Chapter

Root and Tuber Crops: An Underexploited Source of Pectin and Future Prospects

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Abstract

Starchy root and tuber crops are important global sources of carbohydrates with potentials to lift millions of people out of poverty across developing countries. The billion dollar pectin market which relies heavily on pectin isolated from fruits provides ample opportunities for non-conventional sources from the root and tuber food group. Pectins are abundant in higher plants and poses varying properties that can be used across industries including the food, the health and pharmaceutical sector, and in packaging regimes. We review current research into the isolation, modification, characterization and application of pectin sourced from root and tubers and explore the implications for an under-explored market in Africa. Despite the limited research conducted on root and tuber pectin, Citric acid used in the solvent method has shown to be a promising method of extraction, producing high pectin yields with industrial and pharmaceutical properties.

Keywords: root and tuber, food, pectin, isolation, Africa

1. Introduction

Before the introduction of cereals in many regions and especially in the tropics, root and tubers served as the only staple crop group that fed populations. Lebot [1] also described them as among the oldest crops on earth. Examples of these crops include, cassava, yam, potato, sweet potato and cocoyam. They share common characteristics including: vegetative propagation, breeding approaches, post-harvest issues (bulky and perishable), requiring low inputs, adaptability to mixed farming and heavily involves women throughout their production value chains [2].

These food security crops serve as major sources of calories, nutrition, income and employment for millions of people, especially across developing countries in Sub-Saharan Africa, Asia and Latin America [3]. According to current FAO estimates, roots and tubers are the fourth most produced group of crops after cereals, sugar crops and fruits (**Figure 1**) and are the second most important food group, serving around 300 million people across developing countries [2, 4]. Africa produces the highest root and tuber crops at an estimated value of over 300 million tonnes across approximately 39 million hectares of land (**Table 1**). In this region, the food group

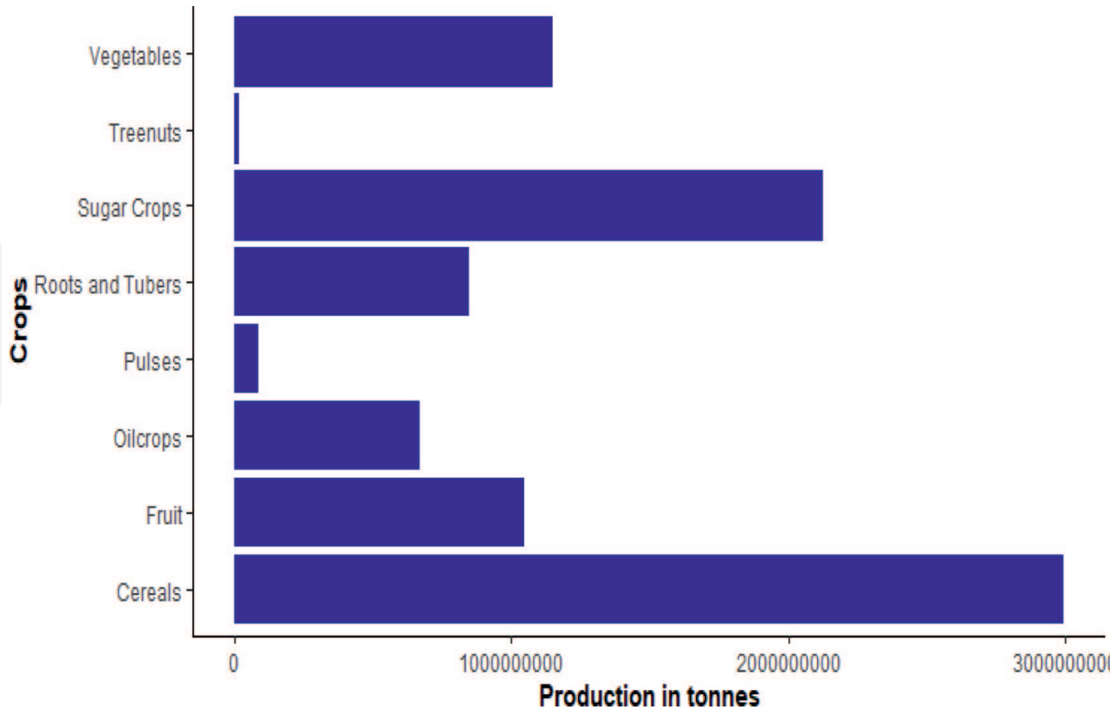

Figure 1.
2020 FAO production estimates of crop groups produced around the world.

	Africa	America	Asia	Europe	Oceania
Production (t)	333,594,726	78,182,331	324,104,149	107,693,897	4,047,282
Area harvested (ha)	38,953,062	4,104,037	15,590,781	4,571,456	318,331

Table 1.
Estimated production and area harvested values of root and tuber crops distributed around the world.

plays an integral part of social cultural activities [5] and has shown great potentials in alleviating poverty and improving the resilience of its mostly limited resourced stakeholders in tackling the growing threats from climate change [6].

For these reasons, root and tubers have received, in the past 20 years, invaluable attention and research funding from national and international agencies like the Consultative Group on International Agricultural Research (CGIAR), the Bill and Melinda Gates Foundations (BMGF), financial institutions (e.g. World Bank) and National Agricultural Centres [7]. These concerted efforts have resulted in the increase in production (development of improved varieties and formal seed quality systems) and innovative research into the complex roles this particular food group plays in nutrition, as animal feed, as raw materials for starch and alcohol production, and fermented foods and beverages [8–10].

2. Pectin research in root and tubers

Root and tubers store edible starchy materials in their stems, roots, rhizomes, corms, and tubers and serve as sources of important bioactive compounds and polymers with nutritional and pharmaceutical potentials [4]. One of the most important but least explored polymers in root and tuber crops are pectins. In higher plants, pectins are an integral part of the primary cell wall and middle lamella and are also most abundant in non-woody parts of the plant [11]. They are non-starch heteropolysaccharides composed mainly of covalently α-1,4-linked D-galacturonic acid (GalA) units (peculiar to the homogalacturonan pectin chain) with the urinate residues in their natural state partially esterified. But they may vary in chemical composition, sugar content and molecular weight based on the development stage of the plant, isolation condition, storage and process of production [12]. Pectins can also be classified based on their degree of esterification and chemical structure. These characteristics contribute to the multi-functionality of pectin that include: textural and rheological properties of plant-based foods, movement of water and nutrients, maintaining the turgidity and concentration of the cell wall and their applications in food and industry [13, 14]. In food and pharmaceutical industries these polymers have been used, for years, as gelling agents, emulsifiers, stabilizers and thickeners [15–17]. Therapeutically, pectins are soluble dietary fibers, can reduce blood cholesterol, used in drug delivery, replace fats in confectionery and improve pre-biotic activities in the gut [11].

Although abundant in most higher plants, commercially produced pectins are primarily sourced from fruit residue (citrus peels and apple pomace especially) generated in large quantities from fruit processing companies. In this chapter, we will be reviewing the structure, extraction, modification and application of pectins from root and tubers and exploring the impact of the food group as a non-conventional source of commercial pectin in Africa.

2.1 Pectin extraction

Extraction techniques are a major factor in determining the quality and yield extracted from pectin sources. Some of which include the most common - microwave heating and direct boiling using chemicals [18]; and the more novel methods that include the use of ultrasonic sound, autoclave, enzymes and electromagnetic induction [19]. In some cases methods have been combined to extract pectin [20]. Pectin from root and tuber crops as well as their food products and by-products have been extracted using different extraction methods (**Table 2**). Infante et al. [21] reported the extraction of pectin from cassava bread using a boiling solution of oxalic acid and ammonium oxalate, while Coelho et al. [22] extracted pectin from cassava residue using ammonium oxalate and further precipitated with ethanol. Menoli and Belia [23] also reported the precipitation of pectin from cassava galacturonic acid using a modified method [30] that involved saturated potassium acetate solution and 95% ethanol in a 4:1 ratio. Ogutu and Mu [24] before evaluating the effect of ultrasonic factors on sweet potato pectin extracted the polymer by using sodium hexametaphosphate. Ultrasound and microwave assisted acid extraction methods have also been used to extract pectin from sweet potato residues [25]. Citric acid was reported as an ideal solvent for the extraction of pectin from sweet potato peels [26]. Yang et al. [27] extracted higher yields of pectin than sourced from citrus and apple, using different acidic solvents from potato pulp. For yam pectin, Tang et al. [28] recently isolated the polymer from *Dioscorea opposita* tubers using the enzyme extraction method while Effah-Manu et al. [29] successfully extracted pectin from *D. rotundata* and *D. alata* tubers using citrus acid as a solvent.

Pectin source	Method of extraction	Characterization	Application	References
Cassava bread	**Solvent extraction**: Extracted with a boiling solution of 0.25% oxalic acid and 0.25% ammonium oxalate **Yield**: 0.34–0.61%	No	No	[21]
Cassava residue	**Solvent extraction**: Three volumes 0.5% (w/v) ammonium oxalate solution and ethanol (92.8° GL) **Yield**: 0.1–0.5%	No	Used to coat nanoparticles containing β-carotene aiming at the gastrointestinal administration of this lipophilic nutraceutical.	[22]
Cassava galactoronic acid	**Solvent extraction**: 5 ml cooking liquor, three volumes of saturated potassium acetates olution and 95% ethanol (4:1)	No	No	[23]
Sweet potato galacturonic acid	**Solvent extraction**: Using sodium hexametaphosphate, purified using an ultrafiltration column then precipitated and washed successively with 60%, 75% and 90% ethanol	12% degree of methoxylation (DE) I.e. low methoxy pectin	No	[24]
Sweet potato residue	Ultrasound/microwave assisted acid extraction method: extraction by HCl (pH 2), centrifuged and collected supernatant was purified through ultrafiltration. Pectin was precipitated using three volumes (v/v) of absolute ethanol and further washed three times with ethanol at different concentrations	Molecular weight: 7.53 × 105 g mol-1 DE: 33.17%; low methoxy pectin	Modified pectin with improved emulsifying properties	[25]
Sweet potato residue	Solvent extraction: using citric acid at different temperatures (60,80,100°C), for different times (40,70 and 100mins) under different pH (1.0,1.5 and 2.0) Yield: 1.9–64%	DE: 58.5%; high methylation pectin	High emulsifying properties	[26]

Pectin source	Method of extraction	Characterization	Application	References
Potato pulp	Solvent extraction: Using HCl, H_2SO_4, HNO_3, citric acid, and acetic acid. Yield: Citric acid produced the highest yield at 14.34%	highly branched rhamnogalacturonan I domain DE: 37.45%; low methoxy pectin	High emulsifying activity and emulsion stability	[27]
Yam residue (Chinease Yam Polysaccharides)	Extracted with pure water and treated with α-amylase (95°C, 90 min), glucoamylase (60°C, 30 min), papain (60°C, 40 min) and enzyme deactivation (100°C, > 10 min) in sequence. The compex was further precipitated with ethanol concentration of 80% (v/v).	33.2%; low methyl-esterified pectin ~38.1% highly branched rhamnogalacturonan I	No	[28]
Yam residue	Solvent extraction: using citric acid, washed and precipitated with ethanol (70, 80 and 90%). Yield: ranged from 4.32–15.88%	DE: 30.52–51.37%	Significantly contributes to the rhelogical and textural properties of prepared Dioscorea species	[29]

Table 2.
Extraction, characterization and application of non-conventional root and tuber pectin sources.

2.2 Characterization of root and tuber pectins

In addition to its characteristic α-1,4-linked D-galacturonic acid units, pectins are composed of chains which classify them into the most abundant classes, namely homogalacturonan and rhamnogalacturonan I [31, 32]. Minor components also include substituted galacturonans: rhamnogalacturonan II (most conserved structure), xylogalacturonan, and apiogalacturonan - mostly found in aquatic plankton. Pectins can also be characterized based on their degree of methylation [33]; where a value higher that 50% is described as a high methyl pectin and as a low methyl pectin when the value is lower than 50%. Although characterization of root and tuber pectins are limited, previous studies have reported that potato residue and sweet potato peels contain large quantities of rhamnogalacturonan I, which is the hairy region of pectin [34]. They also produce high methyl pectin indicating their emulsifying potentials (**Table 2**).

With a series of antibodies and enzymes, Staack et al. [35] identified a diversity of pectin structures in cassava extracts—including methyl-esterifed homogalacturonan and rhamnogalacturonan-II, implying its pre-biotic potentials. Yams are reported to have low methyl pectin [28, 30], although this varies with the spices.

2.3 Application of root and tuber pectin

One of the most important attributes of food products from root and tubers, which determines its acceptability, is its textural and rheological properties [36]. Although these properties are mostly determined by their starchy nature, high pectin yields with high methyl values have been especially reported in potato and sweet potatoes with demonstrable links between pectin structure and the textural properties of their food products [3]. Studies showing this link include the evaluation of cassava and cocoyam root softening and implicates the role of endogenous (pectin methylestherase) and microbial enzymes which target cell wall materials [37, 38]. To improve the bioavailability of beta carotene in animal feed, nano-particles containing the molecule was coated with pectin sourced from cassava residue [22]. The research showed promising strategy for neutraceutical administration of important bioactive compounds through mucosal surfaces.

3. Conclusion and future prospects

From current research, root and tubers have shown potentials as unconventional sources of commercial pectin. They have shown promising emulsifying, textural, pharmaceuticals and neutraceutical properties that can be applied to a variety of industries.

These starchy crops already serve as raw materials for several markets and industries but can compete favorably in the current commercial pectin market which has citrus fruits as its highest contributor. The current pectin market is valued at US$994.45 million and it is expected to exceed US $1 billion by 2030. Africa being the highest producer of root and tubers is poised to be a benefactor from this billion dollar market. It is imperative that national and international agencies fund research into improving root and tuber pectin yields, and structures by optimizing extraction and modification techniques.

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