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Cassava Utilization for Noodles Production: A Mini Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The increasing cost of wheat flour in countries where it is not grown leads to researching alternatives to local flour. Cassava (*Manihot esculenta Crantz*) is an affordable crop for most people in Asian and African countries due to its abundance. Starch and flour made from cassava are used as replacements for wheat as they can be incorporated into diverse food products to enhance their properties. Cassava noodles contribute to food security and address the celiac needs who suffer from adverse health reactions due to the presence of gluten in conventional wheat pasta and noodles. This review addresses specifically the production of cassava noodles. Since cassava flour and starch lack gluten, many challenges occur in the noodles manufacturing process. Original papers, review papers and data related to the topic were searched on Web of Science and Google Scholar. Thus, in the light of the available research, strategies to obtain good

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quality cassava noodles are described in this paper to enhance the sensory properties, cooking properties and nutritional values. Finally, the contribution of cassava noodles to economic development is assessed.

Keywords: Cassava; gluten free; starch; flour; noodles.

1. INTRODUCTION

Noodles and pasta are similar products appreciated worldwide and have become comfort food for many people. The differences between pasta and noodles originate from the raw material and the processing methods. The main ingredient for pasta is semolina flour from Durum wheat, (*Triticum turgidum ssp*) and the processing method used is extrusion (Hager et al., 2012). In comparison, noodles can be produced not only from wheat (*Triticum aestivum*), but also from other cereals (rice, corn, sorghum, millet, buckwheat…), legumes (beans, soybeans, mung beans), pseudo cereals (amaranth, quinoa, etc.), roots and tubers (taro, cassava, yam, potato, sweet potato, etc.). Moreover, the method used in processing noodles has more steps than typical pasta. Originally, noodles processing included mixing the flour and water, followed by kneading, rolling, sheeting, and cutting the dough to obtain noodles strands of diverse lengths and shapes (Yang et al., 2021).

Cassava has gathered interest in recent years, particularly in Asian and African countries due to its availability, low cost and ability to substitute partially or totally wheat flour in the production of pastries and bakeries. Cassava starch is characterized by a neutral taste and odor, it provides a transparent, smooth and viscous gel suitable for many processed food items (Mbanjo et al., 2021). Globally, there are two trends, one related to the high cost of wheat flour in countries where it is imported (Akonor et al., 2017), and secondly the research for healthier alternatives to wheat flour for people suffering from celiac disease (Feyisa, 2021). Therefore, other options are been looking for to replace wheat partially or totally in diverse products such as pastries, pasta and noodles, etc. Most countries in Africa depend on wheat import. On the contrary many roots and tubers varieties are available locally such as cassava. In addition, products such as pasta and noodles are widely consumed in Africa and are mostly imported or made out of wheat flour. Africa is home to some major cassava producers starting with Nigeria, ranking number 1 in the world with an estimated 63 million metric tons of cassava roots in 2021 which equals to 20% of the world production (Shahbandeh, 2023). Although previous investigations (Senanayake et al., 2024, Purwandari et al., 2014, Lawal et al., 2021, Theresa et al., 2020, Adetola et al., 2020, etc.) were carried out towards developing noodles from cassava, there remain challenges related to the absence of gluten, a protein mostly found in wheat flour, which confers to wheat products their elasticity, texture and flavor. In addition, gluten-free noodles which are widely reviewed in the literature are from rice noodles. Literature review on cassava starch exists (Chisenga et al., 2019) due to its ability to enhance diverse food products and non-food products. However, review papers are scarce about cassava noodles. Hence, this paper aims to address cassava noodles production, particularly processing methods into noodles, challenges and enhancing methods to overcome the lack of gluten and the opportunities for future research and contribution to economic development.

2. METHODOLOGY

Original papers, review papers and data related to the topic of the present literature review were searched on Web of Science, Google Scholar. Initially, papers were searched between 2020 to 2024. Upon screening the papers, research was extended to other dates to include relevant information. The searching terms included “cassava”, “tapioca”, “tubers”, “roots”, “noodles”, “pasta”, “gluten-free”, “composite flour”, “additives”, “hydrocolloid”, “fortification”. Boolean operators such as “AND”, “OR”, were utilized to associate the terms used in order to enhance findings of relevant literature. Mainly papers written in English language were selected and read to gather the information.

3. CASSAVA NOODLES: TYPES, PROCESSING AND ENHANCING METHODS

3.1 Different Types of Cassava Noodles

According to the thickness, noodles can be classified as very thin (0.7–1.2 mm), thin (1.3–1.7mm), standard (2.0–3.9 mm) or flat (5.0–7.5 mm) (Hou, 2020). The shape of cassava noodles is diverse from the most common such as spaghetti, vermicelli, shells, penne to unique form such as mesh. Fig. 1 illustrates some examples of cassava noodles around the world. The most atypical is the mesh-like shape from Vietnam. Fresh cassava noodles, can be approximatively 40% water content (Abidin & Adeline, 2013). For longer preservation, water can be removed up to 12.5% to obtain dried noodles (Hager et al., 2012) that can be preserved under good packaging for up to 2 years.

The following Table 1 shows nutritional values of cassava noodles and noodles from other flours. Noodles made from rice, millet and blend of sorghum-mung bean-sago starch exhibited higher carbohydrate content (>80%) than cassava composite noodles (75,28%). The lowest protein was observed in rice (6.55%), millet (7.42%), and corn (8.72%) noodles. Usually, cassava noodles have very low protein content (<2%), however, the formulation in Table 1 is from (Akonor et al., 2017) who incorporated 30% wheat flour to cassava noodles which enhanced the protein level up to 11.11%. Cassava noodles' ash content was found to be 2.05% and was among the highest, behind potato (4.10%), while, corn, rice, sorghum; sweet potato had the lowest ash content.

3.2 Processing of Cassava Noodles

Fig. 2 illustrates the flow charts of wheat noodles and cassava noodles. As can be seen, cassava noodles' processing includes heating, cooling, steaming steps that are not found in wheat noodles. This is due to the absence of gluten which needs to be replaced by suitable processing or additives to obtain noodles with good characteristics.

Traditionally, manufacturing cassava noodles can be done as with common gluten-free flours such as rice and buckwheat. The first method consists of weighing raw material, mixing cassava flour with water, followed by kneading to form a dough, then steaming the dough until half-cooked, pushing dough through a die (small opening) to form noodles strands, cooling, washing, draining, and drying (Li et al., 2021). A slight variant of that method is to form sheets with the steamed dough, then slit, cut, and dry.

Fig. 1. Some examples of noodles made from cassava around the world. Sources: (Natura Market, 2024; Chus, 2024; Aldentee, 2024)

Table 1. Nutritional comparison of cassava noodles with other noodles

Noodles composition	Moisture %	Carbohydrates %	Protein %	Total Lipids %	Dietary fiber %	Ash %	Energy	References
Cassava composite noodles (70% cassava flour + 30 %wheat)	6.17	75.28	11.11	5.40	-	2.05	-	(Akonor et al., 2017)
Potato	-	68.26	13.32	0.17	-	4.10	-	(Fen et al., 2017)
Yellow Sweet potato	29.81	55.43 (wb)	9.03 (wb)	4.21 (wb)	0.64 (wb)	1.56 (wb)	274.98 Cal/100g	(Budiarti et al., 2024)
Purple Sweet potato	29.45	58.3 (wb)	7.3 (wb)	3.05 (wb)	1.21 (wb)	1.90 (wb)	267.74 Cal/100g	(Budiarti et al., 2024)
Yam (70% yam flour + 30 %wheat)	8.86	68.62	11.59	8.09	-	2.86	-	(Akonor et al., 2017)
Cocoyam (70% cocoyam flour + 30 %wheat)	4.74	71.74	13.19	7.43	-	2.91	-	(Akonor et al., 2017)
Plantain (70% plantain flour + 30 %wheat)	7.07	70.65	10.90	8.81	-	2.58	-	(Akonor et al., 2017)
Wheat	-	71.48	12.23	0.16	-	2.55	-	(Fen et al., 2017)
Rice	11.13	80.15	6.55	0.82	0.81	0.94	-	(Kraithong & Rawdkuen, 2021)
Corn (90 % Yellow corn + 10% chickpea)	11.82	-	8.72	1.28	2.88	0.72	392 Kcal/100g	(Ghada, 2020)
Millet	7.67	82.25	7.42	2.41	5.84	2.13	396.49 Kcal/100g	(Asmath & Haripriya, 2021)
Sorghum+mung bean + sago starch (60:30:10)	5.41	86.76	11.83	0.17	-	1.24	398.79 Kcal/100g	(Azkia et al., 2021)

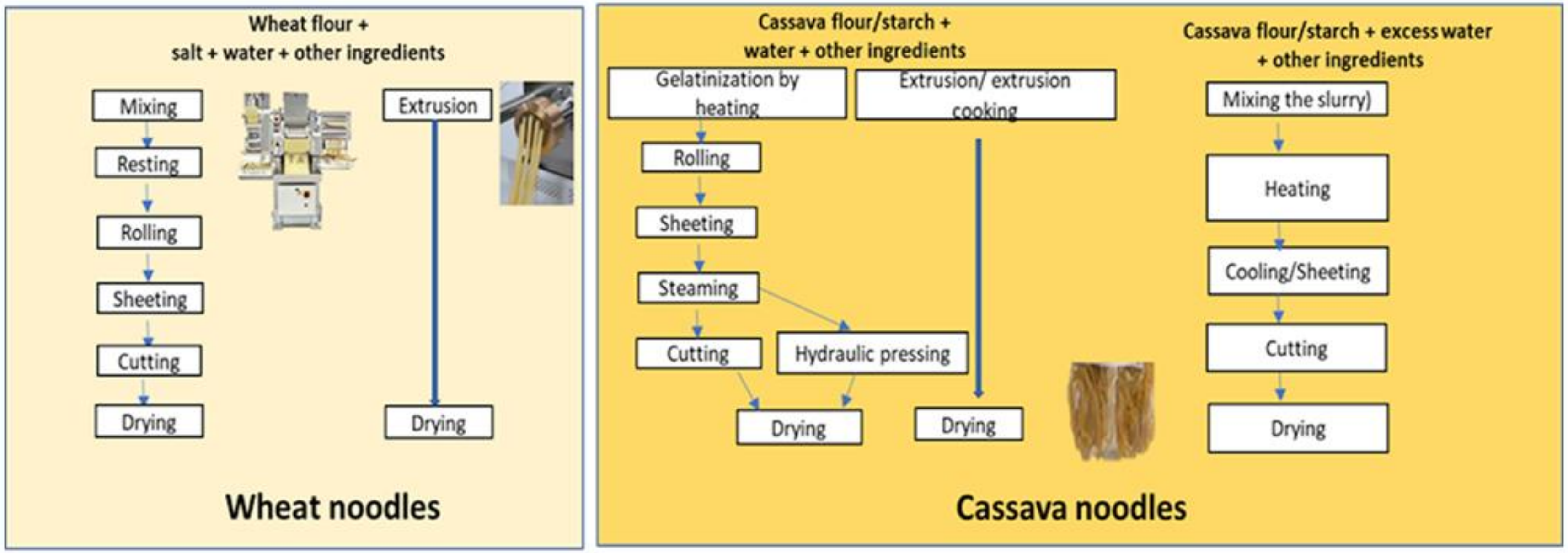

Fig. 2. Wheat noodle *vs* cassava noodles flow charts

The second method consists of making a slurry with cassava flour and water as with rice flour (Ahmed et al., 2016), then steaming the slurry and cutting into noodles strands. Sometimes the slurry can be pushed through a perforated stainless plate or bowl to form strands that are directly put into boiling water to gelatinize and obtain noodles.

Nowadays, technology has helped to reduce the steps of making cassava noodles thanks to use of modern extrusion machines. Generally, as for most gluten-free flour, there is usage of pre-gelatinized flour which is mainly obtained through hydrothermal treatments (Marti & Pagani, 2013). There are two types of extrusion: conventional extrusion and extrusion-cooking. In conventional extrusion method, the flour is pressed through a die to form noodles (Marti & Pagani, 2013). In the extrusion-cooking process, native flour is steamed and extruded at temperature above 100 ºC inside the extruder and directly extruded through the die to form desired shape of noodles (Marti & Pagani, 2013).

Drying is an important step to preserve noodles and limit biochemical and microbiological degradations. It can be achieved through sun drying, oven drying, vacuum drying or deep frying. Nowadays for health reasons, air drying is preferred to frying to avoid oil absorption in instant noodles (Ahmed et al., 2016).

Final step of noodles processing is the packaging to preserve its shelf-life. The packaging used must keep the noodles from moisture, oxygen, dust and keep the products stable during the duration of the storage period (Lestari et al., 2019, Dunno et al., 2016, Souza & Fernando, 2016). Packaging materials used for noodles are usually films impermeable to air and water (Stanislaus, 2014).

3.3 Quality Assessment

Visco-elastic, texture, and cooking properties are the main parameters measured to assess noodles' quality. In addition, for cassava noodles, HCN content must be evaluated to ensure consumers safety. FAO estimated 10 mg/kg d.w. as the limit of HCN in cassava flour (FAO/WHO, 1991). Quality noodles must be chewy, springy, smooth, non-sticky and sustain cooking without disintegration. Good cooking behavior corresponds to low stickiness, cooking time, cooking loss and noodles with firm texture and high rehydration percentage (Ahmed. et al. 2016). Dried noodles must have water content around 12 % to avoid microbial growth during storage (Ahmed et al., 2016). As for the sensory evaluation, Nwabueze, & Anoruoh, (2009) examined cassava noodles acceptance from 8 cassava mosaic disease resistant varieties. Average values of 6.08, 5.95, 5.70 (calculated as mean of the values found for the 8 cassava noodles) respectively for colour, flavour and texture. The general acceptability indicated the highest acceptance value of 7 for the variety 98/0505 and the least accepted with a score of 5.30 were 95/0289 and 97/2205 cultivars.

3.4. Enhancing Methods

Cassava flour and starch do not contain gluten proteins contrary to wheat flour. Thus, challenges occur during manufacturing. Gluten proteins, namely gliadin and glutenin are responsible for promoting starch-protein network which provides the visco-elastic and cooking properties of pasta and noodles. Therefore, strategies are needed to replace gluten and not compromise on the final product quality. In the absence of gluten, the role of starch increases in providing structure and texture to gluten-free products (Witczak et al., 2016). Research on improving gluten-free noodles and pasta has been ongoing for decades and, this section includes the different strategies used to promote better quality of gluten-free flour particularly that of noodles made from cassava flour and starch.

3.4.1 Modification of cassava flour and starch

Native cassava flour does not contain gluten proteins which is responsible for the texture of pasta and noodles products. Therefore, noodles made solely from native cassava flour can be brittle, sticky, and with high cooking loss than wheat noodles. Both cassava flour and starch can be modified to enhance their functional properties for noodles production. Modification techniques consist of changing the structure of cassava starch and flour through various methods: physical, fermentation, enzymatic and chemical modifications.

3.4.1.1 Physical modification

Physical modification consists mainly of hydrothermal treatments such as annealing and high moisture treatment of starch and flour.

Table 2. Some studies on fermented cassava flour and the microorganisms involved

Microorganisms	Fermentation conditions	Key findings	References
L. plantarum, L. fermentum, and L. paracasei	48 hours 72 hours Ratio of lactic acid bacteria culture: cassava: distilled water is 1:1: 0.01	Improved protein content, better color, odor and taste	(Seveline et al., 2020)
R. oryzae	72 hours; room temperature; fungi culture was inoculated into l kg of the mash, as the starter culture and 730mL nutrient solution	Increasing the protein level of Cassava Flour and at the same time reducing the level of some antinutrients, specifically total cyanide	(Akindahunsi et al., 1999)
L. plantarum, S. cereviseae, and R. oryzae	Microbial to cassava mass ratio of 1% for fermentation time of 120 h	Increased the protein level, reduced the level of starch and cyanide	(Gunawan et al., 2015)
Lactobacillus plantarum, Xanthomonas campestris and Saccharomyces cerevisiae	Cassava to tap water ratio of 1:2, v/v mixed with 2.0% (w/v) of microbial culture; 25˚C for 24-72 h.	Increase of swelling power and solubility, Increase of protein and fat and lower levels of cyanide	(Sulistyo & kahara, 2013)

Annealing consists of treating high water content starch (more than 40% and less than 60%) also known as a slurry, to low temperature below the gelatinization (around 60-70ºC for cassava starch) (Abdullah et al., 2018). Starches obtained through annealing are utilized in the manufacturing of noodles due to the enhancing effect on thermal stability and reduction of the degree of set-back of starches (Mathobo et al., 2021,). Whereas, high moisture treatment (HMT) involves low water content starch (<35%) which is heated at high temperature above the gelatinization temperature (Mathobo et al., 2021). Both annealing and HMT induced physico-chemical changes in starch (Marti & Pagani, 2013) which benefit the product quality. However, heat-moisture treatment is more suitable for semi-dried and dried noodles due to the great tensile strength and gel hardness (Padalino et al., 2016). Whereas annealing which induces soft texture is suitable for fresh noodles (Padalino et al., 2016).

3.4.1.2 Fermentation and enzymatic treatments

Fermentation generally by lactic acid fermentation has been effective in conferring positive characteristics to gluten-free noodles such as rice, corn and cassava noodles. Fermentation alters the crystalline regions of starch granules and chemical components, thus changing the physical characteristics of starch and the texture of noodles (Mao et al., 2024). Fermented cassava flour also known as mocaf flour is achieved through microbial fermentation, which involves yeast, mold or bacteria as fermentation agents (Gunawan et al., 2015). The fermentation process can last 24 hours at least, followed by drying at 50 ºC until low moisture content, generally 13% (Seveline et al., 2020), then milled to obtain modified cassava flour (Sulistyo & kahara, 2013). The fermentation enhances the viscosity, gelation ability, rehydration, and confers a neutral flavor. Table 2 shows different microorganisms involved and the fermentation conditions. The most commonly used are *lactobacillus*, others as *Rhizopus oryzae*, *Sacharomyces cerevisiae* and *Xanthomonas campestris*. In general, fermentation enhanced the protein and nutrient contents of cassava flour along with a decrease in starch and carbohydrate contents.

Enzymatic modification is made through microbial fermentation or addition of enzymes to starch in controlled conditions. Starch is then hydrolyzed into low molecules weight such as maltodextrin (Oh et al., 2019). Enzymes are used to modify gluten-free flour to give them appropriate characteristics for food processing. They can create new protein aggregates close to that given by gluten and induce protein modification (Cappelli et al., 2020). Different enzymes are used, most common are amylases, proteases, cyclo dextrinases, hemicellulases, lipases, oxydases and transglutaminases (Cappelli et al., 2020).

3.4.1.3 Chemical treatment

Chemical modifications create consistency, smoothness and transparency in starch paste along with freeze thaw and refrigeration stability (Singh et al., 2007). The common methods are acetylation, oxidation, acid hydrolysis and crosslinking (Obadi & Xu, 2021). For instance, Violalita et al., (2020) partially replaced potato starch with phosphorylated tapioca starch and observed that uncooked noodles had improved strength, and after cooking, noodles had low stickiness and cooking loss.

3.4.2 Extrusion Conditions

Although noodles were initially manufactured through a different process than pasta, extrusion is adopted due to its advantages in simplifying the process and improving the final product. Many authors agreed that in the case of gluten-free pasta or noodles, extrusion-cooking is usually more suitable than conventional extrusion used in typical durum-wheat pasta. Extrusion-cooking is applying high temperature and short time on the food product (Ahmed et al., 2024), then a pressure is applied and forced the dough through a die to form pasta or noodles' strand. Extrusion used the principle of starch gelatinization which converts the crystalline starch macromolecules into a more amorphous material (Enríquez-Castro et al., 2022) that exhibits high viscosity and plasticity (Liu et al., 2011). The products become more malleable and easier to form a dough. The resultant pasta achieves high quality firmness, texture and flavor after cooking (Giménez et al., 2013). The cooking step consists of heating or injecting steam onto the flour (Ahmed et al., 2024). Extrusion-cooking reduces work-load of gluten free-pasta by skipping use of pre-gelatinized starch/flour and avoiding the numerous steps of typical noodles process (steaming, boiling, rinsing) before drying. What is generally found in the literature is that usage of pre-gelatinized flour, high temperature above 100 ºC, optimal water addition, high extruder screw driver speed have contributed to better pasta/noodles quality of gluten-free flour. The temperature of extrusion chamber plays a crucial role in the quality of gluten-free pasta. For instance, extrusion temperature of 115ºC compared with 50ºC gave better cooking quality of rice-based pasta (Marti et al., 2010). Giménez et al. (2013) investigated extrusion-cooking of corn and bean spaghetti-type. They observed that extrusion at 100 ºC and 28% moisture was optimum for good product quality. Similarly, Wang et al. (2012) by using high-temperature extrusion obtained pea starch noodles with reduced cooking loss and stickiness.

3.4.3 Other flours for technological and nutrient improvement

Cassava noodles can be based on cassava flour/starch or mixed with other flour to improve their characteristics. Rice and corn flour are commonly used to enhance cassava noodles. Sabbatini et al. (2015) investigated the use of rice flour with cassava flour and used additives to improve the noodles' quality. Fermented cassava flour was partially mixed with wheat flour, corn and rice in a study by Purwadi et al. (2021). They added hydrocolloid agents such as xanthan gum, guar gum, arabic gum, carboxy-methylcellulose (CMC) and eggs. The best pasta formulation was composed of fermented cassava flour:rice:corn flour by 70:10:20 and addition of 2,5% xanthan gum. The pasta presented strong and elastic texture thanks to rice and corn flour addition, while hydrocolloid increased water-binding of the pasta. Other flours which improved noodles' characteristics were sorghum (Hamidah et al., 2023), banana (Rachman et al., 2020), yam bean (Theresa, et al., 2020), millet (Prema et al., 2018) and *porang* (indonesian tuber rich in glucomannan) (Kamsiati et al., 2022).

Cassava flour is poor in proteins (less than 2%) compared to wheat flour (10-12%). Therefore, researchers have investigated the fortification of cassava noodles through addition of ingredients which are rich in proteins. Al-Baarri et al. (2021) have investigated the usage of basil and spirulina leaf extracts to fortify cassava noodles made from mocaf. They obtained noodles with characteristics such as chewy, dense and not easily broken. Other studies have utilized various flours and starches from diverse sources such as cereals (sorghum, wheat, millet,), pseudocereals (quinoa, buckwheat, amaranth), legumes (pea, beans, soybeans, cassava leaves, moringa), egg proteins, milk proteins, seaweed, pumpkin flour (Padalino et al., 2016, Lawal et al., 2021) and succeeded in enhancing cassava noodles proteins' content.

3.4.4 Addition of additives

The additives used to enhance gluten-free products such as cassava noodles are hydrocolloids, emulsifiers or mineral salts.

3.4.4.1 Hydrocolloids

The main challenge in developing gluten-free noodles is obtaining good texture. Hydrocolloids are polysaccharides with high water-binding ability (Padalino et al., 2016) and are used as partial substitutes for gluten. They are used as texture and taste improvers and also, for extending food product shelf life (Padalino et al., 2016). Incorporation of polysaccharides such as xanthan gum, gellan gum, pectin, agar, chitosan, Carboxymethyl cellulose (CMC), guar gum, basil seed gum, karaya gum, tragacanth gum, locust bean, etc., lead to better quality noodles.

One hydrocolloid which is widely used in the manufacturing of gluten-free noodles is xanthan gum. It requires only small quantity, less than 5%. Xanthan gum can bind, thicken, and bring better stability and extrudability to the noodles without changing their taste. Some studies have investigated the benefits of hydrocolloids in gluten-free noodle manufacturing. Parassih et al. (2020) investigated the effect of two hydrocolloids on two types of cassava flours. Xanthan gum and Konjac Glucomannan were incorporated in addition to pea protein isolate to native cassava and pregelatinized cassava flour. Xanthan gum gave better properties to the noodles obtained compared to konjac glucomannan. The optimal formulation was pre-gelatinized cassava flour + 2% xanthan gum + 4% protein isolate. The control was wheat flour without any additives. Another example of incorporating xanthan gum was made by (Acosta. et al., 2018) with noodles made from cassava bran (10, 20 and 30%) and xanthan gum in a proportion of 0.5, 1 and 1.5%. Though the increase of cassava bran reduced the acceptance of the pasta, addition of xanthan gum improved its sensory properties. The best formulation was found to be 20% cassava bran and 1.5% xanthan gum.

3.4.4.2 Emulsifier

Emulsifiers improve rheological properties of a gluten-free dough by decreasing stickiness, and enhancing positive properties such as elasticity and plasticity (Kosiński & Cacak-Pietrzak, 2020). Common emulsifiers used for gluten-free pasta and bread are lecithins, mono- and diglycerides of fatty acids, soy and sunflower lecithin (Kosiński & Cacak-Pietrzak, 2020). Emulsifiers form complex structure with starch and prevent enzymatic hydrolysis. They have similar properties as hydrocolloids and reduce cooking loss. Kosiński & Cacak-Pietrzak (2020) confirmed these statements when comparing commercial gluten-free pasta to conventional wheat pasta. The authors observed that pastas from maize and rice flours with emulsifiers were comparable to wheat pasta in having the lowest cooking loss compared to pasta samples without emulsifier.

3.4.4.3 Mineral salts

Al-Baarri et al. (2022) researched the effect of mineral salts on cassava noodles by using a combination of potassium chloride (KCl) and magnesium chloride (MgCl). They compared based on the color and salinity three noodles' formulations: noodles with wheat flour, wheat flour + mocaf (MF), mocaf with mineral salt (MFM). The addition of mineral salts improved the texture and brightened the color and salinity of all the noodles and particularly increased the acceptability of MFM noodles. Alkaline salts can be used as artificial gluten as they help the texture become chewy and can induce elasticity due to their ability to form a gel-like structure in the dough (Al-Baarri et al., 2022). Alkaline salts (bicarbonate mixed with carbonate salt or sodium carbonate) at 0.5-1.5% improved the tensile strength of wheat noodles, hardness and chewiness (Li et al., 2018). However, there are few studies including alkaline salts in gluten-free-noodles and cassava noodles in particular, therefore further research is needed in this area.

3.4.5 Drying conditions

Drying reduces noodles moisture content to 11-12% to extend their shelf life for up to two years. If conducted properly drying can impact positively pasta and noodles firmness and reduce stickiness and cooking loss (Ahmed et al. 2024). Inversely, wrong drying method can bring cracks and uneven texture to the noodles with stickiness and breakage during cooking (Ahmed et al. 2024). The drying conditions particularly temperature affect gluten-free products (Marti & Pagani, 2013). Multiple stages of noodles/pasta drying have been identified by Ahmed et al. (2024): surface drying, pre-drying, resting stage, final drying. After final drying, pasta is cooled at ambient temperature before packaging. Pasta can be dried at low (<60ºC), high (60ºC-80ºC) or ultra-high temperature (80ºC-120ºC). Some studies have concluded that high temperatures give the best pasta/noodles quality. For instance, cassava-based noodles were dried using a cabinet dryer at a temperature of 65-75°C for 2-3 hours (Pato et al., 2016). Nonetheless the majority of studies on cassava noodles have

Table 3. Local Multiplier Effects Estimation (in USD) of cassava noodles production

Economic Actor	Output	Price (in USD/kilo)	Capacity monthly (kilos)	Multiplier Effect (in USD)	Employee
Farmer	Cassava	0.12	20000	2450	24
Processing Hub	Cassava Powder	0.92	20000	18375,03	6
Factory	Dirty Noodle	1.96	20000	39200,07	35
Distributor	Dirty Noodle (package)	2.45	20000	49000,09	12
Restaurant/food stall	Dirty Noodle (ready to eat)	5.51	20000	110250,21	200

**Source: Rahadi et al. (2020)*

used mild to low temperature for cassava noodles. This may also be related to rapid browning of the noodles strands when submitted to high temperatures. Two drying temperatures (45 ºC and 35 ºC) were investigated by Milde et al. (2021) with good results on a cassava-corn based pasta (80:20) fortified with egg albumen. Purwandari et al. (2014) dried fermented cassava flour noodles in a cabinet drier at 55 ºC. Mocaf flour, wheat flour, and *latoh* flour were combined in a basin and mixed with water at a dry matter-to-water ratio of 1:0.3 (m/v). These wet noodles were subsequently dried for 12 hours at 50°C with good results.

4. MARKET ACCEPTANCE AND ECONOMIC FEASIBILITY OF CASSAVA NOODLES

Abidin & Adeline (2013) studied the market acceptance of cassava noodles compared with wheat noodles. They found an acceptance score of 17.3 for cassava noodles and 22 for wheat noodles. The differences were found in term of texture and color which were more brittle and darker than wheat noodles. Nonetheless, cassava noodles were about 80% close to wheat noodles and could have potential acceptance from the market especially panelists from age groups of 10-19 and 30-59. Table 3 from a study by Rahadi et al. (2020) shows the effect of developing a cassava noodles factory on the economy of a small area of Indonesia (Jogjakarta). The factory though traditional can process 20 tons of cassava per month, and employs 35 persons directly. In addition, farmers, processing hubs which provides the flour to the factory, noodles distributors such as restaurants and retailers increased the number of working people in the cassava noodles chain to more than 200 people. In the original paper by Rahadi et al. (2020), the calculation was made in Indonesian rupiah (IDR). The purpose of converting in USD in this paper was for global reach. These data demonstrate the benefits of processing a local product namely cassava noodles in creating jobs and increasing local incomes.

5. CONCLUSIONS

Interest is rising about substituting wheat flour to produce noodles and pasta. Although cassava starch and flour are used in many food products, their utilization in manufacturing noodles is limited. This review indicated that pregelatinized cassava flour and starch is the best material to use for cassava noodles with extrusion cooking method and addition of additives such as hydrocolloids and emulsifiers. There could be good potential to use salts and alkaline salts to improve the quality. Though cassava is poor in proteins and certain nutrients, research is ongoing to improve their resultant noodles' nutritional characteristics through composite flour from other cereals, roots and tubers, legumes, pseudo cereals, and plant leaves. Research towards the improvement of genotypes of cassava is also of importance to increase the amylose/amylopectin ratio and biofortification of the cassava roots in vitamins and minerals to provide better quality and nutritious derivative products.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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