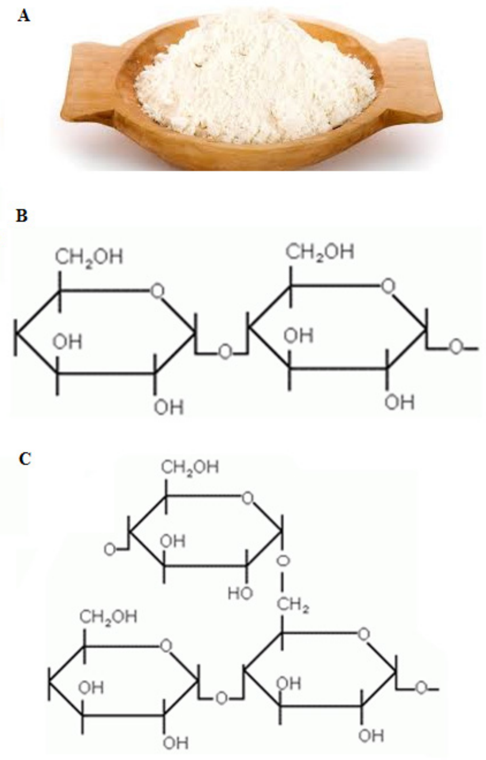

Figure 1. Starch as it such (A) [17], and chemical structure of amylose (B) and amylopectin molecules (C) [18]

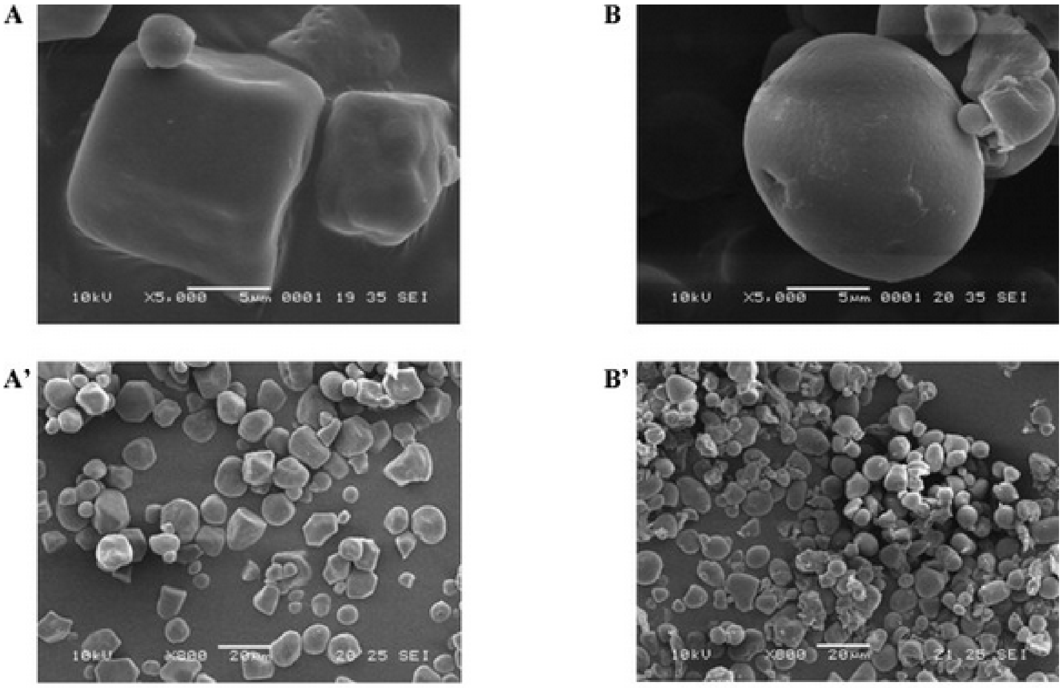

Figure 2. Scanning electron microscopy (SEM) images of_corn (A and A'), and ramon (B and B') granules [7]

Starch varies greatly in form and functionality between and within botanical species and even from the same plant cultivar grown under different conditions. This variability provides starches of different properties, but it can also cause problems in processing due to inconsistency of the raw materials [19].

Figures 2 and 3 deal with structure and whole raw material between two plants that represent common and uncommon sources of starch, respectively.

Figure 3. Corn (A) [20] and ramon (B) [7] plants

Physicochemical (e.g., gelatinization and retrogradation) and functional (e.g., solubility, swelling, water absorption, syneresis and rheological behavior of pastes and gels) properties determine the potential uses of starches in food systems and other industrial applications.

These properties depend on the molecular structural composition of amylose and amylopectin; how they are arranged in starch granules plays an important role in formulations. In food products, the functional roles of starch could be as a thickener, binding agent, emulsifier, clouding agent or gelling agent.

Another important material property of starch is its glass transition, in which the molecules in the amorphous fraction of starch transform from a frozen to a mobile state. Glass transitions of starch have been measured using, e.g., differential scanning calorimetry (DSC) [21]. DSC is one of the most suitable techniques that enable accurate determination of the temperature at which state changes occur in biopolymer systems [22].

The most important physical changes that occur during the industrial processing of native starches are the swelling of the granules upon heating in an excess of water and the subsequent solubilization of amylose and amylopectin ('gelatinization'). Amylose diffuses out of the swollen granule and, upon cooling, forms a continuous gel phase. Swollen amylopectin-enriched granules aggregate into gel particles, generating a viscous solution. This two-phase structure, called starch paste, is desirable for many applications in which processed starches are used as thickeners or binders. Native starches have few other uses because the polymers are relatively inert [15].

Starch hydrolysis has been used in the food industry to convert starches, starch derivatives and starch saccharification products, which have several applications in food processing. The products from starch hydrolysis are certainly highly versatile ingredients used in the food industry and are used in a wide range of food products due to both their functional and nutritional properties [23].

4. Applicability

With wide applications in the food, textile, pharmaceutical, paper and, recently, synthetic polymer industries, starch plays prominent a role even in technological developments [24]. In addition, it is purified in the shape of micro-granules and widely used as a solid matrix for the encapsulation of food ingredients [25].

Starch has been investigated widely for its use in the potential manufacture of products, including water-soluble pouches for detergents and insecticides, flushable liners and bags and medical delivery systems and devices [26]. In ceramic technology, starch is a frequently used as pore-forming agent [27].

Novel approaches in polymer manufacture imply the use of composites; for example, polypropylene carbonate (PPC) is being doped with starch to create ecofriendly, naturally degrading materials, thus reducing the negative effect of polymeric waste production. Starch also shows very interesting optical properties; for example, the second-harmonic generation of light can be achieved on starch granules [28].

The use of edible films in the food industry has been constantly increasing, and starch-based films play a key role in the food industry because starch is abundant, inexpensive, naturally renewable, biodegradable polysaccharide industries especially food products and more readily available worldwide than other natural resources, in applicability part [29].

One way of increasing the usefulness of starch for industrial applications is by treating it with acid at elevated temperature. It is mainly the amorphous part of the native starch that is subjected to acid hydrolysis, and this method is used as a pretreatment in various industrial applications (e.g., for gums, pastilles, jellies) to decrease viscosity and increase gel strength. Acid hydrolysis is also used to determine the degree of crystallinity of native starches and to prepare starch nanocrystals [21].

In addition to physical modifications, blending different native starches is another way to obtain new starch properties. It may also offer an economic advantage when a more expensive starch can be partially replaced by a cheaper alternative without affecting product quality [30]. Jackfruit, a source of new starch; the structure of its starch in formulation with sodium alginate is illustrated in Figure 4. Table 2 lists some general applications of starch.

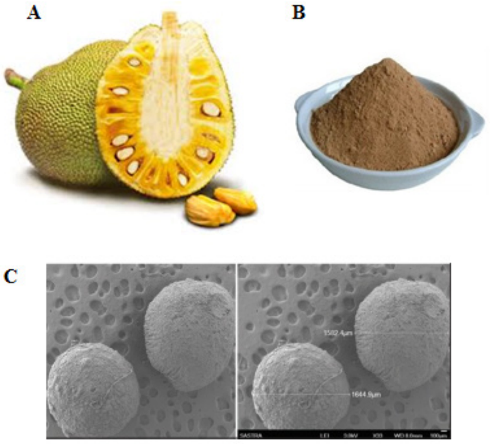

Figure 4. Whole jackfruit (A) [31], jackfruit seed powder (B) [32] and Scanning electron microscopy (SEM) of jackfruit seed starch-sodium alginate optimized formulation (C) [33]

Table 2. Applications of starches

Type of starch	Applications	References
Native starches	Paper, Textile food, cardboard and potable alcohol production (FI) industry	[34]
Hydrolyzed starches		
Maltodextrins:	- Food preparation (bulking agent)	[35]
	- Pharmaceutical (excipient)	[6]
	- Ingredient in ice cream industry	[36]
Glucose syrup:	- Dextrose Equivalent of between 40 and 60: food industry	[37]
	- Beverage and confectionary industry	[38]
	- Used directly as a substrate for the manufacture of fermentation products (such as citric acid, lysine or ethanol or glutamic acid)	[39]
	- Processed into other major starch derivatives, such as isoglucose, fructose syrup	[37]
Modified starches		
Substituted starches (starch esters, ethers, cross-linked starch):	- Textiles	[40]
	- Paper	[41]
	Water treatment (flocculation)	[42]
	Oil industry (fluid loss reducer)	[43]
Degraded/Converted starches:	- Dextrins: Adhesives (gummed paper, bag adhesives, bottle labeling);	[35]
	- Textiles (textile fabric finishing, printing);	[44]
Roast dextrin, oxidized starch, thin-boiled starch:	- Acid-modified starches: Food industry (sweets) and Pharmaceuticals	[45]
	- Oxidized starches: Food and paper industry (surface sizing, coating);	[46]
	- Textile industry (fabric finishing, warp sizing)	[47]
	- Enzymatically converted starch: paper industry and fermentation industry	[48]
Cross-linked starches:	- Food industry (desserts, bakery products, soups, sauces)	[49]
	- Textile industry (printing)	[50]
	- Adhesives	[51]
	- Pharmaceuticals	[6]

Source: Adapted from [52].

5. Non-Conventional Sources

Starch accounts for a significant fraction of a large range of crops. Cereals (e.g., corn, wheat, rice, oat, barley) contain from 60% to 80% of this carbohydrate, legumes (e.g., chickpea, bean, pea) from 25% to 50%, tubers (e.g., potato, cassava, cocoyam, arrowroot) from 60% to 90% and some green or immature fruit (e.g., banana, mango) as much as 70% of the dry weight [53]. Table 3 shows the starch content of some conventional and non-conventional sources.

Starch is frequently isolated and is used in food industries to impart the desirable functional properties, and modify food texture and consistency [54].

New starch preparation is done for each raw material before further analyses and application. There is a huge variety of methods to isolate, or prepare, starch and to evaluate its total content in products.

Among these methods authors take the liberty of using validated methods available in literature [55, 56], or their own method [13], or modified methodologies [7, 57] to isolate the starches from their studied raw materials.

To quantify starch some references use a total starch quantification kit according to the American Association of Cereal Chemists (AACC) [58], or the methodology of Association of Official Agricultural Chemists (AOAC) [59] or those validated and available in literature [60].

The source used for starch production varies worldwide depending on local traditions and climatic conditions, but more or less only starch and starch derivatives of maize and potato are of commercial interest [24].

Starches from different botanical sources vary in size, composition and the fine structure of amylopectin, and these factors influence the physical properties and end-uses for different natural starches [15]. The development of products and characterization of native starches from different botanical sources has been widely studied by several authors [99, 104, 114, 90].

The physicochemical and morphological characteristics of pine nut starch demonstrated its applicability as a pharmaceutical excipient due to the presence of phenolic compounds [6].

Sugar cane provides starches with very attractive properties that are completely different from those of cassava [115].

The addition of cellulose and cellulose nanoparticles to chayote tuber starch films was found to improve some of the mechanical, barrier and functional properties, solving the problems of plastic waste to obtain environmentally friendly materials [26].

The understanding of the gelling behavior of lentil starch and protein in composite gel is helpful for the structure formation of these two biopolymers in mixtures and will help their application in new product development [116].

After minor physical or chemical modification, chickpea starch from different cultivars is suitable for incorporation into foods subjected to high temperature processing, high shear and frozen storage due to its higher crystallinity, higher thermal stability and lower set-back [78].

Native chestnut starch presents a pasting profile similar to corn starch, making it a potential technological alternative to corn starch [76].

Velvet bean appears to be suitable in its native state for incorporation into thermally processed and frozen foods due to its higher thermal stability, higher resistance to shear and lower extent of set-back [90].

The properties of breadfruit starch indicate that it would require modification to reduce retrogradation [71].

A starch-rich fraction from the pulp of cupuassu fruit is described as being rheologically similar to the starches of tapioca (cassava) and corn [79]. The properties of sweetsop starch indicate that it has a potential for application as a thickener in frozen foods [56]. Kamo Kamo (*Cucurbita pepo*) starch exhibits behavior similar to that of potato starch [88].

Mango ginger (*Curcuma amada Roxb*.), a unique species with rhizomes that have a mango flavor, has high medicinal importance and occupies a position between turmeric and ginger starch [97].

Jack fruit seed starch is considered a useful stabilizer in a high-acid sauce [87] and could be used as an alternative for modified starches in a system needing starch with a high thermal and/or mechanical shear stability [117].

Pyrodextrinized lima bean starch is potentially useful in the manufacture of dressings and instant beverages, juices, jelly and soft candy, and it can be used as a stabilizer in sausages [118].

Table 4 briefly shows some of the application of these new starches.

The main benefit of starch addition to dairy products is cost reduction; however, starch does contribute important attributes that can improve the product functionality and performance. Starches are now readily added to yoghurts, cheese, custards etc. and thus, understanding their role within a specific product is extremely important. For example, syneresis can be inhibited or greatly reduced by starch addition; the counter effect could be a grainy texture. Thus, by manipulation the formulation and/or the processing conditions the desired outcome can be achieved [121].

There is strong interest in biologically based and/or biodegradable polymers. The reasons for this include the reduced cost, the abundance of the biomass and biodegradability of the materials, combined to the reduced disposal of non-degradable waste into the environment [122].

Although conventional sources of starch, such as corn, potato, other sources with improved properties are becoming significant to allow simpler and more robust processes. The feasibility of new starches as a renewable material for commercial application may provide cost reduction of raw material.

Industry continually aims to improve on existing products and/or explore solutions for cost reduction. Moreover, finding applications for new or existing ingredients continues to be at the forefront of their research [121].

Table 3. Conventional and non-conventional sources of starch (% dry basis)

Source	Popular name	Specie	Type	Method of obtaining	Content of starch (%)	Reference
Non-conventional						
	Amaranthus	Amaranthus cruentus	Cereal	[61]	57,5	[62]
	Annatto	Bixa orellana L.	Seed	NI *	40	[63]
	Apple	Malus domestica Borkh	Fruit	[64]	45,8	[65]
	Babassu	Orbignya phalerata Mart.	Palm	[66]	60,05	[67]
	Baby lima bean	Phaseolus lunatus	Legume	[68]	63	[68]
	Borassus aethiopum	Borassus aethiopum	Palm	[69]	24,73	[70]
	Breadfruit	Artocarpus altilis	Fruit	[69]	64,5	[71]
	Broad bean	Vicia faba L.	Legume	[72]	35	[14]
	Buckwheat	Fagopyrum tataricum Gaertn.	Pseudocereal	[73]	80,5	[29]
	Chayote	Sechium edule Sw	Tuber	[74]	60	[26]
	Cherimoya	Annona cherimola	Fruit	[75])	27,7	[60]
	Chestnut	Castanea sativa	Nut	[76]	93,2	[76]
	Chickpea	Cicer arietinum L.	Legume	[77]	34,75	[78]
	Cocoyam	Colocasia esculenta	Root	NI *	11,91	[3]
		Xanthosoma sagittifolium	Root	NI *	14,73	[3]
	Cupuassu	Theobroma grandiflorum	Fruit	[79]	15	[79]
	Edible cana	Canna edulis ker.	Grass	[80]	15,62	[81]
	Giginya	Borassus aethiopum	Palm	[50]	24,73	[70]
	Ginger	Zingiber officinale Roscoe	Rhizome	[72]	85	[82]
	Ginkgo biloba nut	Ginkgo biloba L.	Grass	[83]	32	[84]
	Grass pea	Lathyrus sativus L.	Legume	[80]	23,3	[85]
	Horse Chestnut	Aesculus indica	Nut	[72]	38,3	[13]
	Jack Bean	Canavalia ensiformis	Legume	[24]	18,42	[24]
	Jackfruit seed	Artocarpus heterophyllus L.	Fruit	[86]	32,14	[87]
	Kamo Kamo	Cucurbita pepo	Fruit	[72]	23,2	[88]
	Kudzu	Pueraria lobata	Root	[89]	99,5	[58]
	Lablab bean	Lablab purpureus	Legume	[80]	29,9	[90]
	Lentil	Lens culinaris	Legume	[91]	51,7	[92]
	Lima beans	Phaseolus lunatus	Legume	[93]	37,5	[94]
	Maca	Lepidium meyenii Walpers	Root	[95]	23,17	[96]
	Mango ginger	Curcuma amada Roxb.	Rhizome	[77]	43	[97]
	Millet	Panicum sumatrense	Cereal	[98]	70	[99]
	Navy bean	Phaseolus vulgaris	Legume	[80]	24,3	[90]
	Palmirah	Borassus flabellifer L.	Palm	[72]	38,34	[100]
	Pea	Pisum sativum L.	Legume	NI.	40	[101]
	Pehuen seeds	Araucaria araucana (Mol) K. Koch)	Pine	[72]	84	[102]
	Peruvian carrot	Arracacia xanthorrhiza, Bancroft	Root	[80]	80	[9]
	Pine nut	Araucaria angustifolia	Pine	[6]	72	[6]
	Ramon	Brosimum alicastrum Swartz	Fruit	[77]	92,57	[7]
	Soursop	Annona muricata	Fruit	[103]	27,3	[56]
	Sugar cane	Saccharum officinarum L.	Grass	[104]	99,1	[104]
	Sweet sorghum	Sorghum bicolor	Grass	[104]	98,9	[104]
	Sweetsop	Annona squamosal	Fruit	[103]	25,6	[56]
	Tef	Eragrostis tef (Zucc.) Trotter	Grain	[105]	75	[106]
	Tepary bean	Phaseolus acutifolius	Legume	[80]	27,6	[90]
	Turmeric	Curcuma longa L.	Rhizome	[72]	76	[82]
		Curcuma longa L.	Rhizome	[107]	86,62	[55]
		Curcuma zeodoaria	Rhizome	[107]	86,84	[55]
	Wolf Apple	Solanum lycocarpum	Fruit	[80]	51	[4]
	White yam	Dioscorea spp.	Tuber	NI *	83,93	[108]
	Velvet bean	Mucuna pruriens	Legume	[109]	25,2	[90]
Conventional						
	Banana	Musa paradisiaca	Fruit	[110]	26,3	[111]
	Barley	Hordeum vulgare	Cereal	[112]	60	[112]
	Corn	Zea mays	Cereal	[110]	31,3	[111]
	Potato	Solanum tuberosum	Tuber	[110]	23,65	[111]
	Rice	Oryza sativa	Grain	[105]	87,7	[106]
	Cassava	Manihot esculenta	Root	[72]	84	[113]
	Wheat	Triticum aestivum L.	Cereal	[110]	25,03	[111]

* NI – Not Identified

Table 4. Potential application for some new starches

Source	Application	Method of Obtaining	Starch (%)	References
Babassu	Biotechnological applications	[66]	60,05	[67]
Chayote	Biopolymer formation	[74]	60	[26]
Cherimoya	Food processing	[75]	27,7	[60]
Chestnut	Food processing	[76]	93.2	[76]
Edible cana	Biotechnological applications	[80]	15,62	[29]
Giginya	Food and non-food processing	[50]	24,73	[70]
Ginkgo biloba	Food processing	[83]	32	[84]
Jack fruit seeds	Food processing	[86]	32,14	[87]
Kamo Kamo	Food processing	[72]	23,2	[88]
Kudzu	Food processing	[89]	99,5	[58]
Lentil	Biopolymer formation	[91]	51,7	[116]
Lima beans	Food processing	[93]	37,5	[118]
Pea	Biotechnological applications	NI *	40	[119]
Peruvian carrot	Food processing	[6]	72	[9]
Pine nut	Biotechnological applications	[6]	72	[6]
Sweetsop	Food processing	[103]	25,6	[56]
Tef	Food processing	[105]	75	[106]
Turmeric	Biotechnological applications	[72]	76	[120]
Velvet bean	Food processing	[109]	25,2	[90]
White yam	Food processing	NI *	83,93	[71]
Wolf apple	Biotechnological applications	[80]	51	[4]

6. Future Trends and Perspectives: The Uses of Annatto and Turmeric Starches

Commercial extracts of annatto seeds and turmeric rhizomes are rich sources of the natural pigments bixin and curcumin, respectively, which are largely used for the coloring of various food products and for cosmetics and pharmaceutical applications [123, 82]. This has resulted in the increased demand for these compounds and consequently the number of studies published on obtaining these compounds. Nevertheless, there is a lack of research reporting the use of starch from these raw materials (usually contained in the residue).

Turmeric (*Curcuma longa*) and annatto (*Bixa orellana L.*), which are already used in industry to obtain food coloring and pharmaceutical products, may become commercially interesting as starch raw materials (Figures 5 and 6).

Figure 5. Whole form (A) [124], seeds (B) [125] and powder (C) [126] of annatto (*Bixa orellana L.*)

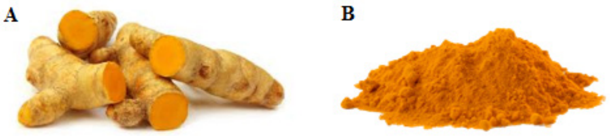

Figure 6. Rhizomes (A) [127] and powder (B) [128] of turmeric (*Curcuma longa L.*)

The main reserve carbohydrate on annatto seeds is starch [129]. Isolated starch from turmeric rhizomes after the extraction of its oil using supercritical fluid extraction (SFE) contains about 40% (w/w) starch [82].

Information on the unique characteristics of uncommon starches would be helpful for practical applications in food and non-food processing to improve the functionality of end-use products.

6.1. Methods of Value Addition to Turmeric and Annatto

6.1.1. New Product Development

The extraction of curcuminoids (pigments) from turmeric rhizomes generates a waste predominantly consisting of starch. This agroindustrial residue is considered to be a potential renewable material for ethanol and lactic acid production when subjected to acid hydrolysis [120].

Curcumin has been encapsulated in baker's yeast (*Saccharomyces cerevisiae*) cells, b-cyclodextrin (b-CD) and modified starch (MS) by various methods [130].

6.1.2. Extraction of Curcuminoids, Turmerones and Bixin Using Supercritical Technology

The starch from turmeric was analyzed before and after supercritical fluid extraction, showed in Figure 7, to obtain oleoresin and essential oil, revealing characteristics similar to commercial starches, indicating the potential for industrial applications [82].

Pressurized liquid extraction is a versatile technique that allows the extraction of natural bioactive compounds such as curcuminoids [131]. Supercritical technology has been employed for optimizing ar-turmerone extraction from turmeric volatile oil [132].

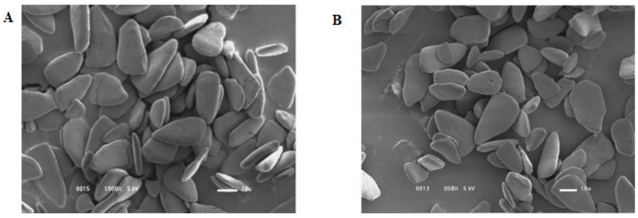

Figure 7. SEM images of turmeric starches before (A) and after (B) SFE [82]

Supercritical CO_2 extraction for the defatting of annatto seeds was studied as a pretreatment for the production of bixin [133]. Pressurized liquid extraction (PLE) and low-pressure solvent extraction (LPSE) methods have been used for the extraction of bixin from defatted annatto seeds [134].

The encapsulation of bixin in poly(3-hydroxybutirate-co-hydroxyvalerate) (PHBV) with dichloromethane as an organic solvent using the SEDS (solution-enhanced dispersion by supercritical fluids) technique was studied to evaluate the behavior of bixin release in different solvent media [135].

6.1.3. Spray-dried Turmeric Oleoresin

Turmeric extract have a commercial potential for obtaining spray-dried microparticles of poorly water-soluble phytochemicals [136].

6.1.4. Microwave and Ultrasound-assisted Extraction Technique for Curcuminoids and Bixin

A microwave-assisted extraction technique was more efficient in curcumin extraction from powdered *C. longa* rhizome in comparison with soxhlet, microwave, ultra-sonic and supercritical carbon dioxide-assisted extraction in terms of percent yield and the required extraction time [137].

Ultrasound-assisted extraction is an effective technique for annatto color extraction in comparison with conventional extraction methods, such as microwave-assisted extraction and supercritical fluid extraction [138].

Ultrasound-assisted curcumin emulsification was successfully used for the preparation of starch-stabilized nanoemulsions at lower temperatures (40–45 ℃) with reduced energy consumption [139].

7. Conclusions

Starch, a renewable biopolymer, is a versatile agricultural raw material for industrial purposes because it is inexpensive, relatively easy to handle, completely biodegradable and widely available in nature from sources such as cereals, roots, tubers, palms and seeds.

Developments in the industrial sector have increased interest in the identification of new starches with distinct properties and their potential for processing at large scales.

However, little information is available on the structure, properties and practical applicability of non-conventional sources of starch. Thus, it is necessary that these starches be studied to obtain and report their structural parameters, information that is required to gain competitiveness in an international-scale industry.

These starches show similarity or advantages with respect to some conventional sources, such as corn, potato and tapioca, making them attractive additives for food formulations in which the retrogradation process is undesirable; in addition, their aqueous suspension gelatinization requires less time and energy.

Legume, rhizome, grass, seed and palm starches can be used as ingredients in the same way as starches from cereals and tubers because of their similarity in physicochemical and functional attributes. These properties will allow the use of new starches with improved functionality, which can be employed to develop new processes and consequently new products.

ACKNOWLEDGEMENTS

The authors are grateful to FAPESP (2012/10685-8) for the financial support. Ádina L. Santana is grateful to CAPES for a Ph.D. assistantship. M. Angela A. Meireles is grateful to CNPq for the productivity grant (301301/2010-7).

REFERENCES

[1] BBCRESEARCH, 2013, "Starches/Glucose: Global Markets.", [Online]. Available: http://www.bccresearch.com/market-research/food-and-beverage/starch-glucose-fod037b.html.

[2] World News Network, 2014, "Starch Derivatives Market to Grow at a CAGR of 6.2% to 2019 in New Research...", [Online]. Available: http://article.wn.com/view/2014/05/09/Starch_Derivatives_Market_to_Grow_at_a_CAGR_of_62_to_2019_in.

[3] Falade, K. O., Okafor, C. A., 2013, "Physicochemical properties of five cocoyam (Colocasia esculenta and Xanthosoma sagittifolium) starches", Food Hydrocolloids, 30, (1), 173-181.

[4] Pascoal, A. M., Di-Medeiros, M. C. B., Batista, K. A., Leles, M. I. G., Lião, L. M., Fernandes, K. F., 2013, "Extraction and

chemical characterization of starch from S. lycocarpum fruits", Carbohydrate Polymers, 98, (2), 1304-1310.

[5] Lawal, O. S., 2011, "Hydroxypropylation of pigeon pea (Cajanus cajan) starch: Preparation, functional characterizations and enzymatic digestibility", LWT - Food Science and Technology, 44, (3), 771-778.

[6] Daudt, R. M., Külkamp-Guerreiro, I. C., Cladera-Olivera, F., Thys, R. C. S., Marczak, L. D. F., 2014, "Determination of properties of pinhão starch: Analysis of its applicability as pharmaceutical excipient", Industrial Crops and Products, 52, 420-429.

[7] Pérez-Pacheco, E., Moo-Huchin, V. M., Estrada-León, R. J., Ortiz-Fernández, A., May-Hernández, L. H., Ríos-Soberanis, C. R., Betancur-Ancona, D., 2014, "Isolation and characterization of starch obtained from Brosimum alicastrum Swarts Seeds", Carbohydrate Polymers, 101, 920-927.

[8] Zhu, F., Wang, Y.-J., 2013, "Characterization of modified high-amylose maize starch-α-naphthol complexes and their influence on rheological properties of wheat starch", Food Chemistry, 138, (1), 256-262.

[9] Albano, K. M., Franco, C. M. L., Telis, V. R. N., 2014, "Rheological behavior of Peruvian carrot starch gels as affected by temperature and concentration", Food Hydrocolloids, 40, 30-43.

[10] Yuan, Y., Zhang, L., Dai, Y., Yu, J., 2007, "Physicochemical properties of starch obtained from Dioscorea nipponica Makino comparison with other tuber starches", Journal of Food Engineering, 82, (4), 436-442.

[11] Chung, H. J., Donner, E., Liu, Q., 4.43 - Resistant Starches in Foods, pp.527-534, in: Comprehensive Biotechnology (Second Edition), M. Moo-Young (Ed.), Academic Press, Burlington, 2011.

[12] Klein, B., Pinto, V. Z., Vanier, N. L., Zavareze, E. d. R., Colussi, R., Evangelho, J. A. d., Gutkoski, L. C., Dias, A. R. G., 2013, "Effect of single and dual heat–moisture treatments on properties of rice, cassava, and pinhao starches", Carbohydrate Polymers, 98, (2), 1578-1584.

[13] Wani, I. A., Jabeen, M., Geelani, H., Masoodi, F. A., Saba, I., Muzaffar, S., 2014, "Effect of gamma irradiation on physicochemical properties of Indian Horse Chestnut (Aesculus indica Colebr.) starch", Food Hydrocolloids, 35, 253-263.

[14] Sofi, B. A., Wani, I. A., Masoodi, F. A., Saba, I., Muzaffar, S., 2013, "Effect of gamma irradiation on physicochemical properties of broad bean (Vicia faba L.) starch", LWT - Food Science and Technology, 54, (1), 63-72.

[15] Santelia, D., Zeeman, S. C., 2011, "Progress in Arabidopsis starch research and potential biotechnological applications", Current Opinion in Biotechnology, 22, (2), 271-280.

[16] Almeida, A. P., Rodríguez-Rojo, S., Serra, A. T., Vila-Real, H., Simplicio, A. L., Delgadilho, I., Beirão da Costa, S., Beirão da Costa, L., Nogueira, I. D., Duarte, C. M. M., 2013, "Microencapsulation of oregano essential oil in starch-based materials using supercritical fluid technology", Innovative Food Science & Emerging Technologies, 20, 140-145.

[17] "The difference among Flour, Cornstarch, Potato Starch, and Arrowroot", 2014, [Online]. Available: http://www.hxcorp.com.vn/news/952-the-difference-among-flour-cornstarch-potato-starch-and-arrowroot.html.

[18] "Starch", 2014, [Online]. Available: http://www.bakeinfo.co.nz/Facts/Bread-making/Bread-ingredients/Starch.

[19] Copeland, L., Blazek, J., Salman, H., Tang, M. C., 2009, "Form and functionality of starch", Food Hydrocolloids, 23, (6), 1527-1534.

[20] BioFlora, 2014, "The Dirty Work – Yellow Field Corn Case Study", [Online]. Available: http://www.bioflora.com/case-study-corn/.

[21] Carlstedt, J., Wojtasz, J., Fyhr, P., Kocherbitov, V., 2014, "Hydration and the phase diagram of acid hydrolyzed potato starch", Carbohydrate Polymers, 112, 569-577.

[22] Homer, S., Kelly, M., Day, L., 2014, "Determination of the thermo-mechanical properties in starch and starch/gluten systems at low moisture content – A comparison of DSC and TMA", Carbohydrate Polymers, 108, (0), 1-9.

[23] Bertolini, A. C., Trends in starch applications, in: Starches: Characterization, Properties and Applications, C. Press (Ed.), 2010.

[24] Lawal, O. S., Adebowale, K. O., 2005, "Physicochemical characteristics and thermal properties of chemically modified jack bean (Canavalia ensiformis) starch", Carbohydrate Polymers, 60, (3), 331-341.

[25] Li, J. Z., Chapter 18 - The Use of Starch-Based Materials for Microencapsulation, pp.195-210, in: Microencapsulation in the Food Industry, A. G. Gaonkar, N. Vasisht, A. R. Khare, R. Sobel (Ed.), Academic Press, San Diego, 2014.

[26] Aila-Suárez, S., Palma-Rodríguez, H. M., Rodríguez-Hernández, A. I., Hernández-Uribe, J. P., Bello-Pérez, L. A., Vargas-Torres, A., 2013, "Characterization of films made with chayote tuber and potato starches blending with cellulose nanoparticles", Carbohydrate Polymers, 98, (1), 102-107.

[27] Gregorová, E., Pabst, W., Bohačenko, I., 2006, "Characterization of different starch types for their application in ceramic processing", Journal of the European Ceramic Society, 26, (8), 1301-1309.

[28] Cyprych, K., Sznitko, L., Mysliwiec, J., 2014, "Starch: Application of biopolymer in random lasing", Organic Electronics, 15, (10), 2218-2222.

[29] Li, M., Liu, P., Zou, W., Yu, L., Xie, F., Pu, H., Liu, H., Chen, L., 2011, "Extrusion processing and characterization of edible starch films with different amylose contents", Journal of Food Engineering, 106, (1), 95-101.

[30] Waterschoot, J., Gomand, S. V., Willebrords, J. K., Fierens, E., Delcour, J. A., 2014, "Pasting properties of blends of potato, rice and maize starches", Food Hydrocolloids, 41, 298-308.

[31] "Jackfruit", 2014, [Online]. Available: http://madscientistskitchen.blogspot.com.br/2014/06/neerphanas-aa-chi-bhaji-green-or-raw.html.

[32] "Jackfruit Seeds", 2014, [Online]. Available: http://hxcorp.com.vn/product/508-jackfruit-seeds.html.

[33] Vedha Hari, B. N., Praneetha, T., Prathyusha, T., Mounika, K., Ramya Devi, D., 2014, "Development of Starch-Gelatin

Complex Microspheres as Sustained Release Delivery System", J. Adv. Pharm. Tech. Res., 3, (3), 182-187.

[34] Shahid ul, I., Shahid, M., Mohammad, F., 2013, "Perspectives for natural product based agents derived from industrial plants in textile applications – a review", Journal of Cleaner Production, 57, 2-18.

[35] Herrero, A. M., Carmona, P., Jiménez-Colmenero, F., Ruiz-Capillas, C., 2014, "Polysaccharide gels as oil bulking agents: Technological and structural properties", Food Hydrocolloids, 36, 374-381.

[36] Homayouni, A., Azizi, A., Ehsani, M. R., Yarmand, M. S., Razavi, S. H., 2008, "Effect of microencapsulation and resistant starch on the probiotic survival and sensory properties of synbiotic ice cream", Food Chemistry, 111, (1), 50-55.

[37] Liu, Y., Bhandari, B., Zhou, W., 2007, "Study of glass transition and enthalpy relaxation of mixtures of amorphous sucrose and amorphous tapioca starch syrup solid by differential scanning calorimetry (DSC)", Journal of Food Engineering, 81, (3), 599-610.

[38] Rosicka-Kaczmarek, J., Kwaśniewska-Karolak, I., Nebesny, E., Miśkiewicz, K., 2013, "Influence of variety and year of wheat cultivation on the chemical composition of starch and properties of glucose hydrolysates", Journal of Cereal Science, 57, (1), 98-106.

[39] Lu, Z., He, F., Shi, Y., Lu, M., Yu, L., 2010, "Fermentative production of L(+)-lactic acid using hydrolyzed acorn starch, persimmon juice and wheat bran hydrolysate as nutrients", Bioresource Technology, 101, (10), 3642-3648.

[40] Poomipuk, N., Reungsang, A., Plangklang, P., 2014, "Poly-β-hydroxyalkanoates production from cassava starch hydrolysate by Cupriavidus sp. KKU38", International Journal of Biological Macromolecules, 65, 51-64.

[41] Becerra, V., Odermatt, J., 2014, "Direct determination of cationic starches in paper samples using analytical pyrolysis", Journal of Analytical and Applied Pyrolysis, 105, (0), 348-354.

[42] Letelier-Gordo, C. O., Holdt, S. L., De Francisci, D., Karakashev, D. B., Angelidaki, I., 2014, "Effective harvesting of the microalgae Chlorella protothecoides via bioflocculation with cationic starch", Bioresource Technology, 167, 214-218.

[43] Li, M., Liu, G.-L., Chi, Z., Chi, Z.-M., 2010, "Single cell oil production from hydrolysate of cassava starch by marine-derived yeast Rhodotorula mucilaginosa TJY15a", Biomass and Bioenergy, 34, (1), 101-107.

[44] Setty, C. M., Deshmukh, A. S., Badiger, A. M., 2014, "Hydrolyzed polyacrylamide grafted maize starch based microbeads: Application in pH responsive drug delivery", International Journal of Biological Macromolecules, 70, 1-9.

[45] Yang, Z., Yuan, B., Li, H., Yang, Y., Yang, H., Li, A., Cheng, R., 2014, "Amphoteric starch-based flocculants can flocculate different contaminants with even opposite surface charges from water through molecular structure control", Colloids and Surfaces A: Physicochemical and Engineering Aspects, 455, 28-35.

[46] Çatal, H., İbanoğlu, Ş., 2014, "Effect of aqueous ozonation on the pasting, flow and gelatinization properties of wheat starch", LWT - Food Science and Technology, 59, (1), 577-582.

[47] Gonçalves, P. M., Noreña, C. P. Z., da Silveira, N. P., Brandelli, A., 2014, "Characterization of starch nanoparticles obtained from Araucaria angustifolia seeds by acid hydrolysis and ultrasound", LWT - Food Science and Technology, 58, (1), 21-27.

[48] van der Maarel, M. J. E. C., Leemhuis, H., 2013, "Starch modification with microbial alpha-glucanotransferase enzymes", Carbohydrate Polymers, 93, (1), 116-121.

[49] Gamonpilas, C., Pongjaruvat, W., Methacanon, P., Seetapan, N., Fuongfuchat, A., Klaikherd, A., 2013, "Effects of cross-linked tapioca starches on batter viscosity and oil absorption in deep-fried breaded chicken strips", Journal of Food Engineering, 114, (2), 262-268.

[50] Lay, C.-H., Kuo, S.-Y., Sen, B., Chen, C.-C., Chang, J.-S., Lin, C.-Y., 2012, "Fermentative biohydrogen production from starch-containing textile wastewater", International Journal of Hydrogen Energy, 37, (2), 2050-2057.

[51] Czech, Z., Wilpiszewska, K., Tyliszczak, B., Jiang, X., Bai, Y., Shao, L., 2013, "Biodegradable self-adhesive tapes with starch carrier", International Journal of Adhesion and Adhesives, 44, 195-199.

[52] Agrosynergie, Description of the sector, pp.17-80, in: Evaluation of Common Agricultural Policy measures applied to the starch sector E. Commission (Ed.), 2010.

[53] de la Torre-Gutiérrez, L., Chel-Guerrero, L. A., Betancur-Ancona, D., 2008, "Functional properties of square banana (Musa balbisiana) starch", Food Chemistry, 106, (3), 1138-1144.

[54] Kuttigounder, D., Lingamallu, J. R., Bhattacharya, S., 2011, "Turmeric Powder and Starch: Selected Physical, Physicochemical, and Microstructural Properties", Journal of Food Science, 76, (9), 1284-1291.

[55] Leonel, M., Sarmento, S. B. S., Cereda, M. P., 2003, "New starches for the food industry: Curcuma longa and Curcuma zedoaria", Carbohydrate Polymers, 54, (3), 385-388.

[56] Nwokocha, L. M., Williams, P. A., 2009, "New starches: Physicochemical properties of sweetsop (Annona squamosa) and soursop (Anonna muricata) starches", Carbohydrate Polymers, 78, (3), 462-468.

[57] Madruga, M. S., de Albuquerque, F. S. M., Silva, I. R. A., do Amaral, D. S., Magnani, M., Queiroga Neto, V., 2014, "Chemical, morphological and functional properties of Brazilian jackfruit (Artocarpus heterophyllus L.) seeds starch", Food Chemistry, 143, 440-445.

[58] Van Hung, P., Morita, N., 2007, "Chemical compositions, fine structure and physicochemical properties of kudzu (Pueraria lobata) starches from different regions", Food Chemistry, 105, (2), 749-755.

[59] Braga, M. E. M., Moreschi, S. R. M., Meireles, M. A. A., 2006, "Effects of supercritical fluid extraction on Curcuma longa L. and Zingiber officinale R. starches. ", Carbohydrate Polymers, 63, 340-346.

[60] Goñi, O., Escribano, M. I., Merodio, C., 2008, "Gelatinization and retrogradation of native starch from cherimoya fruit during ripening, using differential scanning calorimetry",

LWT - Food Science and Technology, 41, (2), 303-310.

[61] Tovar, J., Bjoerck, I. M., Asp, N. G., 1990, "Starch content and .alpha.-amylolysis rate in precooked legume flours", Journal of Agricultural and Food Chemistry, 38, (9), 1818-1823.

[62] Villarreal, M. E., Ribotta, P. D., Iturriaga, L. B., 2013, "Comparing methods for extracting amaranthus starch and the properties of the isolated starches", LWT - Food Science and Technology, 51, (2), 441-447.

[63] Nabard, 2014, "Annatto", [Online]. Available: https://www.nabard.org/english/medical_annato2.aspx.

[64] Kasemsuwan, T., Jane, J., Schnable, P., Stinar, P., Robertson, D., 1995, "Characterization of the dominant mutant amyl-ose-extender (Ae1-5180) maize starch", Cereal Chem., 72, (5), 457-464.

[65] Stevenson, D. G., Domoto, P. A., Jane, J.-l., 2006, "Structures and functional properties of apple (Malus domestica Borkh) fruit starch", Carbohydrate Polymers, 63, (3), 432-441.

[66] Métodos Químicos e Físicos para Análise de Alimentos, Instituto Adolfo Lutz, São Paulo, 2005.

[67] Cinelli, B. A., López, J. A., Castilho, L. R., Freire, D. M. G., Castro, A. M., 2014, "Granular starch hydrolysis of babassu agroindustrial residue: A bioprocess within the context of biorefinery", Fuel, 124, (0), 41-48.

[68] Betancur-Ancona, D., López-Luna, J., Chel-Guerrero, L., 2003, "Comparison of the chemical composition and functional properties of Phaseolus lunatus prime and tailing starches", Food Chemistry, 82, (2), 217-225.

[69] Chrastil, J., 1987, "Improved Calorimetric Determination of Amylose in Starches and Flours", Carbohydrate Research, 158, 154–158.

[70] Barminas, J. T., Onen, A. I., Williams, E. T., Zaruwa, M. Z., Mamuru, S. A., Haggai, D., 2008, "Studies on functional properties of borassus starch from fresh germinating nuts of giginya (Borassus aethiopum) palm", Food Hydrocolloids, 22, (2), 298-304.

[71] Nwokocha, L. M., Williams, P. A., 2011, "Comparative study of physicochemical properties of breadfruit (Artocarpus altilis) and white yam starches", Carbohydrate Polymers, 85, (2), 294-302.

[72] AOAC, Official Methods of Analysis of AOAC International, Vol. 2, 16nd ed., Arlington, 1995.

[73] Morrison, W. R., Laignelet, B., 1983, " An improved colorimetric procedure for determining apparent and total amyl-ose in cereal and other starches", Journal of Cereal Science, 1, (1), 9-20.

[74] Flores-Gorosquera, E., García-Suárez, F. J., Flores-Huicochea, E., Núñez-Santiago, M. C., González-Soto, R. A., Bello-Pérez, L. A., 2004, "Rendimiento del proceso de extracción de almidón a partir de frutos de plátano (Musa paradisiaca), Estudio en planta piloto", Acta Científica Venezolana, 55, 86-90.

[75] Aparicio-Saguilán, A., Méndez-Montealvo, G., Solorza-Feria, J., Bello-Pérez, L. A., 2006, "Thermal and viscoelastic properties of starch gels from maize varieties", Journal of the Science of Food and Agriculture, 86, (7), 1078-1086.

[76] Cruz, B. R., Abraão, A. S., Lemos, A. M., Nunes, F. M., 2013, "Chemical composition and functional properties of native chestnut starch (Castanea sativa Mill)", Carbohydrate Polymers, 94, (1), 594-602.

[77] Hoover, R., Ratnayake, W. S., 2002, " Starch characteristics of black bean, chick pea, lentil, navy bean and pinto bean cultivars grown in Canada. ", Food Chemistry, 78, 489–498.

[78] Hughes, T., Hoover, R., Liu, Q., Donner, E., Chibbar, R., Jaiswal, S., 2009, "Composition, morphology, molecular structure, and physicochemical properties of starches from newly released chickpea (Cicer arietinum L.) cultivars grown in Canada", Food Research International, 42, (5–6), 627-635.

[79] Vriesmann, L. C., Silveira, J. L. M., Petkowicz, C. L. d. O., 2009, "Chemical and rheological properties of a starch-rich fraction from the pulp of the fruit cupuassu (Theobroma grandiflorum)", Materials Science and Engineering: C, 29, (2), 651-656.

[80] AACC, Approved methods of the American Association of Cereal Chemists, Vol. 1-2, 9nd ed., St. Paul, Minnesota, 1995.

[81] Huang, Y., Jin, Y., Fang, Y., Li, Y., Zhao, H., 2013, "Simultaneous utilization of non-starch polysaccharides and starch and viscosity reduction for bioethanol fermentation from fresh Canna edulis Ker. tubers", Bioresource Technology, 128, 560-564.

[82] Braga, M. E. M., Moreschi, S. R. M., Meireles, M. A. A., 2006, "Effects of supercritical fluid extraction on Curcuma longa L. and Zingiber officinale R. starches", Carbohydrate Polymers, 63, (3), 340-346.

[83] Miao, M., Zhang, T., Jiang, B., 2009, "Characterizations of Kabuli and Desi chickpea starches cultivated in China", Food Chemistry, 113, 1025–1032.

[84] Miao, M., Jiang, H., Jiang, B., Cui, S. W., Jin, Z., Zhang, T., 2012, "Structure and functional properties of starches from Chinese ginkgo (Ginkgo biloba L.) nuts", Food Research International, 49, (1), 303-310.

[85] Jayakody, L., Lan, H., Hoover, R., Chang, P., Liu, Q., Donner, E., 2007, "Composition, molecular structure, and physicochemical properties of starches from two grass pea (Lathyrus sativus L.) cultivars grown in Canada", Food Chemistry, 105, (1), 116-125.

[86] Bobbio, F. O., EI-Dash, A. A., Bobbio, P. A., Rodrigues, L. R., 1978, "Isolation and characterization of the physico-chemiscal properties of the starch of jackfruit seeds (Artocarpus heterophyllus)", Cereal Chemistry, 55, 505-511.

[87] Rengsutthi, K., Charoenrein, S., 2011, "Physico-chemical properties of jackfruit seed starch (Artocarpus heterophyllus) and its application as a thickener and stabilizer in chilli sauce", LWT - Food Science and Technology, 44, (5), 1309-1313.

[88] Singh, J., McCarthy, O. J., Singh, H., Moughan, P. J., Kaur, L., 2007, "Morphological, thermal and rheological characterization of starch isolated from New Zealand Kamo Kamo (Cucurbita pepo) fruit – A novel source", Carbohydrate Polymers, 67, (2), 233-244.

[89] Klucinec, J. D., Thompson, D. B., 1998, "Fractionation of High-Amylose Maize Starches by Differential Alcohol Precipitation and Chromatography of the Fractions ", Cereal Chemistry, 75, 887–896.

[90] Maaran, S., Hoover, R., Donner, E., Liu, Q., 2014, "Composition, structure, morphology and physicochemical properties of lablab bean, navy bean, rice bean, tepary bean and velvet bean starches", Food Chemistry, 152, 491-499.

[91] Li, B. W., Schuhmann, P. J., Wolf, W. R., 1985, "Chromatographic Determinations of Sugars and Starch in a Diet Composite Reference Material.", J. Agric. Food Chem. , 33, (33), 531-536.

[92] Sotomayor, C., Frias, J., Fornal, J., Sadowska, D., Urbano, G., Vidal-Verde, C., 1999, "Lentil Starch Content and its Microscopical Structure as Influenced by Natural Fermentation", Starch/Stärke, 51, (5).

[93] I., G., García-Díaz, L., Saura-Calixto, F., 1997, "A starch hydrolysis procedure to estimate glycemic index", Nutr Res., 17, 427–437.

[94] Bello-Pérez, L. A., Sayágo-Ayerdi, S. G., Cháves-Murillo, C. E., Agama-Acevedo, E., Tovar, J., 2007, "Proximal composition and in vitro digestibility of starch in lima bean (Phaseolus lunatus) varieties", Journal of the Science of Food and Agriculture, 87, 2570-2575.

[95] Areas, J. A. G., Lajolo, F. M., 1981, ".Starch transfor-mation during banana ripening: I-The phosphorylase and phosphatase behavior in Musa acuminate", Journal of Food Biochemistry, 5, 19-37.

[96] Rondán-Sanabria, G. G., Finardi-Filho, F., 2009, "Physical–chemical and functional properties of maca root starch (Lepidium meyenii Walpers)", Food Chemistry, 114, (2), 492-498.

[97] Policegoudra, R. S., Aradhya, S. M., 2008, "Structure and biochemical properties of starch from an unconventional source—Mango ginger (Curcuma amada Roxb.) rhizome", Food Hydrocolloids, 22, (4), 513-519.

[98] Annor, G. A., Marcone, M., Bertoft, E., Seetharaman, K., 2013, "In Vitro Starch Digestibility and Expected Glycemic Index of Kodo Millet (Paspalum scrobiculatum) as Affected by Starch–Protein–Lipid Interactions", Cereal Chemistry Journal, 90, (3), 211-217.

[99] Zhu, F., 2014, "Structure, physicochemical properties, and uses of millet starch", Food Research International, 64, 200-211.

[100] Naguleswaran, S., Vasanthan, T., Hoover, R., Bressler, D., 2014, "Amylolysis of amylopectin and amylose isolated from wheat, triticale, corn and barley starches", Food Hydrocolloids, 35, 686-693.

[101] Shi, M., Zhang, Z., Yu, S., Wang, K., Gilbert, R. G., Gao, Q., 2014, "Pea starch (Pisum sativum L.) with slow digestion property produced using β-amylase and transglucosidase", Food Chemistry, 164, 317-323.

[102] Castaño, J., Bouza, R., Rodríguez-Llamazares, S., Carrasco, C., Vinicius, R. V. B., 2012, "Processing and characterization of starch-based materials from pehuen seeds (Araucaria araucana (Mol) K. Koch)", Carbohydrate Polymers, 88, (1), 299-307.

[103] Selected laboratory methods for maize quality evaluation, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, 1995.

[104] Alves, F. V., Polesi, L. F., Aguiar, C. L., Sarmento, S. B. S., 2014, "Structural and physicochemical characteristics of starch from sugar cane and sweet sorghum stalks", Carbohydrate Polymers, 111, 592-597.

[105] Fraser, T. R., Brendon-Bravo, M., Holmes, D. C., 1956, "Proximate analysis of wheat flour carbohydrates. 1. Methods and scheme of analysis", J. Sci. Food Agric., 7, 577-589.

[106] Abebe, W., Ronda, F., 2014, "Rheological and textural properties of tef [Eragrostis tef (Zucc.) Trotter] grain flour gels", Journal of Cereal Science, 60, (1), 122-130.

[107] Rickard, J. E., Behn, K. R., 1987, "Evaluation of acid and enzyme hydrolitic methods for determination of cassava starch", Journal of the Science of Food and Agriculture, 41, 373-379.

[108] Falade, K. O., Ayetigbo, O. E., 2014, "Effects of annealing, acid hydrolysis and citric acid modifications on physical and functional properties of starches from four yam (Dioscorea spp.) cultivars", Food Hydrocolloids, 1-11.

[109] Ambigaipalan, P., Hoover, R., Donner, E., Liu, Q., Jaiswal, S., Chibbar, R., Nantanga, K. K. M., Seetharaman, K., 2011, "Structure of faba bean, black bean and pinto bean starches at different levels of granule organization and their physicochemical properties", Food Research International, 44, (9), 2962-2974.

[110] Williams, P. C., Kuzina, F. D., Hlynka, I., 1970, "A rapid calorimetric procedure for estimating the amylose content of starches and flours", Cereal Chem., 47, 411-420.

[111] Carrillo-Navas, H., Hernández-Jaimes, C., Utrilla-Coello, R. G., Meraz, M., Vernon-Carter, E. J., Alvarez-Ramirez, J., 2014, "Viscoelastic relaxation spectra of some native starch gels", Food Hydrocolloids, 37, (0), 25-33.

[112] Holtekjølen, A. K., Uhlen, A. K., Bråthen, E., Sahlstrøm, S., Knutsen, S. H., 2006, "Contents of starch and non-starch polysaccharides in barley varieties of different origin", Food Chemistry, 94, (3), 348-358.

[113] Osunsami, A. T., Akingbala, J. O., Oguntimein, G. B., 1989, "Effect of Storage on Starch Content and Modification of Cassava Starch ", Starch/Starke, 41, 54-57.

[114] Kim, J.-Y., Choi, Y.-G., Byul Kim, S. R., Lim, S.-T., 2014, "Humidity stability of tapioca starch–pullulan composite films", Food Hydrocolloids, 41, 140-145.

[115] Piyachomkwan, K., Chotineeranat, S., Kijkhunasatian, C., Tonwitowat, R., Prammanee, S., Oates, C. G., Sriroth, K., 2002, "Edible canna (Canna edulis) as a complementary starch source to cassava for the starch industry", Industrial Crops and Products, 16, (1), 11-21.

[116] Joshi, M., Aldred, P., Panozzo, J. F., Kasapis, S., Adhikari, B., 2014, "Rheological and microstructural characteristics of lentil starch–lentil protein composite pastes and gels", Food Hydrocolloids, 35, (0), 226-237.

[117] Mukprasirt, A., Sajjaanantakul, K., 2004, "Physico-chemical properties of flour and starch from jackfruit seeds (Artocarpus heterophyllus Lam.) compared with modified starches", International Journal of Food Science & Technology, 39, (3), 271-276.

[118] Campechano-Carrera, E., Corona-Cruz, A., Chel-Guerrero, L., Betancur-Ancona, D., 2007, "Effect of pyrodextrinization on available starch content of Lima bean (Phaseolus lunatus)

and Cowpea (Vigna unguiculata) starches", Food Hydrocolloids, 21, (3), 472-479.

[119] Ahmed, J., Auras, R., 2011, "Effect of acid hydrolysis on rheological and thermal characteristics of lentil starch slurry", LWT - Food Science and Technology, 44, (4), 976-983.

[120] Nguyen, C.-N., Le, T.-M., Chu-Ky, S., 2014, "Pilot scale simultaneous saccharification and fermentation at very high gravity of cassava flour for ethanol production", Industrial Crops and Products, 56, 160-165.

[121] Considine, T., Noisuwan, A., Hemar, Y., Wilkinson, B., Bronlund, J., Kasapis, S., 2011, "Rheological investigations of the interactions between starch and milk proteins in model dairy systems: A review", Food Hydrocolloids, 25, (8), 2008-2017.

[122] Olivato, J. B., Müller, C. M. O., Carvalho, G. M., Yamashita, F., Grossmann, M. V. E., 2014, "Physical and structural characterisation of starch/polyester blends with tartaric acid", Materials Science and Engineering: C, 39, 35-39.

[123] Santos, L. F., Dias, V. M., Pilla, V., Andrade, A. A., Alves, L. P., Munin, E., Monteiro, V. S., Zilio, S. C., 2014, "Spectroscopic and photothermal characterization of annatto: Applications in functional foods", Dyes and Pigments, 110, (0), 72-79.

[124] OrgenFamily, 2014, "Organic Annatto (Bixa orellana)", [Online]. Available: http://www.orgenfamily.com/orgen-bt.html.

[125] "Annatto Powder", 2014, [Online]. Available: http://www.souschef.co.uk/annatto-powder.html.

[126] GourmetStore, 2014, "Annatto Seed", [Online]. Available: http://www.gourmetstore.com/node/718.

[127] "Curcuma longa", 2014, [Online]. Available: http://www.ndhealthfacts.org/wiki/Curcuma_longa.

[128] "Turmeric: an ancient spice that can benefit you today", 2014, [Online]. Available: http://functionalformularies.com/2014/03/28/turmeric/#sthash.pLOFJ8o4.dpbs.

[129] Amaral, L. I. V., Pereira, M. F. D. A., Cortelazzo, A. L., 2001, "Formação das Substâncias de Reserva Durante o Desenvolvimento de Sementes de Urucum (Bixa orellana L. - Bixaceae)", Acta Bot. Bras., 15, (1), 125-132.

[130] Paramera, E. I., Konteles, S. J., Karathanos, V. T., 2011, "Stability and release properties of curcumin encapsulated in Saccharomyces cerevisiae, β-cyclodextrin and modified starch", Food Chemistry, 125, (3), 913-922.

[131] Osório-Tobón, J. F., Meireles, M. A. A., 2013, "Recent Applications of Pressurized Fluid Extraction: Curcuminoids Extraction with Pressurized Liquids", Food and Public Health, 3, (6), 289-303.

[132] Carvalho, P. I. N., Osório-Tobón, J. F., Rostagno, M. A., Petenate, A. J., Meireles, M. A. A., "Optimization of the Ar-Turmerone Extraction from Turmeric (Curcuma longa L.) Using Supercritical Carbon Dioxide", in 14th European Meeting on Supercritical Fluids, 2014.

[133] Albuquerque, C. L. C., Meireles, M. A. A., 2012, "Defatting of annatto seeds using supercritical carbon dioxide as a pretreatment for the production of bixin: Experimental, modeling and economic evaluation of the process", The Journal of Supercritical Fluids, 66, (0), 86-95.

[134] Rodrigues, L. M., Alcázar-Alay, S. C., Petenate, A. J., Meireles, M. A. A., 2014, "Bixin extraction from defatted annatto seeds", Comptes Rendus Chimie, 17, (3), 268-283.

[135] Boschetto, D. L., Aranha, E. M., de Souza, A. A. U., Souza, S. M. A. G. U., Ferreira, S. R. S., Priamo, W. L., Oliveira, J. V., 2014, "Encapsulation of bixin in PHBV using SEDS technique and in vitro release evaluation", Industrial Crops and Products, 60, 22-29.

[136] Martins, R. M., Pereira, S. V., Siqueira, S., Salomão, W. F., Freitas, L. A. P., 2013, "Curcuminoid content and antioxidant activity in spray dried microparticles containing turmeric extract", Food Research International, 50, (2), 657-663.

[137] Li, M., Ngadi, M. O., Ma, Y., 2014, "Optimisation of pulsed ultrasonic and microwave-assisted extraction for curcuminoids by response surface methodology and kinetic study", Food Chemistry, 165, 29-34.

[138] Yolmeh, M., Habibi Najafi, M. B., Farhoosh, R., 2014, "Optimisation of ultrasound-assisted extraction of natural pigment from annatto seeds by response surface methodology (RSM)", Food Chemistry, 155, 319-324.

[139] Abbas, S., Bashari, M., Akhtar, W., Li, W. W., Zhang, X., 2014, "Process optimization of ultrasound-assisted curcumin nanoemulsions stabilized by OSA-modified starch", Ultrasonics Sonochemistry, 21, (4), 1265-1274.