Cassava as an Important Staple Food and Its Application in the Food Industry -- A Review

A Project Paper

Presented to the Faculty of the Graduate School

of Cornell University

in Partial Fulfillment of the Requirements for the Degree of

Master of Professional Studies in Agriculture and Life Sciences

Field of Food Science

By

Xiaoyu Fu

12 2021

ABSTRACT

Cassava, *Manihot esculenta*, is cultivated in tropical areas around the world as a staple food source that feeds millions. Cassava tubers are rich in starch. Cassava starch, modified or native, is an important ingredient in the food and pharmaceutical industries. For example, the starch can be hydrolyzed to produce glucose or dextrin. Cassava is a gluten-free carbohydrate source that can be used as a fat replacer in meat analogs. Its modified forms can be used to encapsulate active ingredients, and it can be made into edible or biodegradable food packaging materials. However, in many cassava-growing developing countries, cassava farmers who depend on cassava as a staple food source do not have enough resources to convert this starch vegetable into value-added products to improve their economic returns and their lives. In addition, many of them are suffering from diseases brought on by consuming cassava products without enough processing, as cassava tubers are high in cyanide, which is toxic to the human body. Therefore, it is important to bring the issues to the attention of both academics and the food industry. This review discusses topics such as optimizing cassava growing, detoxification of the tubers, sustainable wastewater processing, tapioca starch modifications, tapioca starch as a staple food and the related epidemiology problems, and applications of tapioca starch and its derivatives in the food and pharmaceutical industries. In conclusion, cassava is a rich carbohydrate source once detoxified properly and can be used as a staple food with some supplementation of protein and other essential nutrients. The production waste needs to be processed before being released into the environment; ideally used to generate additional value. Cassava can be easily processed into cassava starch. The starch can be used directly as a food ingredient for

the preparation of a variety of food products. The starch can also be modified, chemically or physically, into different forms with their special properties.

BIOGRAPHICAL SKETCH

Xiaoyu comes from Hangzhou, China. She received her Bachelor’s Degree from the University of Massachusetts in Amherst in Food Science, after which she joined Cornell University for her Master of Food Science studies.

ACKNOWLEDGEMENTS

The work is not funded by an outside grant. Special thanks to my advisor, Dr. Joe M. Regenstein, who guided me and helped me edit this work.

TABLE OF CONTENTS

LIST OF FIGURES

0. Introduction

a. Production figures for tapioca

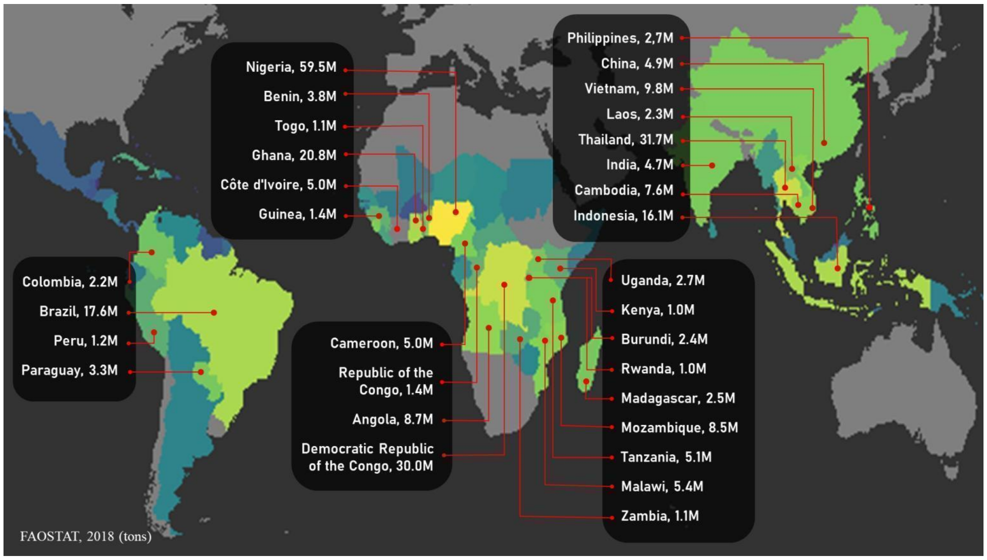

Figure 1: Global Overview of Cassava Production (FAOSTAT, 2018)

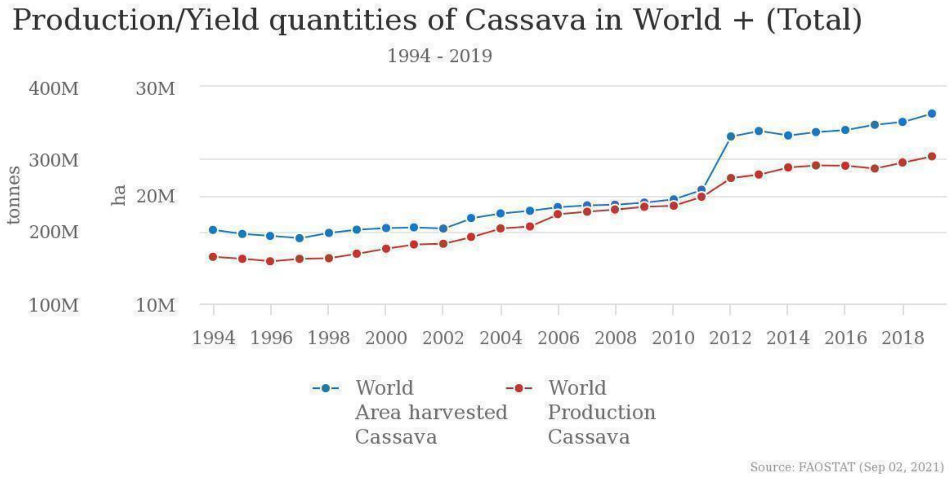

Figure 2: Production/Yield Quantities of Cassava in the World (FAOSTAT, 2021)

Cassava, *Manihot esculenta*, is mainly grown in tropical areas around the world. It is primarily cultivated for consumption of its roots. After being harvested, the tubers must go through a soaking and water boiling process before being consumed to detoxify the tubers. In most of the countries, the tubers will be ground into cassava flour or cassava starch and made into different dishes. In developed countries, the starch or flour is more often processed into value-added products that are not limited to the food industry.

From 1994 to 2019, the production of cassava increased nearly 50% according to the data from the Food and Agriculture Organization (FAO) as shown in Figure 2, to more than 300 million tonnes in 2019. The world's area used to grow and harvest cassava also increased from 16.8 to 27.5 million hectare from 1994 to 2019, which is a little more than the size of 33 million soccer fields.

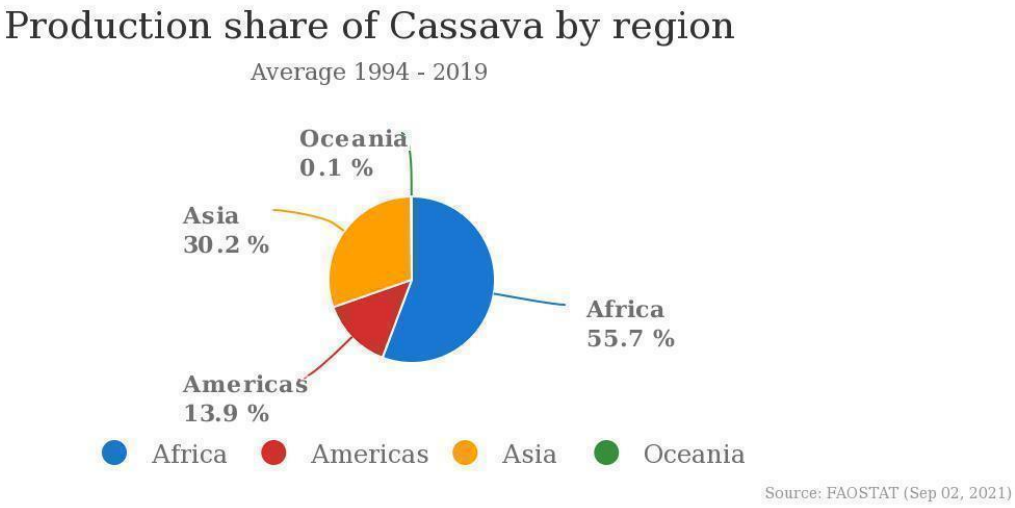

Figure 3: Production Share of Cassava by Region (FAOSTAT, 2021)

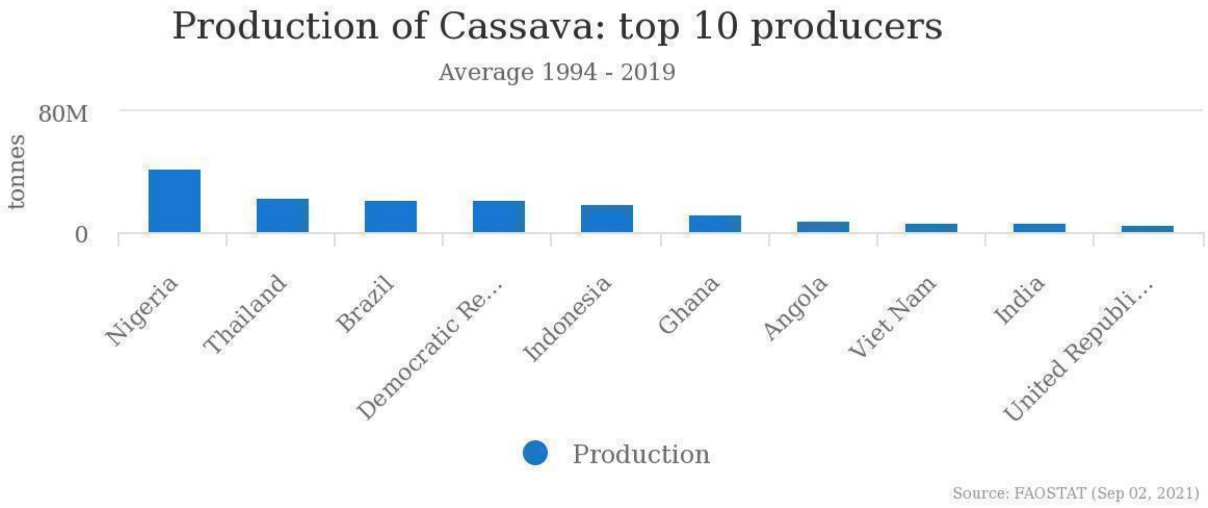

Figure 4: Production of Cassava: Top 10 Producers (FAOSTAT, 2021)

According to the data from FAO as shown in Figure 3, 56% of cassava is produced in Africa, followed by Asia (30%) and the Americas (14%). According to the data shown in Figure 4, Nigeria, Thailand, and Brazil are the top 3 producers of cassava, with ~40 million tonnes of cassava produced by Nigeria alone every year.

b. World trade in cassava

Thailand is the largest exporter of cassava. In 2020, Thailand exported $37,000,000 (UN Comtrade, 2020) of cassava. From 2016 to 2020, the annual export trade value of cassava from Thailand increased from $24 million (UN Comtrade, 2016) to $37 million (UN Comtrade, 2020), which was a 35% increase.

China is the largest importer of cassava. In 2020, China imported $783,000,000 (UN Comtrade, 2020) worth of cassava. Unlike the growing trend of exporting cassava as mentioned above, the importing of cassava in China actually declined from $1.4 billion (UN Comtrade, 2017) in 2017.

The 2020 average price of cassava exported from Thailand was $0.81/kg (UN Comtrade, 2020); and the 2020 average unit price of cassava that was imported into China was $0.23/kg (UN Comtrade, 2020). This seems to reflect a disparity whose origin has not yet been clarified.

c. Major current uses of cassava

Cassava and its processed products have a wide range of uses in many industries including human and animal food, pharmaceutical, chemical engineering, environmental, medical, packaging, textile and construction. After harvesting, the cassava roots need to go through detoxification processes to remove the toxic compounds before being further processed (El-Sharkawy, 1993). Usually after the detoxification process, the product will go through a drying process to collect tapioca starch.

Cassava, bitter or sweet, is harvested and chopped into smaller pieces for easier detoxification using processes such as soaking in water and boiling to wash away the toxic compounds. In most cases, the pieces are then ground into tapioca flour as granules or finer powders. Various dishes are prepared from tapioca flour or naturally fermented tapioca flour as a staple food. In some other cases, the tubers are cut into chunks and stir-fried or roasted with seasonings. The pieces can also be refined into tapioca starch as an ingredient with its unique characteristics and can be used in many areas in the food industry. For example, it can be used as a gluten-free source to replace wheat flour in bread (Milde et al., 2012). It is the main ingredient of tapioca bobas or bubbles that are used in milk tea and it is used by the plant-based “animal protein substitutes" food industry to mimic animal fat, the texture of fish meat (Tawali et al., 2018), or to reduce the fat content of some products such as cheese (Iakovchenko and Arseneva, 2016). It is also an economical animal feed for ruminants and fish (Park et al., 2019; Umar et al., 2013).

The starch can be modified in many ways to prepare value added products. For example, organic acids and other chemical compounds such as fumaric acid (Soccol et al., 1993), poly(lactic acid) (Garlotta, 2001), ethanol (Sugih et al., 2015), and xanthan gum (Gunasekar et al., 2014) can be prepared using fermentation of tapioca starch using different enzymes. Tapioca starch that goes through acid or enzymatic hydrolysis would produce different types of sugars and dietary fibers depending on the degree of hydroxylation and the choices of reagents and/or enzymes (Ahmed et al., 1983; Hermiati et al., 2012; Triyono et al., 2017; Weil et al., 2021). It can be a prebiotic that feeds gut bacteria (Kaulpiboon et al., 2015). Tapioca starch and its modified forms can be used as a wall material to encapsulate nutraceuticals (Loksuwan, 2007) and prepare some nanoparticles (Almeida et al., 2020). Combined use of tapioca starch with gums, gelatin, cellulose, and other starches also have their own unique functionalities that can be applied to different needs such as edible food packaging (Chillo et al., 2008; Loo and Norizah, 2020; Owi et al., 2017).

The starch itself and its chemically modified forms can also be used in the pharmaceutical industry. It is used as fillers in tablets (Atichokudomchai and Saiyavit, 2003), a promising plasma expander (Luang-ni et al., 2015), and oral rehydration solutions (Wapnir et al., 1998).

There are many other uses of the starch and its modified forms as well. For instance, it is a successful medium for culturing bacteria (Ghozali et al., 2021) and algae (Amalah et al., 2018). It can be used as an adsorbent to collect unwanted pollution from the environment (Ogata et al., 2018) and it is a bio-adhesive that can be used as a biodegradable adhesive in particle board (Liew et al., 2018).

Although as mentioned above, the application of cassava and its value-added products are not limited to the food and pharmaceutical industry, in this paper the use of tapioca starch and its derivatives in the food and pharmaceutical industry will be discussed.

d. Major benefits of cassava growing and use

Cassava is easy to grow and requires a minimum amount of water and nutrients from the soil compared with most other staple food sources. The plant is able to tolerate prolonged droughts with its stress-avoidance mechanisms (El-Sharkawy, 1993). Therefore, it is a good choice for farmers in the tropical area where their water source for farming is limited. In addition, cassava has low requirements for soil nutrients. According to Putthacharoen et al. (1998), compared with maize, sorghum, peanut, mung-bean, pineapple, and sugarcane, cassava needs the lowest amount of major nutrients (N, P, K, Ca, Mg) except for mung-beans. The plant is known for its capability of growing and producing on barren lands. Therefore, farmers could make good use of lands that are no longer fertile enough for cultivating other crops.

Some tropical countries that are importing tapioca starch can start growing the plant locally to improve the supply chain and bring economic benefits to their own countries. Starch is used extensively in many countries such as South Africa, but most of the starch is imported from other countries such as Thailand. A study proposed that if countries like South Africa can start producing cassava, the economy of the country will benefit with income generation, job creations, and foreign exchange savings (Amelework et al., 2021). If downstream research and development could be improved, and local processing and production capability could meet the needs, the starch would have a wide range of applications across different industries, which could meet domestic needs and might even be exported to generate additional economic value (Abass et al., 2018; John et al., 2007).

In addition to tapioca starch, maize, wheat, rice, and potato starch are commonly used in the food and pharmaceutical industry, especially maize starch. Starch is used by the food industry to make sugars, syrups, thickening agents, preservatives, and emulsifiers. However, maize starch faces some resistance since being produced from genetically modified maize as the current trend in the food industry is unfortunately going to be more non-GMO, and products such as high fructose corn syrup are increasingly being perceived by consumers as “unhealthy”. On the other hand, tapioca starch has not to date been genetically modified while having all the properties of a starch that is easy to process and modify. Therefore, it is an ideal starch for food companies looking to avoid any possible consumer perception problems with maize starch (Frewer et al., 2013).

e. Major drawbacks to using cassava

Although cassava is relatively easy to grow on lands that many other crops cannot grow, the plant does have some problems with diseases, and how to control the diseases has been studied. Some common diseases include: cassava bacterial blight (CBB), cassava mosaic disease (CMD), and cassava brown streak disease (CBSD). These diseases can lead to significant economic losses to the cassava farmers. There are many ways of engineering the plant to be resistant to these diseases (Lin et al., 2019), although some mean that cassava might become a GMO. Lin et al. summarized different ways of controlling the diseases using genetic modifications, including RNA interference, gene-editing, engineering susceptibility factors, exploiting native resistant mechanisms, immune receptor transfer, and engineering new immune receptor specificity. Noticeably, none of these gene-editing and engineering methods are categorized as GMO according to US regulations although this is not the case in some countries. A review on the current CMD situation in Zambia also showed the importance and difficulties of controlling the spread of the disease (Chikoti et al., 2019). The review pointed out that controlling the disease needs the efforts of multiple stakeholders including scientists, extension workers, seed multipliers, seed certifiers, NGO, and policy makers. It is also important to educate farmers to adopt good phytosanitary practices. Overall a lot of effort is still needed to fight the spread of diseases.

In addition to problems with plant disease control, depletion of certain nutrients and soil erosion can also be problematic. Evidence as described above suggested that compared with many other crops, the overall nutrient uptake of cassava is low in terms of per ton dry matter. The review by Howeler et al. (1991) suggested that the uptakes of N and P were much lower compared with other crops, but the uptake of K is similar to cereals but still lower than other crops such as grain legumes and sweet potatoes, which was consistent with the results from Putthacharoen et al. (1998). Therefore, long-term cultivation of cassava on the same land will cause K depletion, thus impacting the yield. In addition to soil nutrient problems, soil erosion is usually another problem that happens frequently. Because cassava is able to be grown with conditions that other crops cannot tolerate, it is often planted on steep slopes with acidic and infertile soil conditions as the last crop in a rotation (Ofori, 1973). At the beginning of the growing season according to Ofori, the canvas of the plant is usually limited thus it cannot protect the land from rainfalls. In this case, soil erosion will be a problem that will cause yield loss and soil nutrient loss. He suggests managing it by mulching the land or intercropping.

The root of cassava naturally contains cyanogenic glycosides which will be transformed into hydrocyanic acid (HCN) in the stomach during digestion. HCN will cause a range of symptoms such as vomiting and coma, and higher dosage could also cause death (Miles et al., 2011). Therefore, after the root is harvested, detoxification is an important step. Traditional steps to remove the toxic compound include: scraping or peeling, soaking and fermentation in water, pounding or grating into mash, squeezing for dewatering, washing, and roasting or sun-drying (El-Sharkawy, 1993). If these steps are not done carefully, the risks of exposing consumers to HCN is high. Therefore, regulation on the allowed dosage of cyanogenic compounds in tapioca products is important to ensure food safety. The Codex Alimentarius Commission’s international standard for the HCN content of edible cassava flour is 10 mg of HCN eq/kg. In addition to possible consumer food safety issues, the wastewater generated by removing the toxin from the root also needs further processing before being used elsewhere or released into the environment. This extra step increases the cost of production. If not handled appropriately, the toxic compound in the water will also affect the local water supply.

1. Growing the plant

a. Soil nutrients and erosion

Increasing cassava growing compared with growing other crops was observed in East Africa as the farmers' last chance, especially on land with declining soil fertility and in areas where there is a lack of labor and a strong need for food (Fermont et al., 2008). As mentioned in section 0.e, cassava growing causes some soil nutrient depletion and erosion problems. In addition, Isabirye et al. (2007) suggested that cassava harvesting would cause 3.4 tonne/ha soil loss per year. Compared with other tuber crops such as sweet potatoes, cassava tubers have a less smooth surface. Therefore, more soil tends to stick to the harvested tubers and over time it would cause accumulated soil loss leading to further soil degradation. The soil's nutrient profile and pH also have an impact on tuber cyanogenic glycosides content. Imakumbili et al. (2019) observed that some nutrients (K, Mg, Zn) reduced cyanogenic glycosides content of cassava of some varieties, and increased other nutrients (P, S, Fe) and high soil pH levels increased cyanogenic glycosides content of some cassava varieties. Therefore, it is important to manage cassava growing soil problems to enable sustainable and continuous production of cassava to fight against famine.

Fertilization is discussed in many papers as an effective way of managing cassava soil nutrients and erosion. Odedina et al. (2012) suggested that combined use of manure with inorganic fertilizers increased the cassava tuber yield. This practice could save the cost of purchasing inorganic fertilizers for cassava farmers by partially replacing commercial fertilizers with animal manure. Compared with directly applying fertilizers, Xie et al. (2020) found that fertigation, a fertilizing method that delivers fertilizers using an irrigation system, resulted in higher cassava leaf nutrient contents and tuber yield on both sandy clay loam and loamy sandy soil. Compared with fertigation, direct application of fertilizers may result in the nutrients leaking to deeper levels of the soil where cassava roots could not reach. However, in the meantime, fertigation requires more labor and in some cases extra equipment that might not be feasible in every situation. As mentioned previously, cassava growing requires a higher amount of K than other nutrients. Chua et al. (2020) advised using K fertilization to avoid cumulative K depletion. Howeler and Cadavid (1990) found that cassava yield responded differently to different chemical fertilization formulations, suggesting that soils from different areas may have different nutrient deficiency problems and require case dependent fertilization. For example, Charoenphon et al. (2020) found that Mg fertilization was important. However, Nguyen et al. (2001) found that applying only one type of nutrient would result in a decrease of other soil nutrients. Therefore, it might be beneficial to develop modeling tools to analyze soil nutrient deficiencies and find the right amount of fertilization needed for each of the soil nutrients to efficiently and economically solve problems with different land types (Byju et al., 2012). Furthermore, Carsky and Toukourou (2005) suggested that applying even a high amount of fertilizers on degraded soil showed little effect, suggesting the importance of managing soil nutrients early before any nutrient deficiency problem occurs.

There are some other agronomic practices that can effectively manage cassava soil nutrients. Cadavid et al. (1998) suggested that surface mulching was an advantageous way of preserving soil nutrients while producing high quality cassava tubers. Banuwa et al. (2020) found that soil runoff, erosion and nutrient loss could be significantly reduced with the application of ridges in the opposite direction of the growing slope. Hridya et al. (2014) inoculated different combinations of bacteria and fungi (*Azospirillum* and *Trichoderma; Arbuscular mycorrhiza* and *Trichoderma*; and *Pseudomonas fluorescens* and *Trichoderma*) on cassava growing soil and observed significantly increased N, P, and Fe, respectively. Similarly, Osonubi et al. (1995) observed increased tuber nutrient uptake with the inoculation of vesicular-*Arbuscular mycorrhiza*.

Cassava genotypes respond differently to different soil nutrient profiles. Kang et al. (2020) identified cassava genotypes with high yield in low N fields, low yield in low N fields, and high yield in high N fields. If the land had low N, the first genotype should be grown to generate high yield, and if the land had high N, the third genotype should be grown. Marzouk et al. (2020) showed a similar relationship between different cassava genotypes and K content in soil.

However, soil nutrient deficiencies were not observed everywhere. Asadu and Nweke (1998) sampled cassava field soils in 45 villages of Tanzania and found the fertility of soil was medium to high.

b. Tolerating drought

Although cassava is known for its great drought tolerating ability, growing cassava with an inadequate amount of water still leads to problems. Brown et al. (2016) found that drought inhibited tuber yields and was associated with increased tuber toxicity levels, especially when grown at higher temperatures. Similarly, Vandegeer et al. (2013) quantified an 83% decrease in tuber yield and a 4-fold higher cyanogenic glycosides compared with cassava that were grown with adequate irrigation. Cassava that suffered from drought early after being planted was impacted more in terms of loss of total dry weight of the tuber yield compared with drought that came later in the plantation cycle (Pardales and Esquibel, 1996).

Many studies are trying to identify the specific genes and mechanisms that regulate cassava drought or heat/cold stress to pave the way for improved breeding (Zeng et al., 2017). Zhao et al. (2015) observed different mechanisms of two cassava cultivars with mild drought. The first cultivar used a “survival” mode in which lowered photosynthetic activities were observed, while the second cultivar senesced older leaves but continued to grow at a lower rate. The author suggested that the first cultivar was more capable of surviving prolonged drought than the second. Chang et al. (2019) also observed decreased photosynthesis with drought stressed cassava. After examining 37 cassava genotypes, Orek et al. (2020) found that cassava genotypes with high drought tolerance were physiologically less sensitive to water deficiency, which could be used as a way to pre-screen drought tolerant genotypes, but it was difficult to relate stomatal conductance, i.e., the degree of stomatal opening, with tuber yield. On the cellular level, Shan et al. (2018) observed the increased expression of 7 heat shock proteins, 6 decreased heat shock proteins, and reduced net photosynthesis with drought stress, showing the potential cellular metabolism mechanism for drought tolerance of one cultivar. Turyagyenda et al. (2013) identified the mechanism of a drought tolerant genotype to be related to the reduction of oxidative stress and osmotic adjustment on the cellular level, and closure of stomata to reduce water loss at the physiological level.

Many ways have been identified to help alleviate the impact of drought on cassava growing. Breeding can be used to identify cassava cultivars that were more tolerant to prolonged drought (Oliveira et al., 2017). Okogbenin et al. (2013) summarized modern breeding technologies well in their review. They also pointed out the importance of phenotyping strategies like metabolic profiling for accelerating the breeding process to develop drought tolerant cassava. Kengkanna et al. (2019) used digital imaging of root traits (DIRT) to identify root phenotypic traits that were more tolerant to drought, which could be used as breeding targets for high drought tolerant cultivars. In addition to breeding, Utsumi et al. (2019) used acetic acid solution at 10 mM to irrigate young cassava plants for 7 days before the plant was exposed to a 14-day drought. The result showed that, compared with irrigating with pure water, the acetic acid solution irrigation enabled the plant to show better drought avoidance based on higher leaf water content, decreased stomatal conductance, and decreased transpiration rate. These were related to the increased expression of abscisic acid (ABA) signaling related genes. ABA is an important plant signaling hormone that accumulates with increased osmotic pressure (Ali et al., 2020). Zeng et al. (2020) identified 32 heat shock factors and found the association between these factors and the ABA signaling pathways as well, suggesting the possible mechanism of plant drought stress responses.

c. Intercropping

Intercropping is a common practice in agronomy to increase production, control crop disease, manage weeds, and manage soil nutrients (Lithourgidis et al., 2011; Louarn et al., 2021; Weerarathne et al., 2017). Cassava is commonly intercropped with legumes or maize for benefits such as disease control and soil nutrient management (Mutsaers et al., 1993).

Intercropping cassava with legumes or maize can effectively reduce the incidence of related plant diseases such as CMD. Uzokwe et al. (2016) found that intercropping cassava with mung bean (green gram) could effectively lower the small whitefly (a cassava pest) populations found on crop leaves and CMD incidence in all seasons in the Lake Zone areas of Tanzania. Similar results were observed by Ahohuendo and Sarkar (1995) and Fondong et al. (2002) who intercropped cassava with cowpea and/or maize. Fondong et al. also suggested that intercropping provided farmers with additional short-term crops that covered the gap between cassava harvesting, which usually happens late in the season, and the early next cropping season.

Legumes can effectively fix atmospheric N_2 into the soil. Thus, they are often used as an intercropping crop to decrease the amount of fertilizers needed for maximum crop productivity (Jensen et al., 2020; Xu et al., 2020). Intercropping cassava with peanut and soybean on ultisols, acidic soils with low fertility, increased the productivity of the fresh roots even more than fertilizing the soil with NPK fertilizers, suggesting increased soil nutrient contents from growing legumes (Harsono and Pratiwi, 2017). Tang et al. (2020) found that intercropping cassava with peanuts increased soil nitrogen content through increasing the quantity of rhizospheric microbes. Umeh and Mbah (2010) measured the increased nitrogen content when intercropping cassava with soybean.

They observed that soil nitrogen content increased from 0.042 to 0.086 mg/kg 8 months after planting and 0.085 mg/kg 12 months after planting without any measurable soybean yield or quality loss. Compared with intercropping cassava with legumes, intercropping with maize showed different results in terms of soil nutrient. Although intercropping cassava with maize improved the earthworm activity and water infiltration, nutrient uptake from the soil and reduced tuber yields were observed (Olasantan et al., 1996a; Olasantan et al., 1996b). Therefore, intercropping cassava with maize usually requires the addition of nitrogen fertilizers to achieve good yield of cassava tubers. Fertilizers not only raises environmental concerns but also adds a financial burden for the cassava farmers. Harsono and Pratiwi also suggested that intercropping cassava with legumes (peanut and soybean) increased the net income of cassava farmers by 210% compared with monocropping cassava. Olasantan (2005) intercropped cassava with okra and reported a 19 - 21% increased okra pod yield which brought an additional 20 - 26% economic return compared with mono-cropping. However, the author did not study the impact of intercropping on soil nutrients.

Nwaobiala (2018) analyzed farmers' adoption of recommended cassava intercropping practices in Nigeria. The results suggested that more education was needed to increase the awareness of cassava intercropping benefits.

2. Processing

a. Detoxification

Cassava naturally contains cyanogenic glycosides which will be transformed into hydrocyanic acid (HCN) in the digestive system. A symmetrical, permanent, and irreversible neurological disease, Kenzo, that was well-documented on children and young women who use cassava as the main food source in sub-Saharan Africa was found to be related to the consumption of under-processed cassava (Nhassico et al., 2008). Kashala-Abotnes et al. (2019) observed that the occurrence of Kenzo was related to the metabolites of linamarin (the main cyanogenic compound of cassava), cyanide, thiocyanate, and cyanate. Tropical ataxic neuropathy (TAN) is another disease that results from long-term consumption of cassava as the sole food source (Osa et al., 2000). It is usually found in old people and the disease progressively causes impaired ability to walk, hand sensations, and loss of vision and hearing. However, even though the occurrence of human diseases was high, a study that interviewed cassava farmers and processors in Nigeria suggested that these people were not aware of the toxicity of the cassava in food (Oluwole, 2008). There are two major cultivars of cassava classified by their taste as “sweet” and “bitter”, and the taste is related to the cyanogenic compound concentration, with the “bitter” cultivar containing a higher amount of cyanogenic compounds compared with the “sweet” cultivar (Saka et al., 1997). Even though the “sweet” cultivar contain less toxins and are generally better tasting, the study suggested that farmers are still more willing to grow the “bitter” cultivar because the “sweet” cultivars are more susceptible to theft and animal spoilage by trampling or consumption of the leaves (Chiwona-Karltun et al., 2000).Therefore, understanding the detoxification process of cassava and implementing it into the food production and preparation in the growing and processing countries is important for public health to prevent more cyanogenic intoxication in the population.

In cassava, the two cyanogenic glycosides are linamarin and lotaustralin, with the majority being linamarin (Cressey and Reeve, 2019). The total cyanide content, although there are differences between different cultivars, ranges between 23.6 to 238 mg/kg root (Chisenga et al., 2019). Padmaja (1995) and Panghal et al. (2021) describe the detoxification process of cassava well in their reviews. Overall, three methods are usually used -- drying, soaking followed by boiling, and fermentation.

Sun-drying is the most common way that is used by small and medium sized cassava farmers to make dried cassava chips for storage. It is a more effective way to remove cyanogenic compounds compared with oven drying. Using enzymatic hydrolysis, cyanogenic glycosides are converted to HCN by endogenous β-glycosidase (Cressey and Reeve, 2019). Cyanogenic glycosides are stored in cell vacuoles and β-glycosidase are stored in mesophyllic cells of cassava (Panghal et al., 2021). The best temperature range (35 - 45°C) where maximum enzyme reaction would occur is around the sun-drying temperature. During oven drying, the temperature is usually much higher, and at around 55°C enzymatic activity would be inhibited and thus slow the reaction (Perera, 2009). Monroy-Rivera et al. (1996) observed 84 - 89 and 80 - 100% loss of total free and bond cyanide, respectively, upon completion of the sun-drying process. The surface size is highly related to the efficiency of drying. The cyanide reduction in smaller cassava chips or grated cassava is faster than larger cassava chips during the drying process (Jones et al., 1994). However, sun-drying has its problems that are pointed out by Soraya et al. (2017). For example, sun-drying requires a large area of land, otherwise production capability would be limited. In addition, sun-drying depends a lot on weather conditions. During cloudy or rainy days, the production cannot proceed.

Last but not least, exposing products to the environment would cause food safety concerns. Without proper management, germs or dirt from the environment will infect the product and cause public health problems. Furthermore, sun-drying is much less efficient compared with other drying methods. Sun-drying takes up to three days during cloudy or rainy days and industrial drying takes usually one to two hours (Sivakumar et al., 2017).

A 1.5 year case study was done in a small village where Kenzo occurrence was high because local residents rely on cassava as their staple food (Banea et al., 2012). In the village, cassava flour was consumed as a thick porridge called fufu. The group intervened by teaching the locals to mix the flour with water and leave it in the shade for 5 h or under the sun for 2 h. The intervention successfully lowered the average urinary thiocyanate content of local children from 332 to 130 μmole/L, and no new Kenzo cases were observed even during the traditional season of highest occurrence.

Fermentation is also a well-documented method for the removal of cyanogenic compounds from cassava. Compared with slicing, soaking, followed by sun-drying, Kemdirim et al. (1995) suggested that fermentation might be a more efficient way of removing cyanide. Padmaja et al. (1993) hypothesized that fermentation removes cyanogenic compounds by linamarase released from the tubers and also the inoculated microbials. However, Ampe and Brauman (1995) proposed that the endogenous linamarase is responsible for most of the cyanide removal activity during the fermentation, and the amount of linamarases presents in the tubers are high enough to remove the cyanide without the help from linamarases released from inoculated microorganisms. Fufu, a traditional fermented cassava food that is widely consumed in

Africa, can be prepared by spontaneous fermentation of cassava roots. Ampe et al. (1994) concluded that the fufu with the best organoleptic quality could be prepared by peeling and pre-soaking the roots and adding juice from the previously fermented batch. The optimum incubation temperature is between 28 to 37℃, which is related to the maximized β-glycosidase activity as mentioned. Oguntoyinbo and Dodd (2010) identified bacteria strains that initiated the spontaneous fermentation of cassava such as *Lactobacillus plantarum*, *Lactobacillus fermentum*, *Lactobacillus pentosus*, *Lactobacillus acidophilus*, and *Lactobacillus casei*. Apart from spontaneous fermentation, inoculating cassava roots with selected bacteria or fungi can also effectively reduce the cyanide content while retaining good sensory attributes (Kimaryo et al., 2000). Brik et al. (1996) inoculated cassava with *Aspergillus niger* B-1 and successfully reduced cyanide content by 95% to 2 mg/kg. Essers et al. (1995) compared inoculation of 6 different fungi and found *Neurospora sitophila* to be the most effective.

In addition to traditional processing methods that can remove cyanide, breeding or genetic modifications might be another solution. Siritunga and Sayre (2004) proposed two ways to use transgenic approaches. The first is to inhibit the expression of CYP79D1 and CYP79D2 genes. By silencing these two genes, the linamarin content was reduced 60 - 90% in cassava leaves and up to 99% in roots. The second method is to express a leaf-specific enzyme hydroxynitrile lyase (HNL) in cassava roots. HNL speeds up the cyanogenesis by three fold to reduce the accumulation of cyanide. Cyanide is highly volatile, thus HNL reduces the accumulation of cyanide during processing.

b. Transforming production wastewater

As mentioned above, the detoxification process for cassava generates large amounts of waste water that contains cyanide. Cyanide is a threat to living organisms if the wastewater is directly released into the environment without further processing. It disrupts the cellular respiration of living organisms, and prolonged exposure will cause diseases in nerve, respiratory, cardiovascular, and digestive systems, and on the skin of humans and other animals in the environment such as rats, fish, and mice (Akintonwa, 1994; Jaszczak, 2017). The toxicity of water samples from a tapioca processing plant in Thailand was tested using the Microtox test and a duckweed test (Bengtsson, 1994). The Microtox test is often used as a rapid screening tool for the toxicity testing of wastewater (Hao et al., 1996). Duckweed, an easy to cultivate algae, has the ability to assess the toxicity of wastewater samples at a wide range of pH (Sallenave and Fomin, 1997). The study by Bengtsson found that the most used way of treating wastewater, i.e., aging, significantly reduced the toxicity level of the waste, but aging alone is not sufficient to eliminate the toxins from the wastewater. Therefore, it is necessary to develop ways to treat tapioca production wastewater in addition to aging.

Various ways have been developed to treat tapioca wastewater. COD (chemical oxygen demand) and BOD (biological oxygen demand) are usually the two values that are used to evaluate the amount of total and organic compounds in water. In addition to COD and BOD, TSS (total suspended solids), and cyanide, nitrogen, and phosphorus contents are also important parameters in terms of determining the effectiveness of treatments. A general way of removing unwanted compounds from the wastewater includes aging and also flotation, anaerobic fermentation, and aerobic treatment. Fettig et al. (2013) found that using dissolved air flotation, anaerobic degradation, and aerobic post-treatment in a vertical flow constructed wetland, >98% COD, >90% N, >99% cyanide, and 50% P can be removed from the cassava wastewater. Another study looked into anaerobic fermentation using cattle manure as the starter and found the method could successfully remove 72% TSS with optimized conditions (Pandia, 2018). Deshpande et al. (1994) used lime at 600 mg/L as the coagulant to remove suspended solids (52%) and BOD (37%) from the cassava wastewater, and increased the pH of the wastewater from 5.5 to 7.0. These studies all indicated the possibilities of combining different treatment methods to clarify the tapioca wastewater.

In addition to treatment, other technologies are used to transform wastewater into energy such as electricity and biogas. Hasanudin et al. (2019) estimated the possibility of making full use of tapioca wastewater and tapioca fibers to generate electricity that can be used in the drying process of tapioca starch. Based on their estimation and calculation, if the plant of interest in Indonesia was able to utilize cassava fibers in addition to wastewater for the fermentation of cassava fibers and wastewater to methane, they estimated that the energy generated would be able to meet the needs of the tapioca starch drying process. In another study, microbial fuel cells (MFC) were used to transform tapioca wastewater into electricity (Harimawan, 2018). When optimized, 46% COD can be removed from the wastewater, and it reaches an open circuit voltage equilibrium at 676 mV.

Although processing and transforming the wastewater are good ways of post-treatment of tapioca wastewater, they both require significant investments into manufacturing facilities. Most of the current tapioca processing factories around the globe are small to medium sized, and investment without funding support might not be feasible in a short period of time. Therefore, another way of conserving the tapioca wastewater used is by recycling the wastewater back into the production process. Tapioca processing usually goes through several steps that require the input of water, including washing, grating, and settling or separating. The wastewater from the settling or separating process can be reused on the previous mentioned steps (Adnan, 2020).

The average amount of water needed per tonne varies based on different production parameters and efficiency. Generally, it varies between 2500 to 6000 L of water/tonne of tapioca production. Given the quantity of tapioca production worldwide, the amount of wastewater generated each year is large. If no action is taken, it certainly will threaten the local environment. Government agencies can take the initiative to encourage tapioca processing factories to reuse the wastewater, transform the wastewater into biogas or electricity, and process the water before releasing it into the environment by providing funding and education. An up-flow anaerobic sludge blanket (UASB) is an anaerobic digestion reactor that uses microorganisms to transform wastewater into biogas such as methane (Latif et al., 2011). A case study in a small to medium sized tapioca starch processing plant in Thailand found that by investing in UASB, the system was able to produce 1350 m^2 biogas/day, which could be used to substitute for 8100 L fuel oil/day (Chavalparit, 2009). UASB has been tested with many scenarios to be able to effectively remove COD, BOD, and TSS from wastewater (Mungary, 2010). Although the investment in UASB for the tapioca production wastewater processing in the plant in Thailand costed 55 million baht (~$1.6 million), the savings on fuel oil every year would be 25 million baht (~$0.7 million) meaning the return on investment is a little over two years.

3. Tapioca starch modification

a. Native tapioca starch properties

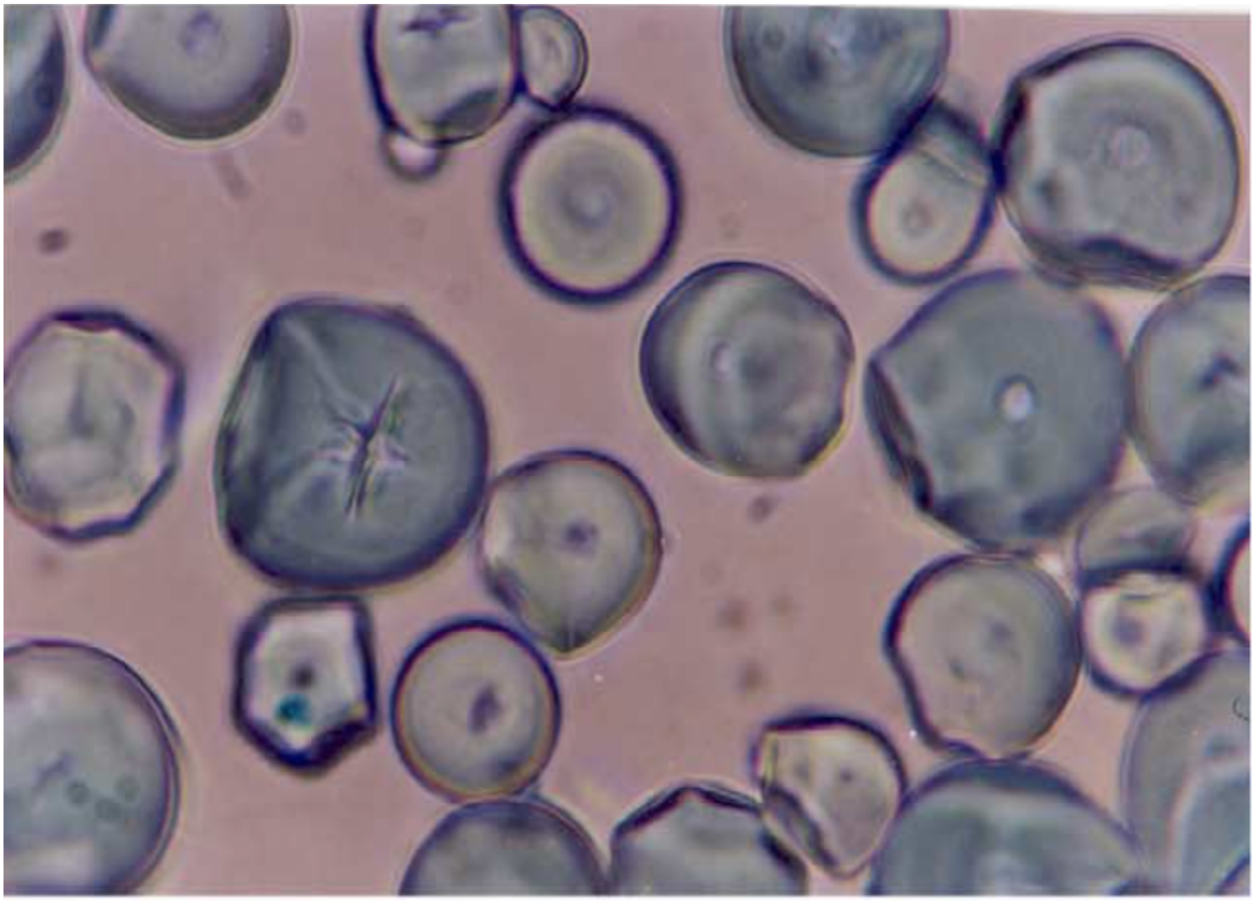

Figure 5: Tapioca Starch Granules as seen with Light Microscopy (Mishra and Rai, 2006)

The appearance of tapioca starch is shown in Figure 5. The granules are mostly spherical and truncated with the position of the hilum in the center of each granule. Hilum is the point where starch granules start to grow, and in different starch sources the position of hilum might be different (Cai and Wei, 2012). According to Mishra and Rai (2006), the size of tapioca starch granules varies between 7.1 - 25μm. The pH of tapioca starch is 4.8 and solubility is 1.9% at 20℃. Solubility increases to 14.4% at 70℃. Tapioca starch paste shows a shear thinning (pseudoplastic) behavior with WHC (WHC) of 10 g H_2O/g starch. The gelatinization temperature of the starch was 66.2℃, and the peak viscosity was 1770 cP. For production and storage safety, Zhang et al. (2018) analyzed the minimum ignition energy of tapioca starch at a powder pressure of 90 kPa as 58 mJ. Chisté et al. (2011) graphed the sorption isotherm of tapioca flour at 25℃. At a water activity of 0.6, the moisture content of tapioca flour was ~10.1%, suggesting a moisture content limit for microbiological safety during storage.

b. Starch heating and cooling with water

Generally, the addition of excess amounts of water followed by heating leads to a series of steps that includes gelatinization, pasting, and retrogradation of the starch. The changes of viscosity and temperature with time are summarized by Balet et al. (2019) in Figure 6 with a typical RVA (Rapid Visco Analyser) pasting profile. RVA measures the viscosity of the substance within a period of time when it is being stirred and heated (Tang and Copeland, 2007). Like any other starch, tapioca starch is composed of amylose and amylopectin. Amylose has mostly a linear structure with α-1,4 glycosidic bonds (Takeda et al., 1984). Amylopectin, on the other hand, is much larger and complex branched structures due to the presence of both α-1,4 and 1,6 glycosidic bonds that contribute to the crystalline structure of starch granules (Hizukuri, 1986). When being heated with an excess amount of water, the crystalline double-helix structure of starch breaks down and becomes amorphous, and the viscosity of the paste continues to increase until it reaches a peak viscosity (Ai and Jane, 2015). According to Cozzolino (2016), peak viscosity also indicates the maximum WHC of the starch. In Figure 7, Huang et al. (2017) shows the morphological change of a tapioca starch granule. At the beginning of the gelatinization, starch granules absorb water which promotes the mobility of the amorphous region of starch granules (Ratnayake and Jackson, 2007). During the heating process, the blocklets in the starch granule are released and deformed into olive shaped strings that connect blocklets together. At the pasting temperature, deformed blocklets would merge together to form larger blocklets. Increasing viscosity is observed. With continuous heating to reach a temperature higher than the pasting temperature, more merged blocklets are formed until the eventual formation of a three-dimensional starch paste. Because the structure of the starch is completely destroyed, this process is irreversible. Huang et al. reported that the onset, peak, and completion gelatinization temperature of tapioca starch was 64.6, 70.3, and 80.2℃, which is slightly different from what Mishra and Rai (section 3.a) observed. This is because the tapioca starch samples used have variations. Generally tapioca starch has an onset gelatinization temperature around 65℃.

After reaching the peak viscosity, the viscosity of starch paste starts to decrease before retrogradation where the viscosity starts to increase again. According to Balet et al., it is hypothesized that the observed decrease of viscosity is a result of the free water movement into starch granules as the crystalline structure of starch becomes loose.

Starch retrogradation occurs when the viscosity starts to increase again. It is well studied that retrogradation contains two steps. The first step refers to the short-term amylose crystallization which is thermodynamically irreversible; the second long-term step refers to the amylopectin crystallization which is thermodynamically reversible (Miles et al., 1985). Retrogradation transforms non-waxy starch paste to a firm gel, which may or may not be desirable in different scenarios (Wang et al., 2015). In most cases, retrogradation causes unwanted properties changes in starchy products. For example, the staling of bread (Aguirre et al., 2011). However, in some cases retrogradation modifies the products into a stage where it is desirable. For example, in the production of breakfast cereals or parboiled rice, dehydrated potato mash, Japanese “harusame”, and Chinese rice vermicelli (Karim et al., 2000). Therefore, it is important for the product developer to understand the role that starch retrogradation plays in their products and delay or facilitate it from happening.

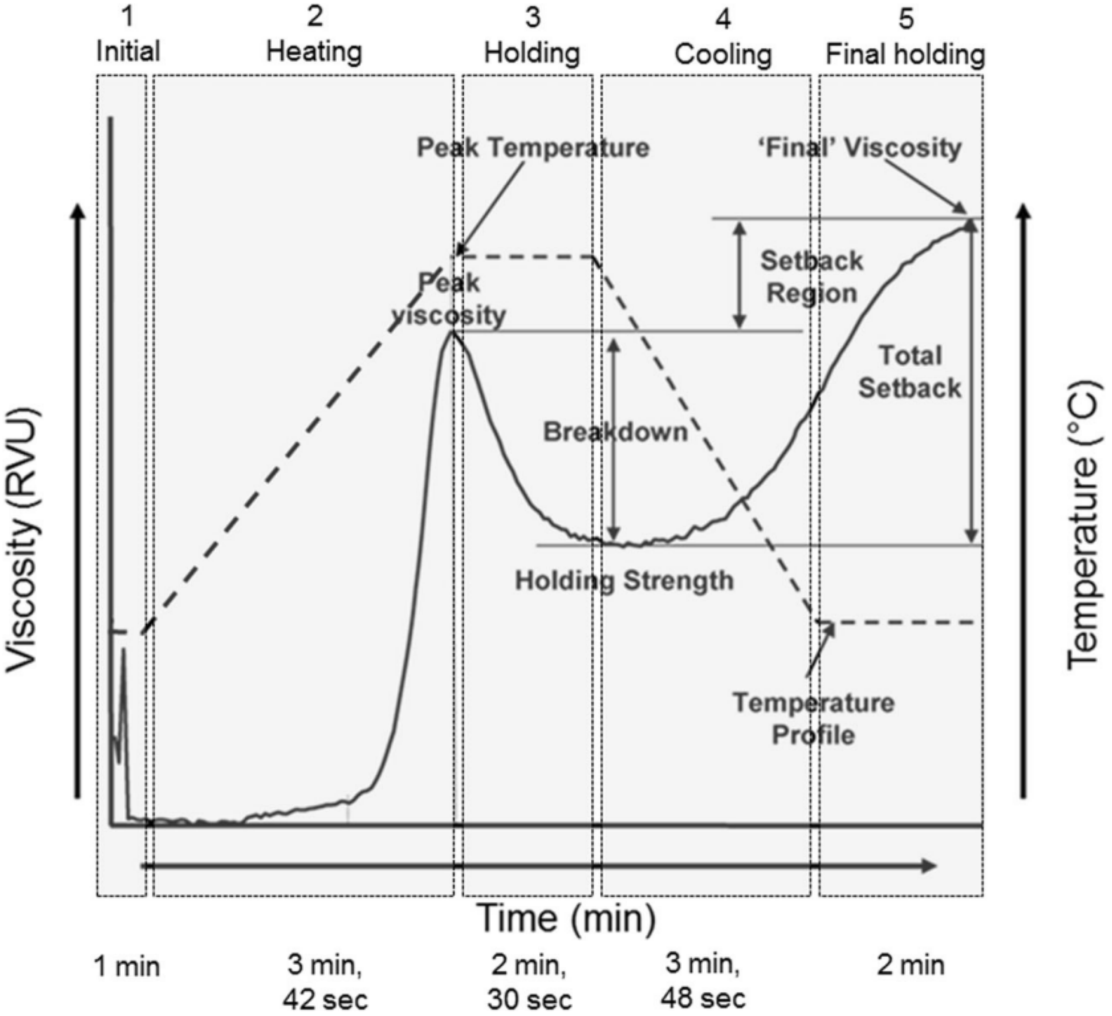

Figure 6: A Typical RVA (Rapid Visco Analyser) Pasting Profile of Starch (Balet et al., 2019)

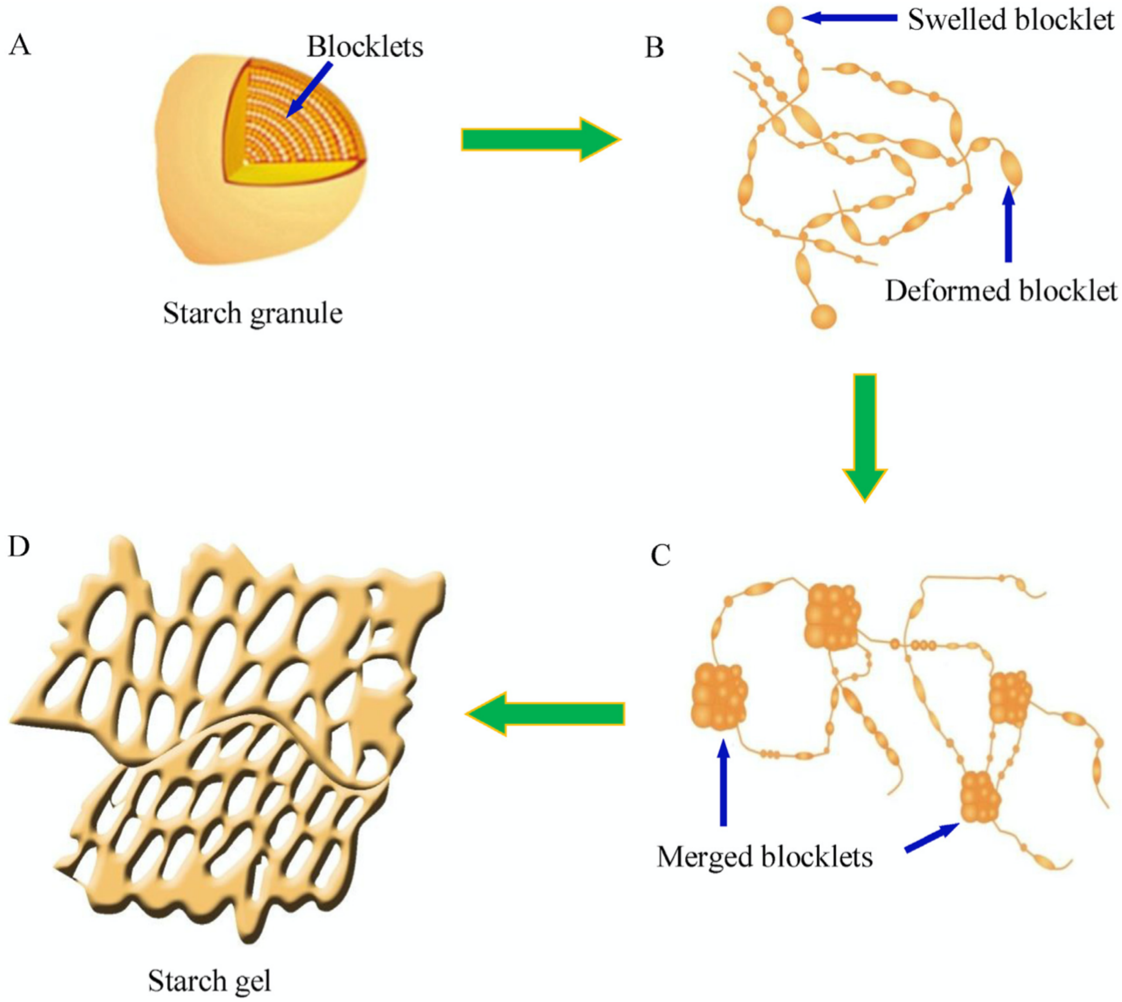

Figure 7: A Schematic Diagram of the Morphology Change of Blocklets during the Gelatinization Process of a Tapioca Starch Granule. A, a tapioca starch granule; B, deformed and swollen blocklets; C, merged blocklets; D, starch gel (Huang et al., 2017).

c. Glucose production using hydrolysis

Cassava roots contain a high carbohydrate content (Kolapo and Sanni, 2009). The starch thus can be processed into glucose or dextrin using hydrolysis. Glucose syrup and dextrin are widely used in the food industry with confections, baked products, and beverages (Ahmed et al., 1983). It is a good opportunity for cassava producing countries to produce glucose syrup and dextrin within the country instead of importing them. In addition, it is also the pathway for the fermentation of ethanol, as starch needs to be hydrolyzed into simple sugar first before being used by microorganisms to produce ethanol (Nuwamanya et al., 2012). Converting tapioca starch to glucose or dextrin can be achieved by acid hydrolysis, enzymatic hydrolysis, or a combination of both. Dextrose equivalent (DE) value is often used to describe the degree of hydrolysis. Starch has a DE value of 0% and glucose has a DE value of 100%. In between there are dextrins (1 - 13%), maltodextrins (3 - 20%), and glucose syrup (≥20%) (Sun et al., 2010). Compared with acid hydrolysis, enzymatic hydrolysis yields final glucose products with better quality (Tester and Karkalas, 2006). Aggarwal et al. (2001) reported that enzymatic hydrolysis could avoid the off-taste that is generated using acid hydrolysis. In addition, they point out that acid hydrolysis cannot achieve DE >55 without the occurrence of off-tastes. Native tapioca starch resists the hydrolysis by ɑ-amylase because different factors such as the size and shape of the starch granule restrict the availability of the enzyme to the interior of the starch granule (Tester et al., 2006). In this case, it is difficult to obtain glucose with DE values >20%. For example, Triyoni et al. (2017) used ɑ-amylase to hydrolyze native tapioca starch and obtained maltodextrin as the final product with the best conditions. Therefore, different ways to improve the efficiency of converting tapioca starch to glucose were investigated.

Franco et al. (1987) reported that using a combination of ɑ-amylase with glucoamylase can more effectively hydrolyze native tapioca starch compared with using any of the enzymes alone. A conventional tapioca starch saccharification at 90% within 24 h was done by Aggarwal et al., (2001). The starch slurry at a concentration of 25% was liquefied and gelatinized at the same time at 104℃ for 45 min at pH 5.0. Enzymes were able to attack substrates in the gelatinized amorphous starch much more easily compared with starch granules (Slaughter et al., 2001). Then a combination of commercial α-amylase with glucoamylase was used for the saccharification at 60℃ of the starch slurry. This approach is used as a conventional way to produce glucose syrup. The heating temperature during liquefaction and the gelatinization status affect the final DE of the hydrolyzed product. Shariffa et al. (2009) kept the temperature of liquefaction of the starch slurry at 60℃ (a temperature below the gelatinization temperature of tapioca starch) and pH 5-6 for 30 min, and lowered the temperature to 35℃ during the 24 h hydrolysis with α-amylase with glucoamylase. They reached a final DE value of 50%, which was lower than what Franco et al. was able to achieve (90%) at a higher liquefaction temperature when tapioca starch was gelatinized.

To decrease production cost, the enzymes that are used in the hydrolysis can be recycled. For α-amylase, Agustian and Hermida (2019a) used mesoporous cellular foam (MCF) silica and successfully immobilized 80% of the α-amylase from the hydrolysis reaction. MCF works as a filter that can adsorb desired substances from liquid (Oda et al., 2002; Wang et al., 2015). MCF silica was also used to collect glucoamylase by Agustian and Hermida (2019b) in another paper during the tapioca starch hydrolysis, and 82% of the enzyme was immobilised in the process. The group also noticed a slower reaction rate with immobilized enzymes compared with free enzymes. Abd Rahim et al. (2013) encapsulated α-amylase, glucoamylase, and cellulase into sodium alginate-clay beads. The beads were able to retain 51.8% enzyme activity after 7 hydrolysis cycles, suggesting a promising way of recycling enzymes for glucose production.

d. Dextrin production using starch modification

Dextrins with a final DE value ≤20% could be obtained using tapioca starch modifications. Maltodextrin, a common food ingredient that is used as a fat replacer or dietary supplements in drinks, can be derived from tapioca starch using enzymatic hydrolysis with α-amylase (Akbari et al., 2019; Hofman et al., 2016). Similar to the production of glucose with tapioca starch, the starch is liquefied before being hydrolyzed by α-amylase using acidic conditions (Moore et al., 2005; Triyono et al., 2017). Maltodextrin is also commonly used as a natural spraying drying agent or wall material when combined with other hydrocolloids for encapsulation (Busch et al., 2017). For example, Febrianta et al. (2020) found that encapsulating turmeric using maltodextrin showed the highest encapsulation efficiency and solubility as turmeric is a hydrophobic compound compared with using cassava flour or skim milk as the wall material. The encapsulated turmeric could be used as natural antioxidants or colorants.

Resistant maltodextrin with high solubility (90 - 100% depending on the temperature) and low digestibility (~50%) can be obtained using a series of reactions that include pyroconversion with acidic conditions and enzymatic hydrolysis of tapioca starch (Toraya-Avilés et al., 2016; Toraya-Avilés et al., 2017). Pyroconversion breaks down starch molecules and leads to recombination of smaller molecules using the hydroxyl groups to form branched structures with arbitrary α or β -1,2/1,4/1,6 glycosidic linkages

(Bai et al., 2014; Li et al., 2020). However, because humans can only digest α-1,4 and α-1,6 glycosidic linkages, the remaining parts of the modified starch are not digestible in the human digestive system. A clinical trial done by Astina and Sapwarobol (2020) successfully used tapioca resistant maltodextrin on healthy individuals to control the postprandial plasma glucose and insulin levels. However, they pointed out that higher doses would cause flatulence as a result of gut bacteria fermentation.

e. Interaction with hydrocolloids, carbohydrates, and salt

As a food ingredient used in many different food products that require different storage and preparation conditions, tapioca starch is mixed with gums, fibers, carbohydrates, and salts for improved stability and functionalities such as freeze-thaw stability, better rheological and pasting properties, and thermal stability (Temsiripong et al., 2005).

Many food products that contain tapioca starch require storage at frozen temperatures (Seetapan et al., 2013). The freeze-thaw stability is important to preserve the texture and quality of these food products. Upon freezing and thawing, the food matrix such as starch molecules would reorganize which would result in the release of water molecules (syneresis). Various gums, sugars, and salts are used to minimize the retrogradation and syneresis of food products containing tapioca starch during the freeze-thaw cycles. Xanthan gum, which interacts with gelatinized starch at low concentrations, was found to effectively reduce syneresis during freeze-thaw cycles. A schematic diagram is shown in Figure 8. Both Maphalla and Emmambux (2016), and Pongsawatmanit and Srijunthongsiri (2008) reported that increased xanthan gum in the tapioca starch gel would increase the viscosity of the gelatinized paste due to the interaction between xanthan gum and amylose (gum-amylose) formed by hydrogen-bonding. This interaction also contributes to the reduced syneresis by reducing the available water. Retrogradation occurs during the cooling of gelatinized starch paste. Sae-Kang and Suphantharika (2006) found that the syneresis of tapioca starch with xanthan gum during freeze-thaw cycles was mainly due to the retrogradation of amylose, not amylopectin, which agrees with the results of Maphalla and Emmambux and Pongsawatmanit and Srijunthongsiri. Tunnarut and Pongsawatmanit (2017) reported that adding sucrose could further decrease available water during the freeze-thaw cycles in a tapioca starch and xanthan gum matrix to show better syneresis inhibition results. In addition, sucrose also increased the hardness of the gel during the storage, which may or may not be desirable in different food matrices. Similar cryoprotectant effects of sucrose were observed in a tapioca starch and pectin matrix, which can be applied as fruit fillings in frozen desserts such as fruit pies (Agudelo et al., 2014). Chen et al. (2015) reported that when the anionic gum Arabic is added to the anionic tapioca starch gel, the syneresis decreases. On the other hand, anionic gum Arabic accelerates the syneresis of cationic tapioca starch gels. Chen et al. suggested that when the negatively charged gum Arabic attracts the positively charged tapioca starch gel aggregate, their WHC decreases, thus more water leaks out. Varavinit et al. (2000) found that tapioca starch paste thawed at a higher temperature (90℃) has lower syneresis compared with the paste thawed at a lower temperature (60℃). They also used a method called cryogenic quick freezing (CQF) to accelerate the freezing and found the method effectively reduced syneresis to zero during the thawing no matter if the thawing temperatures were high or low. CQF requires the sample to be frozen in liquid nitrogen for 3.5 min before transferring to -18℃. The instantaneous freezing does not allow the starch gel to have enough time to go through retrogradation, thus less syneresis is observed.

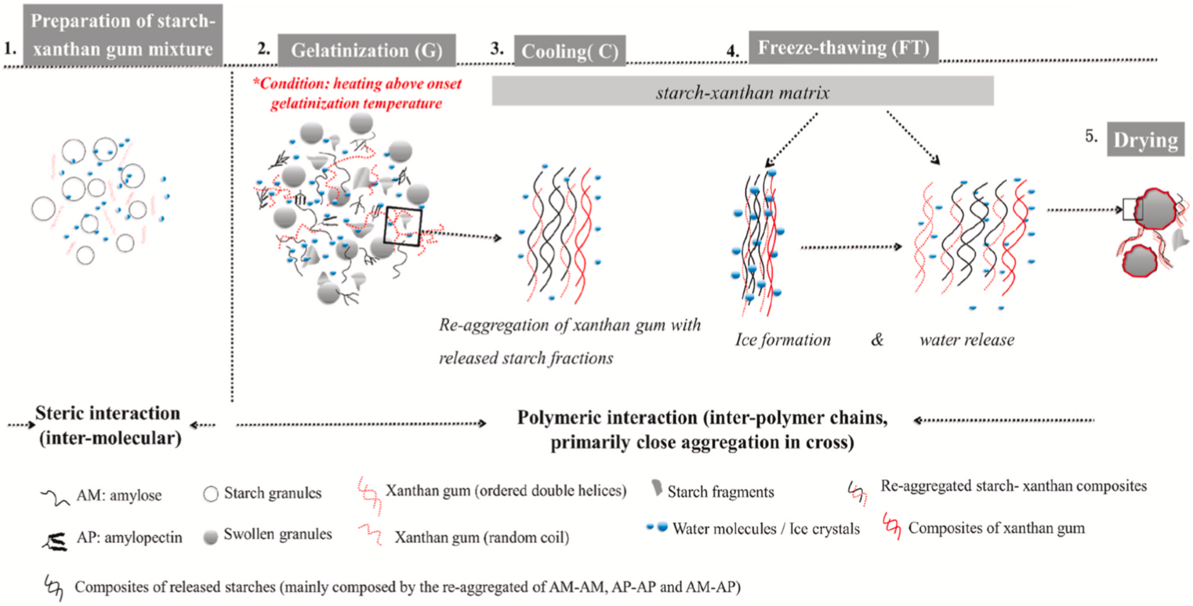

Figure 8: Interactions between Xanthan Gum and Starch Molecules during Gelatinization, Cooling, Freezing Thawing, and Drying (Zhang and Lim, 2021)

Interactions with gums, carbohydrates, or salts can also change the rheological and thermal properties of tapioca starch. According to Singh et al. (2017) the same results without chemical modifications might be achieved by simply mixing the starch with gums, carbohydrates, or salts. These are considered “natural” and in most cases are more cost effective. In addition, the more rigid the structure of the starch and the gums, e.g., guar gum, the greater the inhibition of the hydrolysis of α-amylase. This will slow down the digestion in the GI tract, which could be applied to diets that require prolonged release of glucose (Hong et al., 2015).

Addition of xanthan gum increases the initial, peak, breakdown, final, and setback viscosities of the tapioca starch during the heating and cooling process (Hong et al., 2014). Chantaro et al. (2013) reported results consistent with Hong et al. except that they observed a decreased setback viscosity. The way that Chantaro et al. define setback viscosity is "the difference between the final viscosity and the minimum viscosity after peak viscosity". In Figure 6 (3.b), Balet et al. (2019) used total setback to represent the definition proposed by Chantaro et al., and setback region to represent the difference between peak viscosity and final viscosity. Comparing the graphs that Hong et al. and Chantaro et al. plotted with their data (not shown here), the viscosity of the paste after xanthan gum addition actually showed the same trend in both cases. When the tapioca starch to xanthan ratio (10:0, 9.5:0.5, 9:1, and 8.5:1.5) decreased, the difference between final viscosity and the minimum viscosity after peak viscosity also decreased, and the difference between final viscosity and peak viscosity increased. Therefore, the variance comes from different ways of defining the setback viscosity. Pectin, carrageenan, and a cellulose (xyloglucan) were found to be able to increase the viscosity of tapioca starch (Babić et al., 2006; Pongsawatmanit et al., 2006; Pongsawatmanit et al., 2007).

Hong et al. (2014) also suggested that the addition of sucrose or NaCl increased the pasting temperature of the tapioca starch xanthan gum mix. The sugar or salt would compete with xanthan gum to attract water thus inhibiting the hydration of starch molecules during heating. Chantaro and Pongsawatmanit (2010) reported that the pasting temperature of tapioca starch and xanthan gum (5% w/w) gel increased from 72 - 78 to 82 - 90°C with increased sucrose from 0 - 30%. Zhang et al. (2012) reported that the addition of trehalose had similar effects on tapioca starch gels. Sugars with different molecular weights increased the gelatinization temperature and decelerated retrogradation to different degrees. Babić et al. (2009) used differential scanning calorimetry (DSC) and observed that glucose has the strongest effect on increasing the gelatinization temperature and enthalpy of tapioca starch, followed by sucrose, trehalose, and fructose. They also found that sugars with lower molecular weight (fructose and glucose) retarded retrogradation of tapioca starch less effectively compared with sugars with higher molecular weight (sucrose and trehalose), and different starch sources would change the results. More investigation is needed to study these mechanisms.

Ofman et al. (2004) reported the interaction between preservatives (potassium sorbate and sodium benzoate) with tapioca starch during the gelatinization of the starch. They found that when the water activity of gelatinized gel is ≥0.775, 95 - 97% pre-added preservative solutions would interact with the starch, which might affect their functionality as a preservative in the matrix. Addition of monosodium glutamate to tapioca starch led to higher gelatinization temperatures and reduced swelling and viscosity of the final paste (Yagishita et al., 2011).

f. Interaction with proteins and fats

Tapioca starch, native or modified, is used in food products (e.g., sausages, high protein tapioca puff snacks, and burger patties) that contain proteins and fats to improve the overall sensory profile of the products or act as a fat replacer to reduce the overall fat content (Hughes et al., 1998; Desmond et al., 1998; Lyons et al., 1999; Patel et al., 2016). It interacts with other ingredients in the matrix and improves the quality of the products mainly due to its good WHC. Lyons et al. observed that the increased water holding capability with tapioca starch decreased the cook loss and increased the shear force so that it was similar to that of full-fat sausage products.

More research is needed to understand the mechanism of the interaction between protein and starch. Villanueva et al. (2018) found that the addition of protein (egg albumin or soy protein isolate) to tapioca starch gel resulted in a lower tan δ value with both G’ and G’’ increasing upon the addition of protein, meaning the starch gel became less rigid with higher viscosity than elasticity. Slightly different results were observed by Carvalho et al. (2007) using a micro-visco-amylograph (MVA). They observed similar G’ values and decreased G’’ values which led to a decreased tan δ value after the addition of whey protein isolate (WPI). During heating to 85℃, Ren and Wang (2019) observed increasing G’ values with WPI and tapioca cross-linked starch gels, but they did not measure G’’ or calculate tan δ values. They concluded that the higher gel strength was a result of the electrostatic forces between the protein molecules and the starch molecules. Wu et al. (2018), on the other hand, attribute the higher gel strength to the higher pressure that the starch gel exerted onto the protein gel due to the swelling. They observed that potato starch that has greater amylopectin content showed better “packing effects" than tapioca starch that has lower amylopectin content. As the amylopectin content has a greater effect on the swelling ability of the starch, potato starch, upon gelling, will exert more pressure onto the gel, thus leading to a higher gel strength.

g. Chemical modification

Native tapioca starch has its drawbacks when used in different food matrices. Food products using starch as an ingredient with different functionality requirements usually require the starch to be modified, chemically or physically, to better accomplish the needed product functionality (Zia-ud-Din et al., 2017). Chemical modification is an efficient way of modifying an undesirable property of tapioca starch into a more desirable one (Zhu, 2015). Zhu summarized chemical modifications of tapioca starch well in their review. The chemical modification they mentioned in detail includes cross-linking, alkaline, acid modifications in aqueous solution or in ethanol, cationization, oxidation, and substitution. Therefore, in this discussion, more emphasis will be targeted to the applications of modified starch. Hydrolysis was discussed above and thus will not be included.

Esterification of tapioca starch could be achieved with the addition of octenylsuccinic anhydride (OSA) with a degree of substitution (DS) value ranging from 0 to 0.04 (Makmoon et al., 2013). Whitney et al. (2016) suggested that the esterification of tapioca starch induced by OSA only occurred on the amylose chains but not the amylopectin chains. According to Makmoon et al., the modified esterified tapioca starch was thixotropic and thus could be used as an associative thickener to modify the texture of water-based systems. For example, Domian et al. (2018) prepared 40 to 55% linseed oil powder encapsulated with tapioca OSA starch and trehalose. The product could be used as a creamer for its good stability in hot water. Esterification could also be achieved with the addition of maleic anhydride (Triwises et al., 2016). At a DS of 0.25, the esterified tapioca starch could be cross-linked with trimetaphosphate for the preparation of curcumin embedded hydrogels with an encapsulation efficiency at 80% (Meng et al., 2020).

Oxidation is another common way of modifying tapioca starch. Exposing tapioca starch to ozone for 10 min increased the carboxyl and carbonyl groups in the starch (Chan et al., 2009). Decreased swelling power and solubility were observed. decreased viscosity, and the same gelatinization temperature and enthalpy were also observed in the oxidized starch samples (Chan et al., 2011). Dialdehyde tapioca starch can be prepared by oxidizing tapioca starch with periodic acid (sodium metaperiodate and hydrochloric acid) (Wongsagon et al., 2005). Increased gelatinization temperature, decreased gelatinization enthalpy, increased pasting temperature and peak viscosity as well as breakdown and increased solubility were observed in the dialdehyde tapioca starch. Dialdehyde tapioca starch can be used as a biodegradable adhesive in the manufacturing of particle board (Ye et al., 2018). Purcell et al. (2014) used oxidized starch to lower the fat content of oven-baked chicken nuggets while maintaining a good product texture.

Cross-linked tapioca starch can be prepared using sodium trimetaphosphate (STMP) and sodium tripolyphosphate (STPP) at different concentrations (Wongsagonsap et al., 2014). The cross-linked tapioca starch can be used in soups to improve the texture and sensory profiles. Acetylated tapioca starch was prepared by the reaction with acetic anhydride (Babic et al., 2007). Acetylated tapioca starch could be used to prepare smaller microparticles (8 - 58 µm) loaded with potassium sorbate compared with those prepared using native tapioca starch (30 - 227 µm). These decreased the amount of antimicrobials added in food products by increasing surface area (Alzate et al., 2016). Fan et al. (2019) modified tapioca starch by both cross-linking and acetylation and found that a low-degree of cross-linking and acetylated tapioca starch at a pasting temperature >61℃ could significantly increase the G' value and improve the textural properties of freshwater fish myofibrillar protein gel. Therefore, the modified tapioca starch could be a good texture modifier for freshwater surimi products.

Cationic tapioca starch was prepared by Han and Sosulski (1998) using 3-chloro-2-hydroxypropyltrimethyl ammonium chloride in aqueous alcoholic-alkaline solvent. Cationization reduced the pasting temperature of tapioca starch from 67.5 to 46.5℃ and the viscosity of modified tapioca starch was lower throughout the gelling process. When interacting with gums, cationic tapioca showed different properties compared with native starch as mentioned in section 3.e. The electrostatic interaction between gums and cationic tapioca starch could create gels with unique functionality.

Hydroxypropyl tapioca starch was prepared by reacting with propylene oxide with alkaline conditions (pH 9 - 10) with the presence of Na_2SO_4 (Kishida et al., 2001). Kato et al. (2009) showed that hydroxypropyl tapioca starch with high DS (0.18) was resistant to ɑ-amylase digestion in a KKAy mice model with unknown mechanism, indicating the potential of resistant starch. With pasting properties, cross-linked hydroxypropyl tapioca starch showed a lower gelatinization temperature and enthalpy compared with the native starch (Thirathumthavorn and Trisuth, 2007). Therefore, hydroxypropyl tapioca starch is used as a modified starch in many food products to improve the texture and functionality such as noodles or bread. In noodle products, partially substituting wheat flour with hydroxypropyl tapioca starch increased the moisture content of the noodles (Fuzuzawa et al., 2016). Miyazaki et al. (2008) used 18.4% hydroxypropylated tapioca starch with 1.6% dried gluten to substitute 100% of the wheat flour to prepare frozen bread dough. The resulting dough with high DS (0.1) with hydroxypropylated tapioca starch retarded bread staling compared with those made with 100% wheat flour or native tapioca starch, which indicated that hydroxypropylated tapioca starch could be a promising anti-staling agent for frozen bread dough making. Dihydroxypropyl tapioca starch could be prepared using chloropropilene glycol reacting with tapioca starch in alkaline conditions (Schmitz et al., 2006). The resulting dihydroxypropyl tapioca starch product showed higher swelling power and viscosity, lower retrogradation, and higher freeze-thaw stability compared to hydroxypropyl tapioca starch or native tapioca starch. However, chloropropilene glycol was not found in CFR 21 172.892 Food Starch -- Modified to be a listed starch modifier, suggesting the limited use of this modified starch in food products.

h. Physical modification

Chemical modification, although the desired functionality could be achieved, is usually perceived as “unnatural” by consumers and might generate environmental pollutants. Physical modifications, on the other hand, do not require the addition of chemicals, thus are usually more welcomed by the consumers and produce less pollution compared with chemical processing.

Noble gas plasma treatment induces starch modifications using the interaction between ionized gas and the starch surface (Thirumdas et al., 2017). Deeyai et al. (2013) used a dielectric barrier discharge (DBD) argon plasma to treat tapioca starch and observed starch cross-linking at low relative humidity. Wongsagonsup et al. (2014) used a jet atmospheric argon plasma at different powers (50 or 100 watt) and different sample preparation methods (cooked tapioca starch or tapioca starch granules) and observed the occurrences of both cross-linking and depolymerization of samples. The mechanism suggested was that the jet atmospheric argon plasma modifies the samples by breaking C-O, O-H, or C-H bonds of the starch. However, both Deeyai et al. and Wongsagonsup et al. did their study at atmospheric pressure, thus the modification was mainly limited to the surface of the starch sample. In addition, they did not investigate if their ideas could be utilized with large scale production. Therefore, based on their study, Chaiwat et al. (2016) proposed using a semi-continuous downer reactor for large scale production of low-pressure argon plasma treated tapioca starch. The downer reactor utilizes the force of gravity to achieve uniform contact between gases and solids in both axial and radial directions. They observed a higher G’ value and decreased tan δ value after 1 treatment cycle indicating the formation of cross-linking and increased depolymerization, which weakened the gel structure with repeated cycles (3 or 6 cycles). Therefore, using the semi-continuous downer reactor with low-pressure argon plasma treatment, instantaneously (<0.3 s) which lowers the degree of cross-linked tapioca starch could be used for large-scale production.

Gelatinization of starch, as mentioned, can be achieved by heating the starch with an excess amount of water. In addition to this method, applying high pressure to the starch slurry could also obtain similar results. Specifically, high hydrostatic pressure processing (HPP) is often used to modify tapioca starch at ~550 - 600 MPa at room temperature (20 - 27℃) (Oh et al., 2008). HPP has been used in the food industry since the 1990s as a non-thermal processing method to produce high quality safe food by inactivating microbes in the food matrix while maintaining the original color and tastes of the products (Yamamoto, 2017). Different from heat induced gelatinization, HPP treated tapioca starch partially preserves the starch's granular structures while altering the chemical interactions of starch-starch or starch-water interactions, resulting in a modified tapioca starch gel with higher stability compared to the unmodified tapioca starch gel (Vittadini et al., 2008). On the other hand, the granular structure of gelatinized tapioca starch obtained by heating is destroyed during the process of heating. After HPP treatment, amorphous granular starch (AGS) was prepared by washing with ethanol, which preserved the granular structure, while non-AGS was prepared by washing with water (Song et al., 2015). AGS maintained the preserved starch granule structure while in the non-AGS the granular structure was lost. They observed higher WHC in the HPP modified non-AGS than AGS. They concluded that the released amylose and amylopectin from non-AGS are able to bind more water, thus resulting in higher WHC. The group continued their study and found that HPP reduced the gelatinization temperature of tapioca starch and decreased the pasting viscosity (Song et al., 2017). The results were consistent with Liu et al. (2012). Because of its unique characteristics, the group indicated that HPP can be applied to different products, e.g., starch films or hydrogels as biodegradable packaging. Because HPP does not require heat, the inhibition of moisture loss and slower retrogradation during the gelling enabled

HPP prepared tapioca starch films to have higher tensile strength and elongation at break than thermally gelatinized tapioca starch films (Kim et al., 2018). Larrea-Wachtendorff et al. (2020) successfully prepared a tapioca starch hydrogel with the desired viscosity, G’, and firmness with HPP at 600 MPa and 15 min treatment.

High-speed jets (HSJ) are an ultra-high speed homogenizer that generates high pressure using hydraulic mechanisms and induces disruption of the materials but does not require heating as described by Fu et al. (2015a). HSJ treatment of rice starch resulted in complete loss of integrity of the starch granules as suggested by the observed degradation of amylopectin (Fu et al., 2015b). Similar pressure dependent starch granule disruptions could also be observed with tapioca starch with HSJ treatment (Xia et al., 2015). Specifically, the breakdown of amylopectin to smaller sizes led to higher solubility; the breakdown of the granules exposed more hydroxyl groups to the water with partial gelatinization, reduced viscosity, and decreased G’ values (Xia et al., 2019). Xia et al. also suggested that HSJ treated tapioca starch might be a good ingredient for low viscosity extrusion foods.

Nano-sized starch has an increasingly important role in the current food and pharmaceutical industry. The applications of nano-sized starch are not limited to but include polymer composites, packaging materials, emulsion stabilizers, adsorbents, drug delivery vehicles and coating, and film enhancers (Wang and Zhang, 2021). Wet media milling is a well-developed physical modification method to transform large particles (e.g., chitosan and fish bones) to nano-sized particles (Yin et al., 2015; Zhang et al., 2012). Li et al. (2020) used this method and successfully prepared nano-scale tapioca starch (size 140 nm). The disrupted granules led to a decreased gelatinized temperature and viscosity, more surface exposure of C-O bonds, and a higher surface to size ratio, which could be a good candidate additive to improve the texture of seafood products such as surimi. Xia et al. (2017) showed that HSJ could also be used to prepare nano-sized tapioca starch. However, using this method required the starch to be micronized before using a vibrating superfine mill for >0.5 hr before going through HSJ cycles (1 - 3 cycles), which overall is much more complicated compared with wet media milling.

Lamanna et al. (2013) used gamma irradiation to prepare tapioca starch nanoparticles with sizes ranging from 20 – 30 nm. This method is convenient and rapid. However, irradiated products may not be appropriate for some food products such as when a clean label is desired. Minakawa et al. (2019) used ultrasound at 20 kHz for 30 min followed by 1 h standing to obtain nano-sized tapioca starch (35 – 65 nm) in the liquid phase and micro-scale tapioca starch (3 – 7 μm) in the sedimentation. This method, although relatively easy to carry out, still requires long sedimentation times and filtration. In addition, the sizes of both the micro- and nano-sized starch have relatively large variations. Manchun et al. (2012) treated tapioca starch slurry at higher energy (24 kHz) for 30 min using ultrasonic but did not report any obtained micronized tapioca starch. Instead, they reported increased DE value of ultrasonic treated tapioca starch compared with the native ones. The increased DE, as they suggested, was a result of the disrupted starch granule structure. Hedayati et al. (2020) prepared tapioca starch nanoparticles using nanoprecipitation (particle size peak at 219 ± 7 nm) or nanoprecipitation followed by sonication (particle size peak at 163 ± 6 nm). Starch nanoparticles prepared with sonication had smaller sizes because the treatment further broke down the size of the granules. Nanoprecipitation was completed by continuous addition of distilled water dropwise into starch acetone solutions with constant stirring. The preparation of the starch nanoparticles was based on the interfacial deposition of the starch followed by the removal of the semi-polar solvent, in this case acetone, miscible with water (Fessi et al., 1989). The starch nanoparticles showed lower gelatinization enthalpy, and might be able to work as a nanocarrier for hydrophobic bioactive compounds (Qin et al., 2016).

Pulsed electric field (PEF) is usually used to treat samples using high electric pulses (30-50 kV/cm) in a short period of time (less than 1 s) for non-thermal pasteurization (Ravishankar et al., 2008). Recent studies focused on using this method to modify the structure of food biopolymers such as creating covalent bonds between proteins or degrading large starch molecules (Zhu, 2018). Han et al. (2012) observed that PEF treatment up to 50 kV/cm (equivalent to 49.4 J/g) of tapioca starch caused the granules to completely lose their crystalline structure, resulting in a decreased gelatinization temperature, gelatinization enthalpy, peak viscosity, breakdown viscosity, and final viscosity of the starch gel. However, Maniglia et al. (2021) tried to use PEF to improve the performance of wheat and tapioca starch in 3D printing but found the modification only improved the functionality of wheat starch in 3D printing but tapioca starch remained unchanged. Unlike what was observed by Han et al., Maniglia et al. did not observe any tapioca starch granule surface or morphology changes. The PEF treatment done by Han et al. used up to 50 kV/cm for 214 µs while Maniglia et al. used the same energy but much shorter time (5 µs). The result obtained by Han et al. also suggested that the disruption of starch granules was positively correlated to the energy input.

Therefore, the variations in the results of the two studies might be due to the time difference.

5. Poverty, economy, and nutrition

a. Tapioca as a part of the solution for food security and its problems

Cassava is a suitable plant as a food source for barren areas because of its high tolerance of drought and soil infertility. It is part of the solution to food security in many parts of the world. Reincke et al. (2018) summarized a logic chain as shown in Figure 9 to explain why cassava is widely grown for this purpose. The countries that benefited the most from cassava growing often suffered from drought and infertile land. It was also found that the degree of difficulties with the environment and the growing conditions has been positively connected to the importance of cassava as a crop in areas in Africa (Prudencio and Al-Hassan, 1994).

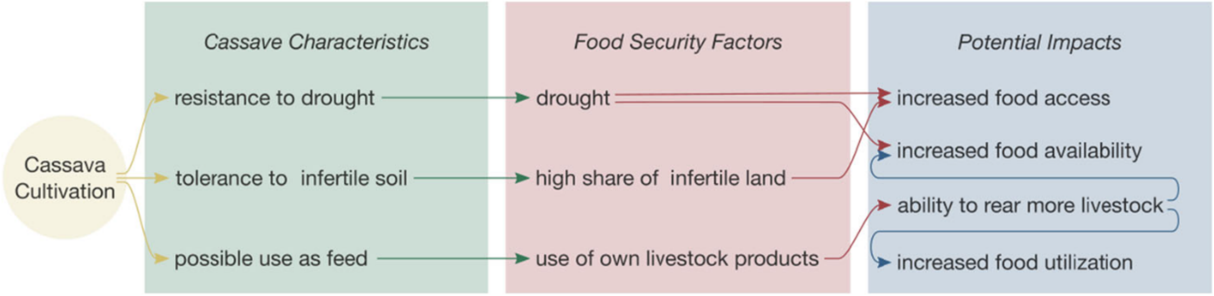

Figure 9: Logical Chain of Effects for the Cultivation of Cassava According to Results from a Qualitative Survey in Tanzania (Reincke et al., 2018)

Cassava is grown in more than 100 countries and feeds millions of people in tropical areas of Africa, Asia, and America (Parmar et al., 2017). The plant is mainly used as a staple food for food security in Africa and some Asian countries. A study found that the food secure rate of cassava growers in Indonesia was 81.3% (Saediman et al., 2019). However, in many African countries where cassava is consumed as a staple food, the food insecurity rate is much higher. One study found that the food insecurity rate was 64% in the participating households in Ondo State, Nigeria (Ajayi and Olutumise, 2018).

Although compared with other crops, cassava growing requires minimum resources such as nutrients and water, and is able to provide much higher yield rates compared with other crops with the same growing conditions, there are many factors contributing to food insecurity, especially in African countries. First of all, viral diseases on the plant such as CBSD and CMD cause significant yield loss every year in many cassava growing regions (Patil et al., 2015). It was estimated that in 2001 the production loss was between 20 to 25%, and equals $6 -- 7 million. Second, lack of processing technologies, poor storage conditions, and unavailable industrial applications of cassava limits the growing potential while causing financial loss every year (Parmar et al., 2018). After being harvested, cassava is manually processed into cassava chips using sun drying and stored for seasons when food is less available. The poor manual processing techniques limit the potential of industrial uses due to food safety and quality concerns. For example, the chips are manually chopped into sizes that are not uniform by women and older children at home using kitchen knives, and sun-drying will expose the products to many environmental hazards that may cause food safety problems. During storage, significant loss was observed due to insects. In these situations, no industrial application could be applied to produce value added products due to lack of funding support.

Most cassava farmers in key producing countries are in poor financial condition. In Indonesia, the incomes of the majority of cassava farmers are able to meet decent living needs, but they have limited access to finance such as loans (Banowati et al., 2020; Yulianto et al., 2020). In Thailand, cassava farming significantly improves the lives of farmers, but smallholder farmers still need to seek non-farming incomes as farming income could only cover 40% of their total income (Polthanee, 2018).

Some strategies should be adopted to support the use of cassava as a food security solution in food insecure areas. First, farmers need to be educated about cassava growing and how to manage the plant in a way to benefit themselves. This includes good agricultural practices such as proper irrigation, use of a soil profile, and use of fertilizers that fit the growing conditions (Visses et al., 2018). Also, it is important to educate the farmers about the value of the crop, because in some regions people perceive cassava as a “poor man’s crop”, and are thus unwilling to grow it (Reincke et al., 2018). Second, government or official support would also benefit the cassava farmers. From 2001 to 2007, a Presidential Cassava Initiative (PCI) was established and implemented in West African countries including Nigeria, Ghana, and the Democratic Republic of Congo. Throughout the years, PCI was able to increase cassava output, promote an increase in the food supply, and enhance food security in the areas where the policy was implemented (Donkor et al., 2017). Last but not least, statistics showed that more scientific research related to cassava would help small cassava farmers in a systematic way (Rusike et al., 2010). Understanding the genome using sequencing of the plant would support research related to gene modifications to solve problems such as disease control or adaptability with different conditions. For example, varieties that are able to tolerate higher salinity will help food insecure farmers in the coastal areas as their farming lands contain higher salt compared with in-land farmers (Gleadow et al., 2016). There are many open source genomes of the cassava that have been determined by researchers and are available (Ayling et al., 2012; Wilson et al., 2017). Overall, the ways of improving the lives of cassava farmers in food insecure households as suggested above would also require funding support. The status of food insecure farmers, especially those in African countries, will benefit if more foundations with capital participate.

b. Tapioca nutrition and fortification

Unmodified and unfortified cassava has a simple nutrition profile. Although there will be small variations between different varieties, cassava root was reported to be made up of carbohydrates (94.8 ± 0.8%), moisture (4.3 ± 0.2%), ash (0.34 ± 0.03%), crude protein (0.31 ± 0.00%), and fat (0.17 ± 0.02%) (Kolapo and Sanni, 2009). They also reported mineral and other micronutrient contents of cassava. For minerals, cassava tubers contain 17.0 ± 0.1 ppm of Fe, 3.3 ± 0.2 ppm of Zn, 2.24 ± 0.01 ppm Mn, 1.79 ± 0.01 ppm Cu, and 1.1 ± 0.3 ppm Na. For other micronutrients, cassava tubers contained 0.133 ± 0.004% K, 0.03 ± 0.001% crude P, 0.01 ± 0.00% Ca, and 0.01 ± 0.00% Mg. Overall, cassava tubers are composed mainly of carbohydrates, with some moisture and small amounts of protein and fat. For micronutrients and minerals, cassava tubers contain some Fe and Zn, but the amounts are relatively low.

As a staple food in many developing countries, the poor nutrient profile of cassava brings problems. Anandan et al. (2015) reported a case in which a 20-year-old male patient was diagnosed with endomyocardial fibrosis (EMF) in India. Similar EMF cases were also reported in Uganda (Sezi, 1996). Both Anandan et al. and Sezi concluded the cause of EMF in these cases to be consuming tapioca as the main food source without intake of adequate amounts of protein. EMF can lead to heart failure and thus be fatal (Mocumbi et al., 2009). Therefore, cassava nutrient fortification is important for public health concerns, especially for countries where cassava serves as the major food source.

Mixing tapioca flour with other flour or protein mixes was studied by Kolapo and Sanni (2009). They mixed tapioca flour with soybean flour to increase the crude protein, P, fat, and ash content of the flour. Addition of protein and minerals would change the properties of the flour such as rheological and thermal properties that might change the texture of the final product (Villanueva et al., 2018). However, the problem of protein deficiency occurs mainly in areas where other food sources are limited. People do not have choices and financial access to other sources of food such as soybean flour. In this case, fortification of consumer products is unlikely to solve the problem. Fermentation was also found to be able to increase the crude protein content. Boonnop et al. (2009) used *Saccharomyces cerevisiae* to ferment the cassava chips and fresh roots. They observed an increase in the crude protein content in both fermented cassava chips (30.4% increase) and fermented fresh roots (13.5% increase), as well as enhanced fat content (5.8% increase in cassava chips and 3.0% increase in fresh roots). Although the goal of the study was to use the fermented product for animal feed, it was also relevant to human food nutrition improvement. Soccol et al. (1994) used strains of *Rhizopus* on raw cassava and observed an increase of crude protein from 1.75 to 11.3%. During the fermentation, they also observed production of fumaric and lactic acid, as well as ethanol. Production of ethanol might not be desired in this situation, and heating and evaporation can be used to remove the ethanol.

Just like golden rice, biofortification of β-carotene in cassava was developed to solve the problems of vitamin A deficiency (Failla et al., 2012). Howe et al. (2009) found that the bioavailability of β-carotene fortified cassava tubers had similar bioavailability as β-carotene dietary supplements on a vitamin A deficient gerbil model. In a human clinical trial on healthy American women, the vitamin A conversion rate of β-carotene fortified cassava was found to be 4.5:1 μg (β-carotene:retinol) (La Frano et al., 2013). La Frano et al. also indicated that the processing method that is used to remove the cyanide from cassava tubers would cause loss of β-carotene in the fortified tubers. For different preparation methods, frying the cubes of cassava was found to be able to better retain β-carotene compared with boiling the cubes in water (Berni et al., 2014). However, Berni et al. did not consider the cyanide removal efficiency in their study. Storage of β-carotene fortified cassava in the form of chips was observed to be better than storage in the form of cassava flour (Chavez et al., 2007). Degree of recovery of β-carotene after tapioca processing is genotypically dependent (Iglesias et al., 1997). Therefore, in addition to high β-carotene content, it is also important to consider the stability of β-carotene during the processing of fortified cassava when selecting the genotypes. Furthermore, it was observed by Beyene et al. (2018) that cultivars with the highest concentration of β-carotene had a reduction of 50 to 60% of dry matter content.

For cassava farmers in the areas where the food supply is extremely limited, such a high decrease in the dry matter content might not be good even with higher β-carotene content in the tubers.

Boba or bubbles that are made from tapioca starch are popular in many countries. They are added into milk teas and contribute to the total calories of milk teas. Milk teas with tapioca boba or bubbles are popular with young people, and are causing problems such as obesity because of their high calorie content. It is of health concern that the intake of boba milk tea should be limited in young people (Pei et al., 2018).

6. Tapioca starch fermentation

a. Poly(lactic acid)

Poly(lactic acid) (PLA) is a biodegradable thermoplastic material that is derived from fermentation of starch to lactic acid, followed by polymerization to PLA as described in Figure 10 (Sanglard et al., 2012). PLA has a wide range of applications in many industries. For example, in the medical and pharmaceutical industry, it is used to make surgical implants, a FDA approved suture material, a carrier in controlled drug delivery, and PLA scaffolds for supporting cell growth in tissue engineering (Gupta et al., 2007). It is also a 3D printing material whose use is increasing in the fashion, architectural, and engineering industries (Van den Eynde and Van Puyvelde, 2017). PLA straws are being used in coffee or milk tea shops to replace plastic straws that are environmentally unfriendly or paper straws that are less user-friendly.

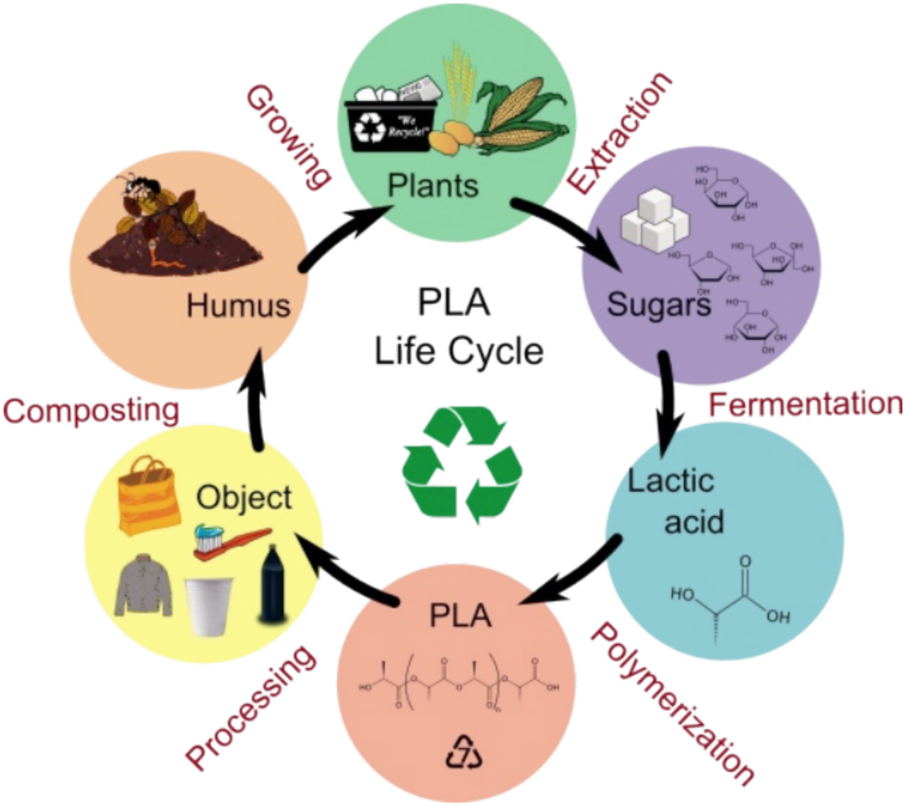

Figure 10. Life Cycle of PLA (Sanglard et al., 2012)

Converting tapioca starch to lactic acid is done using fermentation with different bacteria. *Lactobacillus* is a common bacterial species used to convert starch to lactic acid (Anuradha et al., 1999). Trakarnpaiboon et al. (2017) used ɑ-amylase treated liquified tapioca starch to produce L-lactic acid with *Rhizopus microsporus* DMKU 33. Olszewska-Widdrat et al. (2020) reported using *Bacillus coagulans* spp. for the fermentation of liquified tapioca starch to obtain lactic acid. Wee et al. (2008) successfully produced lactic acid using *Enterococcus faecalis* to ferment tapioca starch on corn steep liquor as the nitrogen source. For more efficient and economical lactic acid production, cell-immobilization or recycling could be adopted to achieve continuous fermentation instead of batch fermentation (López-Gómez et al., 2019). For converting lactic acid to PLA, Byers et al. (2018) summarized synthesizing PLA by ring-opening polymerization of lactide, a cyclic dimer of lactic acid, and discussed the pros and cons of using different catalysts. Compared with other methods such as self-condensation of lactic acid, high molecular weight PLA could be derived using ring-opening polymerization.

Combining PLA with starch could be used to prepare biodegradable food packaging to replace petrochemical polymers (Muller et al., 2017). The PLA-starch multilayer films showed good water and vapor barrier capacity, and had the ability to carry antioxidant or antimicrobial active ingredients to extend food product shelf life. Although PLA-starch blends are promising materials, they are inherently brittle. Koh et al. (2018) summarized toughening strategies in their reviews. For example, Tsou et al. (2014) observed that combining PLA with granular tapioca without plasticizers resulted in poor tensile properties. The group used methylenediphenyl diisocyanate as an interfacial compatibilizer and plasticizer. They successfully improved the tensile strength of PLA-starch films by 60%, and greatly improved elongation at break, as well as reduced brittleness.

b. Xanthan gum

Xanthan gum, a polysaccharide that is used in the food industry, could be derived from fermentation of lower cost food by-products such as spent malt grains, fruit pomace, citrus peels, and chestnut extract with *Xanthomonas campestris*

(Liakopoulou-Kyriakides et al., 1999; Stredansky and Conti, 1999). Stredansky and Conti found that xanthan production efficiency depends on the C and N sources of the substrate, as well as the moisture content. Bilanovic et al. (1994) suggested that xanthan production was mainly contributed by the pectins, organic acids, and simple carbohydrates of the substrate.

Sulphuric acid hydrolyzed cassava production waste at a DE value of 12 with 30% initial reducing sugar was able to yield xanthan gum at 7.1 g/L, higher than those produced using hydrolyzed cassava with higher DE value (Gunasekar et al., 2014). Although hydrolyzed cassava with higher DE value also contained more simple sugar, the formation of microorganism inhibitory substances such as HMF (hydroxymethylfurfural) and furfural were observed, which explained the lowered xanthan gum production. This problem could be resolved by hydrolyzing cassava waste with enzymes. However, the cost of enzymes is higher compared with the cost of acids. Therefore, it is important to compare the production and economic efficiency of using enzymes or acid for hydrolysis case by case. Strategies such as enzyme recycling and/or immobilization should also be considered to decrease the cost.

7. Novel application of tapioca starch in food products

a. An alternative gluten-free carbohydrate source

About 0.5 to 1% of the world's population suffers from celiac disease (Gujral et al., 2012). Patients suffer from symptoms such as diarrhea, bloating, anemia, osteoporosis, and have higher risks of some cancers. The only treatment for celiac disease is to strictly follow a gluten-free diet (Caio et al., 2019). Gluten is a protein found in cereal grains such as wheat. With more attention to celiac disease, products with gluten-free options are becoming more popular (Melini and Melini, 2019). Therefore, tapioca starch or flour, as a gluten-free ingredient, is used to replace gluten-containing ingredients like wheat flour in products like breads, pasta, noodles, and so on.

Tapioca starch is used as a lower cost ingredient in gluten-free noodles. Some noodles like clear noodles made with mung bean starch are already gluten-free. However, mung bean starch is expensive compared with other starches, so in many cases other starches such as potato or tapioca starches are used to partially or completely replace mung bean starch in starch noodles (Muhammad et al., 1999). In addition, tapioca starch enhances the quality of noodle products. Violalita et al. (2020) found that tapioca starch increased the elasticity of gluten-free noodles so that noodles were not easily broken. They partially replaced potato starch with phosphorylated tapioca starch and observed noodle products with better quality (uncooked products with improved strength, cooked products with reduced stickiness and less cooking loss). Cross-linked tapioca starch can be used to replace the more expensive mung bean starch when combined with high amylose maize starch to obtain products with similar textural and sensory quality as mung bean starch noodles (Kasemsuwan et al., 1998).

Horstmann et al. (2016) used tapioca starch to replace wheat flour in a conventional bread formulation. The resulting bread product had irregular shapes with large holes that were undesirable. They hypothesized that the small and easily agglomerated granules of tapioca starch led to a weak baking performance. Therefore, tapioca starch alone may not be able to produce gluten-free bread with desirable qualities. Therefore, tapioca starch is used in combination with other hydrocolloids or gums to improve the overall quality of gluten-free bread. Bourekoua et al. (2018) found that tapioca starch influenced the specific volume, hardness, and springiness of gluten-free bread. For sorghum based gluten-free bread, replacing sorghum flour with up to 10% tapioca starch with the addition of 3% hydroxypropyl methylcellulose produced gluten-free bread with good properties (Akin and Miller, 2017). However, in the sensory analysis, compared with adding tapioca starch and hydroxypropyl methylcellulose, the addition of rice starch and xanthan gum to sorghum based gluten-free bread showed better texture and mouthfeel (Akin et al., 2019). Rodriguez-Sandoval et al. (2015) added guar gum to tapioca starch and corn flour based gluten-free bread to increase the storage stability of the product. Sigüenza-Andrés et al. (2021) observed that addition of tapioca starch or tapioca flour improved the specific volume and texture upon storage, and bread crumbs at <20% in their gluten-free bread formulation (rice flour and maize starch based). However, when the concentration was higher, the opposite results would be observed. Overall, tapioca starch interacts with other ingredients in the bread matrix, and in different products to impact the product quality differently. To increase the nutrient profile of gluten-free bread for celiac patients, Korus et al. (2009) supplemented it with resistant tapioca starch to increase the dietary fiber content of gluten-free bread.

Apart from gluten-free noodles and bread, tapioca starch could also impact the sensory properties of other gluten-free products such as spaghetti, snack bars, nugget coating and so on (Padalino et al., 2013; Prazeres et al., 2020; Silva et al., 2021). The optimum formulation requires bench-top and sensory testing with each product.

b. Tapioca starch as a fat replacer

Dietary saturated fat has become a public health concern as a high intake is related to cardiovascular disease, the leading cause of death globally (Sacks et al., 2017). The American Heart Association recommended healthier dietary patterns such as DASH (Dietary Approaches to Stop Hypertension) or the Mediterranean Diet to reduce saturated fat intake. Food companies are also looking for ways to reduce saturated fat content in food products. Using tapioca starch as a food replacer in products such as meat patties and dairy products are being studied, and the goal is to prepare products with lower fat content but similar organoleptic and textural properties of the full-fat originals (Varga-Visi and Toxanbayeva, 2017).

The good WHC of tapioca starch made it a promising candidate as an ingredient to improve the texture and sensory properties of low-fat meat or meat analogue products. Nisar et al. (2009) added tapioca starch to buffalo meat patties and compared the low fat patties versus beef fat patties. During the cooking process, with the good WHC of tapioca starch, low fat patties showed better cooking yield, better maintained the volume of the patties, higher moisture content, and higher sensory test score in terms of overall acceptability, juiciness, and texture compared with that of the high fat patties. Chatterjee et al. (2019) added tapioca starch to ground chicken breast meat to improve the bland and dry sensory attributes of chicken breast meat. The addition of tapioca starch improved the texture of the cooked meat without affecting the flavor due to its good WHC. Brewer (2012) pointed out that the addition of a combination of the fat replacers would result in products with better characteristics without sacrificing the flavor or the texture of the ground meat product. Berry (1997) observed that combined use of tapioca starch with sodium alginate improved the juiciness, tenderness, and cooking yield of the beef patty while maintaining good sensory attributes. Troy et al. (1999) compared the effects of different combinations among tapioca starch, whey protein, oat fiber, and pectin on beef patties. The results suggested that juiciness and texture could be improved with the addition of tapioca starch, oat fiber, and whey protein due to their good WHC. In a more detailed study related to the interaction between added hydrocolloids and meat flavor compounds, Chevance et al. (2000) found that fat replacers would bind to flavor compounds of meat products to slow down the release of some flavor compounds and impact the sensory attributes. In meat analog products, tapioca starch could also be a candidate ingredient as a fat replacer. Many plant-based meat companies have tapioca starch, native or modified, on their products' ingredient list.

In dairy products like cheese or yogurt, tapioca starch is also used as a fat replacer. Sipahioglu et al. (1999) prepared low-fat feta cheese with the addition of tapioca starch and lecithin as fat replacers. They observed that the protein aggregated as the fat content decreased, resulting in increased hardness and yield loss of the low-fat cheese product. The microstructure of low-fat cheese with the addition of tapioca starch and lecithin resembled that of full fat cheese, mainly due to the good WHC of tapioca starch and lecithin. Hence, the problem with hardness could be resolved. In addition to higher moisture retention, Diamantino et al. (2019) observed a low retrogradation rate after adding tapioca starch to fresh cheese, which preserved the quality of the cheese during refrigeration. Sandoval-Castilla et al. (2004) incorporated modified tapioca starch into yogurts as a fat-replacer. The resulting yogurts had higher firmness compared with full fat yogurt, as the starch formed an independent structure. In the fat-reduced yogurts prepared by Lobato-Calleros et al. (2014), addition of tapioca starch increased the acidity of the yogurt as bacteria grew better in yogurts with higher carbohydrates that accelerated the transformation of lactose to lactic acid. In addition, tapioca starch also changed the rheological properties of the yogurts in ways that may or may not meet the expectation of the consumers in different scenarios. With these studies, incorporation of tapioca starch into low-fat dairy or vegan ice cream might also be feasible.

8. Application of native and modified tapioca starch in encapsulation and nanotechnology

a. Tapioca used for encapsulation

Encapsulation is a common food technology process to improve stability and bioavailability of the encapsulated ingredients (Lu et al., 2016). The success of encapsulation and delivery depends highly on the wall materials. Tapioca starch, a low cost and non-allergic ingredient, is a good candidate for encapsulating different chemicals when used alone or combined with other wall material (Zhu, 2017).

Tapioca starch is used as a wall material for the encapsulation of oxygen sensitive food ingredients. Kamaldeen et al. (2020) used native tapioca starch and soy protein isolate to encapsulate powdered carrot and observed that native tapioca starch and soy protein isolate at a 50:50 ratio most effectively prolonged the shelf life of carrot powder from 13 to 106 days as suggested by the carotene oxidation level. The particle sizes ranged between 2.18 to 2.64 mm. Keatkrai et al. (2017) compared encapsulating menthone, a minty flavor chemical, using tapioca starch, rice starch, and mung bean starch. The result showed that tapioca starch and mung bean starch with higher amylose content had higher menthone entrapment (4%) compared with rice starch that contain less amylose (<1%). However, sometimes compared with other ingredients, tapioca starch might not be the best wall material for encapsulation. Murali et al. (2015) compared encapsulating black carrot juice with maltodextrin, tapioca starch, or gum Arabic using spray drying or freeze-drying. Maltodextrin showed the highest EE at 98.5% at an average particle size of 23.1 μm. It retained the highest anthocyanin, and showed the highest antioxidant activity compared with the other two carriers. Similar results were also observed by Tonon et al. (2009). They prepared acai powders with diameters ~10 μm encapsulated using tapioca starch, maltodextrin, or gum Arabic. Compared with gum Arabic and maltodextrin, tapioca starch encapsulated particles had the lowest polyphenolic retention and antioxidant activity with storage (40℃ for 15 days). According to Gharsallaoui et al. (2007), the success of spray drying encapsulation depends strongly on the solubility of the wall material. The solubility of maltodextrin and gum Arabic are both higher than that of tapioca starch, thus better results would be observed. However, Loksuwan et al. (2007) compared the EE using acid modified tapioca starch at a DE value of 2, native tapioca starch, and maltodextrin to encapsulate β-carotene prepared by spray drying. They observed that acid modified tapioca starch encapsulated the highest total β-carotene (82.2%), followed by native tapioca starch (68.4%), and maltodextrin (46.7%). Acid modified tapioca starch had the lowest surface β-carotene content (19.5%) among the three, followed by maltodextrin and native tapioca starch. They suggested that the soluble amylose in the acid modified tapioca starch formed a network connected by hydrogen bonds that protected β-carotene from loss during the spray drying process. In addition, the soluble amylose might form a crust around the β-carotene to protect it during the drying process. Maltodextrin had smaller molecules thus was unable to form a film with β-carotene during the drying process. Therefore, the EE also depends on particle size and electrostatic strength between molecules in addition to the solubility of the wall material. In this case, combined use of wall material might also increase the stability of the encapsulated particles. For example, when using both gum Arabic and tapioca starch as the wall material to encapsulate limonene, tapioca starch retained a crystalline structure that slowed the migration of limonene to the surface of the particles to increase the stability of the system (Ordoñez and Herrera, 2014).

Encapsulation technology is used to protect sensitive ingredients such as probiotics from environmental stress such as heat or oxygen exposure (Tripathi and Giri, 2014; Zhang et al., 2016). Pitigraisorn et al. (2017) added egg albumen and stearic acid to assist alginate based *Lactobacillus acidophilus* as the first layer of the shell and coated tapioca starch granules as the second layer of the shell. The multilayer encapsulation of the probiotic achieved an EE >90%, and with moisture heat at 70℃ for 30 min, cell viability reduction decreased from 3.3 (alginate capsule without a shell) to 0.6 CFU/g, suggesting a good protecting effects that could be applied on products to keep probiotic viability while ensuring product food safety.

Tapioca starch as an encapsulation wall material is used in agriculture for protection and controlled release of fertilizers, biofertilizers, and herbicides. As a much lower cost and biodegradable ingredient compared to the alternatives, tapioca starch was used to encapsulate urea fertilizer for controlled slow release of N into the soil (Naz et al., 2014). Naz et al. used tapioca starch modified with urea and borax to coat urea granules and observed longer release times compared with those that were uncoated. Rohman et al. (2021) encapsulated *Rhodopseudomonas palustris*, a plant growth promoting bacterium, with sodium alginate and tapioca starch and found the highest EE (70.8%) at 4% w/v starch with viable bacteria at 2.55×10^9 CFU/g, much higher than what could be achieved by encapsulating using alginate alone. The authors observed newly formed hydrogen bonds between alginate and tapioca starch using Fourier-transform infrared spectroscopy (FTIR) spectrum. When combined with sodium alginate, Lozano-Vazquez et al. (2015) proposed that the addition of starch increased the tortuosity of the matrix, in a way that delayed the release of entrapped material physically and electrostatically. In addition, the increased tortuosity also created extra obstructions for oxygen from the outside environment to invade, thus protecting the materials from being oxidized.

Encapsulating essential oils using tapioca starch as a wall ingredient has also been investigated. Moura et al. (2021) prepared *Siparuna guianensis* leaf essential oil beads encapsulated using tapioca starch with EE ranging from 82.8 to 95.3% depending on the essential oil and tapioca starch ratio and an average particle size of 8.56 μm. The encapsulated beads showed slowed oil degradation and enhanced lethal activities (>50%) on mosquito larvae while showing low toxicity to non-targeted zebrafish embryos.

In addition to the encapsulation applications discussed, tapioca starch and its modified form were also used as wall materials in other situations. It was mentioned previously in section 3.g that acetylated tapioca starch could be used to encapsulate potassium sorbate, a food preservative, to decrease the additive usage in food products. It was also mentioned in the same chapter that esterified tapioca starch could be used to encapsulate linseed oil or curcumin to protect them from oxidation.

b. Tapioca starch and nanoparticles

In section 3.h, the preparation of nano-scale tapioca starch using physical modification was introduced. Ge et al. (2017) used starch nanoparticles, including tapioca starch nanoparticles, as particulate emulsifiers to prepare Pickering emulsions, the emulsions prepared with solid particles that reside between the two immiscible phases to prevent aggregation (Pickering, 1907). Good emulsion stability was observed when using tapioca starch nanoparticles in Pickering emulsions. The interfacial wettability as expressed by the oil-in-water three-phase contact angle was 84.5°, which is close to the optimum contact angle (90°). Therefore, they suggested that tapioca starch nanoparticles could be a promising emulsifier with good stability for Pickering emulsions.

Yang et al. (2016) used starch nanoparticles to inhibit the activities of tyrosinase, the enzyme responsible for the browning of fruits and vegetables when exposed to oxygen. Product development such as anti-browning products containing tapioca starch nanoparticles are needed as this property of tapioca starch nanoparticles could be used beneficially.

According to 21 CFR 182.8991, ZnO is a generally recognized as safe (GRAS) ingredient. With its good antimicrobial ability, ZnO is used in food packaging to prevent biological hazards. Almeida et al. (2021) successfully prepared ZnO nanoparticles from zinc nitrate hexahydrate and tapioca as a chelating agent. The ZnO nanoparticles had particle sizes ranging from 30 to 100 nm. Ramasami et al. (2015) used a tapioca starch gel combustion method with zinc nitrate hexahydrate and obtained ZnO nanoparticles with an estimated average size of 76 nm. The ZnO nanoparticles showed good antimicrobial effects on both Gram positive and negative bacteria. This method is more rapid compared with the method used by Almeida et al.

9. Application of tapioca starch with food packaging

Tapioca starch is able to form thin and transparent films that can be used as edible food packaging material. Antimicrobials and preservatives can be incorporated into such films to develop biodegradable or edible food packaging materials to extend the shelf life of different food products. For example, tapioca starch films containing alginate encapsulated *Lactobacillus acidophilus* with EE of 49.6% were used to coat Manaba cheese (Santacruz and Castro, 2018). The addition of the bacteria encapsulated starch film inhibited the growth of *Salmonella* spp. during storage. Nisin, an antimicrobial peptide produced by *Lactococcus lactis*, was used by Sanjurjo et al. (2006) to prepare tapioca- and glycerol-based edible films. The resulting film showed good antimicrobial activity with good mechanical properties so that it can be used as food packaging materials. Other commonly used antimicrobials or preservatives include potassium sorbate, natamycin, and ZnO (Ahmad et al., 2021; Basch et al., 2013; Resa et al., 2014).

For food packaging, good physical and barrier properties of the film are important. Different materials such as hydrocolloids, gums, proteins, and polyols in combination with tapioca starch are used to improve the physical and barrier properties of edible or biodegradable food packaging films. Gelatin-based tapioca films are commonly used as the films showed good physical properties while being environmentally friendly and low cost (Said et al., 2021). Loo and Sarbon (2020) added tapioca starch at 10% to chicken skin gelatin and obtained films with better textual and barrier properties with good elongation at break. Lee et al. (2021) prepared chicken skin and tapioca starch composite films containing nano-scale ZnO as an antimicrobial. They concluded that the addition of ZnO nanoparticles at 3% to be the optimum formulation as the film showed the highest melting temperature, lowest water vapor permeability, and moderate tensile strength and elongation at break. Marvizadeh et al. (2017) added nano ZnO to tapioca starch and gelatin films. They observed that the addition of nano-ZnO increased the hydrophobicity of the film, and decreased the elongation at break and oxygen permeability of the film. In addition, these improvements were more pronounced with tapioca starch gelatin films compared with those prepared with either tapioca starch or gelatin alone. Similar results were observed by Tamimi et al. (2021). They suggested that the starch film also had good UV barrier properties in addition to the mentioned properties. Pullulan is a commonly used ingredient for the preparation of edible films. However, the cost of pullulan is higher and the ingredient is less stable in a humid environment. Kim et al. (2014) added tapioca starch to improve the pullulan film. They observed increased stability of the composite film with humid conditions during storage, but the solubility decreased. Thus, it was more suitable for non-edible films. Gums also affect the physical properties of tapioca starch films. Kim et al. (2015) tested the minor addition of gum Arabic, kappa-carrageenan, gellan, or xanthan gum (0.2% gum solids) to a tapioca starch film (5% total solids). They found that the addition of gellan or xanthan gum could produce films with similar physical qualities to those prepared with 20% pure pullulan films, suggesting that the addition of gums to tapioca starch films would be comparable to pullulan film but at a lower cost. Pérez et al. (2021) added zein to tapioca starch films containing nisin and natamycin as preservatives. While maintaining its good antimicrobial ability, the addition of zein increased the firmness at break and reduced the strain at break of the films, as well as reduced the WVP and solubility of the films. Othman et al. (2019) incorporated microcrystalline cellulose into a tapioca starch based film and improved the mechanical and barrier properties of the film.

Addition of plasticizers to tapioca starch overcomes the mechanical weakness of tapioca starch films and improves its physical and barrier properties (Bangyekan et al., 2005). Chillo et al. (2008) compared the addition of two plasticizers, chitosan and glycerol, to tapioca starch films. They observed that the addition of chitosan had a positive effect on the mechanical properties of the film while the addition of glycerol showed the opposite. However, WVP was negatively affected by the addition of chitosan and positively affected by the addition of glycerol. Chang et al. (2006) found that the addition of the small glycerol molecules showed anti-plasticization on systems when the water activity was low, and classic plasticizing effects on systems with higher water activity. Vásconez et al. (2009) prepared chitosan tapioca starch solutions and films with or without potassium sorbate and found that chitosan was more available in edible solutions than in the films in terms of inhibiting the growth of some bacteria strains. Thirathumthavorn and Charoenrein (2007) used sorbitol as the plasticizing agent for the preparation of tapioca starch films. They found that commercial non-crystallizing sorbitol could inhibit the crystallization of the film during aging to maintain the mechanical properties of the films.

The addition of preservatives or antimicrobials also affects the storage stability of the films. Famá et al. (2005) found that the addition of sorbate, an antimicrobial, to tapioca starch and glycerol films improved the elasticity and extensibility of the film, but also decreased the gas, water, and vapor barrier properties of the films due to the plasticizing effects of sorbate.

The method and processing parameters used for the preparation of films also affect the final product. In most cases, tapioca starch films were prepared by gelatinization of the starch slurry followed by casting in a petri dish and drying (Maran et al., 2013). Flores et al. (2007a) compared the effects of gelatinization and drying time on tapioca starch films containing sorbate. They observed that quick gelatinization (1.8℃/min for ~30 min) and drying (drying over $CaCl_2$ at 25℃ for 2 days) produced films with better antimicrobial abilities and better consumer appeal but weaker mechanical properties compared with slower gelatinization (1.6℃/min for ~25 min followed by 0.3℃/min for ~40 min) and drying (drying without $CaCl_2$ for a week). They further successfully developed a mathematical model for the release of potassium sorbate from the prepared films (Flores et al., 2007b). Kim et al. (2018) compared the preparation of tapioca starch films using high pressure processing (HPP) at 600 MPa (20℃ for 20 min) or thermal processing (90℃ for 20 min). They found the films prepared using HPP had lower WVP and water solubility, suggesting that HPP might be a better method for the preparation of tapioca starch films.

10. Application of tapioca starch in the pharmaceutical industry

a. Excipients in tablet preparation

Excipients in drugs are defined as the inactive ingredient as constituents of a pharmaceutical -other than the active ingredient (Santos et al., 2020). Starches are used as binders or disintegrants in tablet formulations to control the release of the active ingredients of the tablets (Desai et al., 2016; Mimura et al., 2011).

Direct compressing of tapioca starch with a drug (propranolol) to be delivered was found to be efficient (Fernandes et al., 2019). In this case, tapioca starch acted as the excipient, binder, filler, and disintegrant agent of the tablet. Native tapioca starch prepared tablets had the weakness of low crushing strength (Atichokudomchai et al., 2004). For example, Uhumwangho and Okor (2004) observed that in cellulose and tapioca starch based directly compressed tablets, increased tapioca content (>50%) produced tablets that were more crumbly. Atichokudomchai and Varavinit (2003) compared the performance of tablets prepared with direct compressing of acid-modified cross-linked tapioca starch versus native or acid-modified tapioca starch. They found that cross-linking could not increase the crystallinity of the starch and as a result the crushing strength would be low, but acid hydrolysis did increase the crystallinity of the starch thus increasing the crushing strength. Therefore, cross-linking followed by acid modification is able to improve the mechanical properties of the prepared tablets. Similarly, Tukomane et al. (2007) increased the crystallinity of tapioca starch using annealing followed by enzymatic hydrolysis. Using direct compression to prepare the tablets, they also observed increased crushing strength as well as a prolonged disintegration time, suggesting the benefits of the increased crystallinity of tapioca starch. Apart from increasing the crushing strength by increasing the crystallinity of the excipient, Casas et al. (2009) grafted ethyl methacrylate on native or hydroxypropyl tapioca starch. The graft copolymerization resulted in tablets with longer disintegration time compared with those prepared using raw tapioca starch, and the resulting disintegration time was comparable with the commercial directly compressed excipient. Casas et al. (2010) then tested their graft copolymerized tapioca starch to control the release of theophylline. They found that the prepared tablets controlled drug release by diffusion, and grafted hydroxypropyl tapioca starch prepared tablets released the drug faster compared with those grafted to native tapioca starch because it had better binding properties.

b. Plasma expander

Modified starch is used as plasma expanders for patients with severe bleeding (Levi and Jonge, 2007). According to the authors, native starches cannot be used as the plasma substitute because they degrade rapidly and are insoluble at blood pH. Therefore, hydroxyethyl starch (HES) is usually used as plasma expanders (Kulicke and Heinze, 2005). Brecher et al. (1997) pointed out that HES is biochemically similar to glycogen, so that the likelihood of the occurrence of immunogenicity and adverse reactions would be lower. However, HES also has problems related to kidney functions and increased mortality (Mutter et al., 2013). Therefore, it is important to evaluate patients’ status before using it.

11. Resistant Tapioca Starch

Resistant starch cannot be digested by human enzymes but some of them can be utilized by gut microbes to exert some health benefits (Ashwar et al., 2016). In addition, they are used as a sensory-acceptable food ingredient to improve the functionalities of different food products (Bede and Lou, 2021).

Le et al. (2009) prepared enzyme-digestion-resistant highly-branched tapioca starch using a combined treatment of branching enzyme and maltogenic amylase. The resulting highly-branched tapioca starch showed a low digestive rate when exposed to α-amylase and glucoamylase, suggesting that the product may be utilized to control blood glucose. Isomaltooligosaccharides (IMO) are prepared using carbohydrates such as starch, maltose, sucrose, and dextran, and it has biological functions such as promoting the growth of gut bacteria (Aslan and Tanriseven, 2007). Kaulpipoon et al. (2015) prepared IMO from tapioca starch using amylomaltase and transglucosidase. They were able to tolerate heat, acid, and human digestion.

12. Tapioca as an animal feed

Cassava can be used as an economical animal feed for ruminants and poultry (Garcia and Dale, 1999; Wanapat and Kang, 2015). All parts of the cassava including roots, leaves, and hay could be utilized (Wanapat, 2009). However, some factors must be considered. For example, the high carbohydrate content and low protein content of the tubers, and the cyanide content may affect the animals' metabolism. Therefore, various methods are used to improve the nutritional profiles of cassava as an animal feed.

Using cassava as a lower cost partial feed replacement is feasible in some cases. Sommart et al. (2000) replaced ground maize with cassava. They observed that it was possible to use 20 to 30% replacement using cassava to feed dairy cows to replace rice straw. Cassava hay contains 227 g/kg crude protein, and cassava leaves contain 210 g/kg crude protein, both are higher than that of cassava roots (Phengvichith and Ledin, 2007; Ravindran, 1993). Wanapat et al. (2000) found that feeding cassava hay to dairy cows resulted in similar milk yield but improved milk fat and protein content.

Saccharomyces cerevisiae was identified by Boundy-Mills et al. (2019) to be the most efficient yeast species that can ferment and increase the protein content of cassava. Polyorach et al. (2013) fermented cassava chips with *S. cerevisiae* and obtained products with 47.5% crude protein. Promkot et al. (2017) fermented cassava roots with *S. cerevisiae*. The products were used to feed cattle at 20% of the concentrate fed. The fermented cassava improved the rumen bacteria population and also the neutral detergent fiber (NDF) digestibility of the cattle. In addition, Sommai et al. (2020) found that fermentation increased the digestibility of cassava pulp for animals.

To increase the cassava crude protein content, urea can be added as a supplement (Ampapon et al., 2016). For example, Cherdthong et al. (2011) found that supplementation of a mixture of urea and calcium chloride to cassava chips as lactating cows' were feeding improved the apparent digestibility, rumen fermentation, and milk yield of the cows.

However, the cyanide content of cassava might still be a problem. Thang et al. (2010) suggested that the high HCN content of cassava foliage as an animal feed negatively affected the animals' growth rate. Nevertheless, processing treatments that are similar to cassava products prepared for human consumption can be adopted to control the cyanide content in poultry feeds (Okoli et al., 2012). Also, unlike human metabolism, ruminants are able to detoxify HCN from food to the less toxic thiocyanate and excreted it in the urine with the help of rhodanese, β-mercaptopyruvate-sulfurtransferase, and rumen microbes, as well as a diet supplemented with sulfur at 4% (Cherdthong et al., 2018). However, Silva et al. (2018) observed that feeding cassava processing wastewater to lambs negatively affected their dry matter and NDF intake and rumination, suggesting that high cyanide might still be a concern in ruminant diets. Cassava hay contains protein-tannin complexes (Wanapat, 2003). Wanapat and Khampa (2006) observed that using cassava as a source of condensed tannins reduced the fecal parasite egg counts of ruminants. Thus, it has the potential to be an anthelmintic for ruminants.

13. Tapioca as a growth medium

As a rich carbohydrate source, tapioca can be used as a nutrition source for the growth of bacteria, algae, and molds. For economic reasons, tapioca liquid waste is often used. Ghozali et al. (2021) used tapioca liquid waste mixed with a nitrogen source as the growth medium for *Acetobacter xylinum* for the production of bacterial cellulose. Amlah et al. (2018) successfully used tapioca liquid waste to culture a microalgae, *Navicula* sp. The tapioca liquid waste dilution level and the growing density of the microalgae both would affect the growth rate of the microalgae.

14. Other applications

a. Adhesives

Tapioca starch could work as a biodegradable adhesive for the adhesion of boards such as particleboards. Liew et al. (2018) added tapioca starch to a seaweed adhesive and improved the mechanical and physical properties of the particleboard. Ye et al. (2018) combined dialdehyde tapioca starch prepared using sodium periodate with corn stalks for the preparation of particleboards. The dialdehyde tapioca starch acted like an adhesive to tightly bind the corn stalks.

b. Adsorbent

Tapioca starch is modified to work as an adsorbent for the adhesion of unwanted metals or dyes from the environment. Boiled and calcined tapioca starch was found to be able to efficiently adsorb Sr(II) and Cs(I) and desorb with the addition of hydrochloric acid (Ogata et al., 2018). Lian et al. (2021) prepared nano-scale tapioca starch to adsorb Cu(II) from the simulated industrial effluent.

15. Conclusions

Cassava has an important role in people’s daily life as it is used extensively in the food and pharmaceutical industry. The tubers can be a great carbohydrate source for human or animal consumption after being properly detoxified. The wastewater needs to be processed before being released to the environment. The nutritional profile of cassava tubers is poor as the protein and other important nutrient contents are low. Diseases related to malnutrition because of using cassava as the only food source is of concern. Various ways can be adopted to solve this problem such as supplementation and plant genetic modification. It is also important to manage cassava-growing soil nutrients even if the plant can be grown in soil with minimum nutrients. Intercropping and applying fertilizers can be effective ways of soil management. Tapioca starch can be processed into many value-added products. Enzymatic or acid hydrolysis can convert tapioca starch into smaller sugars or dextran, and fermentation of the sugars can produce products like ethanol or PLA. Native or modified tapioca starch is a good ingredient choice for many products. It is a gluten-free carbohydrate source that is suitable for food products aiming for a gluten-free label. It can be used as a fat replacer in meat or fish analogs. Its modified forms can be used to encapsulate active ingredients for target delivery. It can be made into tasteless and odorless edible or biodegradable food packaging material. The leaves, stems, and tubers can all be used as animal feeds for livestocks. Modified tapioca starch can be used as a plasma expander in some cases. The mechanical properties allow it to work as an excipient for drug preparation. As a carbohydrate source, it can be used as a medium for the growing of some bacteria or algae. It improves the mechanical properties as an adhesive in particleboard preparation. It is able to absorb unwanted compounds from wastewater. Overall, with these possible applications, cassava growing farmers in different countries are able to manufacture value-added products using cassava as an ingredient.

REFERENCES

Abass, A. B., Awoyale, W., Alenkhe, B., Malu, N., Asiru, B. W., Manyong, V., & Sanginga, N. (2018). Can food technology innovation change the status of a food security crop? A review of cassava transformation into “bread” in Africa. *Food Reviews International*, *34*(1), 87–102. https://doi.org/10.1080/87559129.2016.1239207

Adnan, A. A., Ismayana, A., Sailah, I., Shobi, I., & Indrasti, N. S. (2020). The potential usage of recycled waste water in small scale tapioca industry in Bogor. *IOP Conference Series: Earth and Environmental Science*, *472*, 012033. https://doi.org/10.1088/1755-1315/472/1/012033

Aggarwal, N. K., Nigam, P., Singh, D., & Yadav, B. S. (2001). Process optimization for the production of sugar for the bioethanol industry from Tapioca, a non-conventional source of starch. *World Journal of Microbiology & Biotechnology*, *17*, 783–787.

Agudelo, A., Varela, P., Sanz, T., & Fiszman, S. (2014). Formulating fruit fillings. Freezing and baking stability of a tapioca starch–pectin mixture model. *Food Hydrocolloids*, *40*, 203–213. https://doi.org/10.1016/j.foodhyd.2014.02.020

Aguirre, J. F., Osella, C. A., Carrara, C. R., Sánchez, H. D., & Buera, M. del P. (2011). Effect of storage temperature on starch retrogradation of bread staling. *Starch - Stärke*, *63*(9), 587–593. https://doi.org/10.1002/star.201100023

Agustian, J., & Hermida, L. (2019a). The optimised statistical model for enzymatic hydrolysis of tapioca by glucoamylase immobilised on mesostructured cellular foam silica. *Bulletin of Chemical Reaction Engineering & Catalysis*, *14*(2), 380. https://doi.org/10.9767/bcrec.14.2.3078.380-390

Agustian, J., & Hermida, L. (2019b). Review of large-pore mesostructured cellular foam (Mcf) silica and its applications. *Open Chemistry*, *17*(1), 1000–1016. https://doi.org/10.1515/chem-2019-0107

Ahmad, A. A., & Sarbon, N. M. (2021). A comparative study: Physical, mechanical and antibacterial properties of bio-composite gelatin films as influenced by chitosan and zinc oxide nanoparticles incorporation. *Food Bioscience*, *43*, 101250. https://doi.org/10.1016/j.fbio.2021.101250

Ahmed, S. Y., Ghildyal, N. P., Kunhi, A. A. M., & Lonsane, B. K. (1983). Confectioner's syrup from tapioca processing waste. *Starch - Stärke*, *35*(12), 430–432. https://doi.org/10.1002/star.19830351207

Ahohuendo, B., & Sarkar, S. (1995). Partial Control of the Spread of African Cassava Mosaic-Virus in Benin by Intercropping. *Journal of Plant Disease and Protection*, *102*(3), 249–256.

Ai, Y., & Jane, J. (2015). Gelatinization and rheological properties of starch. *Starch - Stärke*, *67*(3–4), 213–224. https://doi.org/10.1002/star.201400201

Ajayi, C. O., & Olutumise, A. I. (2018). Determinants of food security and technical efficiency of cassava farmers in Ondo State, Nigeria. *International Food and Agribusiness Management Review*, *21*(7), 915–928. https://doi.org/10.22434/IFAMR2016.0151

Akbari, M., Eskandari, M. H., & Davoudi, Z. (2019). Application and functions of fat replacers in low-fat ice cream: A review. *Trends in Food Science & Technology*, *86*, 34–40. https://doi.org/10.1016/j.tifs.2019.02.036

Akin, P. A., & Miller, R. A. (2017). Starch–hydrocolloid interaction in chemically leavened gluten-free sorghum bread. *Cereal Chemistry Journal*, *94*(5), 897–902. https://doi.org/10.1094/CCHEM-05-17-0094-R

Akin, P. A., Miller, R., Jaffe, T., Koppel, K., & Ehmke, L. (2019). Sensory profile and quality of chemically leavened gluten‐free sorghum bread containing different starches and hydrocolloids. *Journal of the Science of Food and Agriculture*, *99*(9), 4391–4396. https://doi.org/10.1002/jsfa.9673

Akintonwa, A., Tunwashe, O., & Onifade, A. (1994). Fatal and non-fatal acute poisoning attributed to cassava-based meal. *Acta Horticulturae*, *375*, 285–288. https://doi.org/10.17660/ActaHortic.1994.375.28

Alexander Essers, A. J., Jurgens, C. M. G. A., & Nout, M. J. R. (1995). Contribution of selected fungi to the reduction of cyanogen levels during solid substrate fermentation of cassava. *International Journal of Food Microbiology*, *26*(2), 251–257. https://doi.org/10.1016/0168-1605(94)00116-N

Ali, A., Pardo, J. M., & Yun, D.-J. (2020). Desensitization of aba-signaling: The swing from activation to degradation. *Frontiers in Plant Science*, *11*, 379. https://doi.org/10.3389/fpls.2020.00379

Almeida, W. L. de, Rodembusch, F. S., Ferreira, N. S., & Caldas de Sousa, V. (2020). Eco-friendly and cost-effective synthesis of ZnO nanopowders by Tapioca-assisted sol-gel route. *Ceramics International*, *46*(8), 10835–10842. https://doi.org/10.1016/j.ceramint.2020.01.095

Almeida, W. L. de, Ferreira, N. S., Rodembusch, F. S., & Caldas de Sousa, V. (2021). Study of structural and optical properties of ZnO nanoparticles synthesized by an eco-friendly tapioca-assisted route. *Materials Chemistry and Physics*, *258*, 123926. https://doi.org/10.1016/j.matchemphys.2020.123926

Alzate, P., Zalduendo, M. M., Gerschenson, L., & Flores, S. K. (2016). Micro and nanoparticles of native and modified cassava starches as carriers of the antimicrobial potassium sorbate: Native and modified cassava starch particles as carriers of potassium sorbate. *Starch - Stärke*, *68*(11–12), 1038–1047. https://doi.org/10.1002/star.201600098

Amalah, N., Widyartini, D. S., Christiani, C., & Hidayah, H. P. (2018). The effect of dilution level of liquid tapioca waste culture medium and concentration of phosphate on the growth of microalgae Navicula sp. *Nusantara Bioscience*, *10*(1), 65–69. https://doi.org/10.13057/nusbiosci/n100110

Amelework, A. B., Bairu, M. W., Maema, O., Venter, S. L., & Laing, M. (2021). Adoption and promotion of resilient crops for climate risk mitigation and import substitution: A case analysis of cassava for south african agriculture. *Frontiers in Sustainable Food Systems*, *5*, 617783. https://doi.org/10.3389/fsufs.2021.617783

Ampapon, T., Wanapat, M., & Kang, S. (2016). Rumen metabolism of swamp buffaloes fed rice straw supplemented with cassava hay and urea. *Tropical Animal Health and Production*, *48*(4), 779–784. https://doi.org/10.1007/s11250-016-1026-5

Ampe, F., & Brauman, A. (1995). Origin of enzymes involved in detoxification and root softening during cassava retting. *World Journal of Microbiology & Biotechnology*, *11*(2), 178–182. https://doi.org/10.1007/BF00704644

Ampe, F., Brauman, A., Treche, S., & Agossou, A. (1994). Cassava retting: Optimisation of a traditional fermentation by an experimental research methodology. *Journal of the Science of Food and Agriculture*, *65*(3), 355–361. https://doi.org/10.1002/jsfa.2740650314

Anandan, P. K., Shukkarbhai, P. J., George, J., Bhatt, P., & Manjunath, C. N. (2015). Tapioca cardiomyopathy: Curse of cassava endomyocardial fibrosis. *Cardiology Research*, *6*(2), 260–262. https://doi.org/10.14740/cr394w

Anuradha, R., Suresh, A. K., & Venkatesh, K. V. (1999). Simultaneous saccharification and fermentation of starch to lactic acid. *Process Biochemistry*, *35*(3–4), 367–375. https://doi.org/10.1016/S0032-9592(99)00080-1

Asadu, C. L. A., & Nweke, F. I. (1998). Soil fertility status and cassava yield in tanzania: (I) nutrient levels in cassava-growing soils. *Outlook on Agriculture*, *27*(3), 187–193. https://doi.org/10.1177/003072709802700309

Ashwar, B. A., Gani, A., Shah, A., Wani, I. A., & Masoodi, F. A. (2016). Preparation, health benefits and applications of resistant starch-a review: Resistant starch-a review. *Starch - Stärke*, *68*(3–4), 287–301. https://doi.org/10.1002/star.201500064

Aslan, Y., & Tanriseven, A. (2007). Immobilization of Penicillium lilacinum dextranase to produce isomaltooligosaccharides from dextran. *Biochemical Engineering Journal*, *34*(1), 8–12. https://doi.org/10.1016/j.bej.2006.11.008

Astina, J., & Sapwarobol, S. (2020). Attenuation of glycaemic and insulin responses following tapioca resistant maltodextrin consumption in healthy subjects: A randomised cross-over controlled trial. *Journal of Nutritional Science*, *9*, e29. https://doi.org/10.1017/jns.2020.22

Atichokudomchai, N., & Varavinit, S. (2003). Characterization and utilization of acid-modified cross-linked Tapioca starch in pharmaceutical tablets. *Carbohydrate Polymers*, *53*(3), 263–270. https://doi.org/10.1016/S0144-8617(03)00070-5

Atichokudomchai, N., Varavinit, S., & Chinachoti, P. (2004). A study of ordered structure in acid-modified tapioca starch by C CP/MAS solid-state NMR. *Carbohydrate Polymers*, *58*(4), 383–389. https://doi.org/10.1016/j.carbpol.2004.07.017

Ayling, S., Ferguson, M., Rounsley, S., & Kulakow, P. (2012). Information resources for cassava research and breeding. *Tropical Plant Biology*, *5*(1), 140–151. https://doi.org/10.1007/s12042-012-9093-x

Babic, J., Subaric, D., Ackar, D., Kovacevic, D., Pilizota, V., & Kopjar, M. (2007). Preparation and Characterization of Acetylated Tapioca Starches. *Deutsche Lebensmittel-Rundschau*, *103*, 580–585.

Babić, J., Šubarić, D., Ačkar, Đ., Piližota, V., Kopjar, M., & Nedić Tiban, N. (2006). Effects of pectin and carrageenan on thermophysical and rheological properties of tapioca starch. *Czech Journal of Food Sciences*, *24*(No. 6), 275–282. https://doi.org/10.17221/3325-CJFS

Babić, J., Šubarić, D., Milicevic, B., Ačkar, D., Kopjar, M., & Nedic Tiban, N. (2009). Influence of trehalose, glucose, fructose, and sucrose on gelatinisation and retrogradation of corn and tapioca starches. *Czech Journal of Food Sciences*, *27*(No. 3), 151–157. https://doi.org/10.17221/31/2009-CJFS

Bai, Y., Cai, L., Doutch, J., Gilbert, E. P., & Shi, Y.-C. (2014). Structural changes from native waxy maize starch granules to cold-water-soluble pyrodextrin during thermal treatment. *Journal of Agricultural and Food Chemistry*, *62*(18), 4186–4194. https://doi.org/10.1021/jf5000858

Balet, S., Guelpa, A., Fox, G., & Manley, M. (2019). Rapid visco analyser (Rva) as a tool for measuring starch-related physiochemical properties in cereals: A review. *Food Analytical Methods*, *12*(10), 2344–2360. https://doi.org/10.1007/s12161-019-01581-w

Banea, J. P., Nahimana, G., Mandombi, C., Bradbury, J. H., Denton, I. C., & Kuwa, N. (2012). Control of konzo in DRC using the wetting method on cassava flour. *Food and Chemical Toxicology*, *50*(5), 1517–1523. https://doi.org/10.1016/j.fct.2012.02.001

Bangyekan, C., Aht-Ong, D., & Srikulkit, K. (2006). Preparation and properties evaluation of chitosan-coated cassava starch films. *Carbohydrate Polymers*, *63*(1), 61–71. https://doi.org/10.1016/j.carbpol.2005.07.032

Banowati, E. (2020). Increasing the competency of cassava farmers as a revitalization efforts of tapioca industries for food private realization. *International Journal of GEOMATE*, *19*(72). https://doi.org/10.21660/2020.72.ICGeo17

Banuwa, I. S., Hidayat, K. F., & Zulkarnain, I. (2020). Soil loss and cassava yield under ridge tillage in humid tropical climate of sumatera, indonesia. *International Journal of GEOMATE*, *18*(67). https://doi.org/10.21660/2020.67.78211

Basch, C. Y., Jagus, R. J., & Flores, S. K. (2013). Physical and antimicrobial properties of tapioca starch-hpmc edible films incorporated with nisin and/or potassium sorbate. *Food and Bioprocess Technology*, *6*(9), 2419–2428. https://doi.org/10.1007/s11947-012-0860-3

Bede, D., & Zaixiang, L. (2021). Recent developments in resistant starch as a functional food. *Starch - Stärke*, *73*(3–4), 2000139. https://doi.org/10.1002/star.202000139

Bengtsson, B.-E., & Triet, T. (1994). *Tapioca-starch wastewater toxicity characterized by microtox and duckweed tests* (pp. 473–477). Springer. https://www.jstor.org/stable/4314263

Berni, P., Chitchumroonchokchai, C., Canniatti-Brazaca, S. G., De Moura, F. F., & Failla, M. L. (2014). Impact of genotype and cooking style on the content, retention, and bioacessibility of β-carotene in biofortified cassava (*manihot esculenta* crantz) conventionally bred in brazil. *Journal of Agricultural and Food Chemistry*, *62*(28), 6677–6686. https://doi.org/10.1021/jf5018302

Berry, B. W. (1997). Sodium alginate plus modified tapioca starch improves properties of low-fat beef patties. *Journal of Food Science*, *62*(6), 1245–1249. https://doi.org/10.1111/j.1365-2621.1997.tb12254.x

Beyene, G., Solomon, F. R., Chauhan, R. D., Gaitán‐Solis, E., Narayanan, N., Gehan, J., Siritunga, D., Stevens, R. L., Jifon, J., Van Eck, J., Linsler, E., Gehan, M., Ilyas, M., Fregene, M., Sayre, R. T., Anderson, P., Taylor, N. J., & Cahoon, E. B. (2018). Provitamin A biofortification of cassava enhances shelf life but reduces dry matter content of storage roots due to altered carbon partitioning into starch. *Plant Biotechnology Journal*, *16*(6), 1186–1200. https://doi.org/10.1111/pbi.12862

Bilanovic, D., Shelef, G., & Green, M. (1994). Xanthan fermentation of citrus waste. *Bioresource Technology*, *48*(2), 169–172. https://doi.org/10.1016/0960-8524(94)90205-4

Birk, R., Bravdo, B., & Shoseyov, O. (1996). Detoxification of cassava by Aspergillus niger B-1. *Applied Microbiology and Biotechnology*, *45*(3), 411–414. https://doi.org/10.1007/s002530050705

Boonnop, K., Wanapat, M., Nontaso, N., & Wanapat, S. (2009). Enriching nutritive value of cassava root by yeast fermentation. *Scientia Agricola*, *66*(5), 629–633. https://doi.org/10.1590/S0103-90162009000500007

Boundy‐Mills, K., Karuna, N., Garay, L. A., Lopez, J. M., Yee, C., Hitomi, A., Nishi, A. K., Enriquez, L. L., Roberts, C., Block, D. E., & Jeoh, T. (2019). Conversion of cassava leaf to bioavailable, high‐protein yeast cell biomass. *Journal of the Science of Food and Agriculture*, *99*(6), 3034–3044. https://doi.org/10.1002/jsfa.9517

Bourekoua, H., Różyło, R., Benatallah, L., Wójtowicz, A., Łysiak, G., Zidoune, M. N., & Sujak, A. (2018). Characteristics of gluten-free bread: Quality improvement by the addition of starches/hydrocolloids and their combinations using a definitive screening design. *European Food Research and Technology*, *244*(2), 345–354. https://doi.org/10.1007/s00217-017-2960-9

Brecher, M. E., Owen, H. G., & Bandarenko, N. (1997). Alternatives to albumin: Starch replacement for plasma exchange. *Journal of Clinical Apheresis*, *12*(3), 146–153. https://doi.org/10.1002/(SICI)1098-1101(1997)12:3<146::AID-JCA8>3.0.CO;2-A

Brewer, M. S. (2012). Reducing the fat content in ground beef without sacrificing quality: A review. *Meat Science*, *91*(4), 385–395. https://doi.org/10.1016/j.meatsci.2012.02.024

Brown, A. L., Cavagnaro, T. R., Gleadow, R., & Miller, R. E. (2016). Interactive effects of temperature and drought on cassava growth and toxicity: Implications for food security? *Global Change Biology*, *22*(10), 3461–3473. https://doi.org/10.1111/gcb.13380

Busch, V. M., Pereyra-Gonzalez, A., Šegatin, N., Santagapita, P. R., Poklar Ulrih, N., & Buera, M. P. (2017). Propolis encapsulation by spray drying: Characterization and stability. *LWT*, *75*, 227–235. https://doi.org/10.1016/j.lwt.2016.08.055

Byers, J. A., Biernesser, A. B., Delle Chiaie, K. R., Kaur, A., & Kehl, J. A. (2017). Catalytic systems for the production of poly(Lactic acid). In M. L. Di Lorenzo & R. Androsch (Eds.), *Synthesis, Structure and Properties of Poly(lactic acid)* (Vol. 279, pp. 67–118). Springer International Publishing. https://doi.org/10.1007/12_2017_20

Byju, G., Nedunchezhiyan, M., Ravindran, C. S., Mithra, V. S. S., Ravi, V., & Naskar, S. K. (2012). Modeling the response of cassava to fertilizers: A site-specific nutrient management approach for greater tuberous root yield. *Communications in Soil Science and Plant Analysis*, *43*(8), 1149–1162. https://doi.org/10.1080/00103624.2012.662563

Cadavid, L. F., El-Sharkawy, M. A., Acosta, A., & Sánchez, T. (1998). Long-term effects of mulch, fertilization and tillage on cassava grown in sandy soils in northern Colombia. *Field Crops Research*, *57*(1), 45–56. https://doi.org/10.1016/S0378-4290(97)00114-7

Cai, C., & Wei, C. (2012). In situ observation of crystallinity disruption patterns during starch gelatinization. *Carbohydrate Polymers*, *92*(1), 469–478. https://doi.org/10.1016/j.carbpol.2012.09.073

Caio, G., Volta, U., Sapone, A., Leffler, D. A., De Giorgio, R., Catassi, C., & Fasano, A. (2019). Celiac disease: A comprehensive current review. *BMC Medicine*, *17*(1), 142. https://doi.org/10.1186/s12916-019-1380-z

Carsky, R. J., & Toukourou, M. A. (2005). Identification of nutrients limiting cassava yield maintenance on a sedimentary soil in southern Benin, West Africa. *Nutrient Cycling in Agroecosystems*, *71*(2), 151–162. https://doi.org/10.1007/s10705-004-1803-9

Carvalho, C. W. P., Onwulata, C. I., & Tomasula, P. M. (2007). Rheological properties of starch and whey protein isolate gels. *Food Science and Technology International*, *13*(3), 207–216. https://doi.org/10.1177/1082013207079897

Casas, M., Ferrero, C., de Paz, M. V., & Jiménez-Castellanos, M. R. (2009). Synthesis and characterization of new copolymers of ethyl methacrylate grafted on tapioca starch as novel excipients for direct compression matrix tablets. *European Polymer Journal*, *45*(6), 1765–1776. https://doi.org/10.1016/j.eurpolymj.2009.02.019

Casas, M., Ferrero, C., & Jiménez-Castellanos, M. R. (2010). Graft tapioca starch copolymers as novel excipients for controlled-release matrix tablets. *Carbohydrate Polymers*, *80*(1), 71–77. https://doi.org/10.1016/j.carbpol.2009.10.065

Chaiwat, W., Wongsagonsup, R., Tangpanichyanon, N., Jariyaporn, T., Deeyai, P., Suphantharika, M., Fuongfuchat, A., Nisoa, M., & Dangtip, S. (2016). Argon plasma treatment of tapioca starch using a semi-continuous downer reactor. *Food and Bioprocess Technology*, *9*(7), 1125–1134. https://doi.org/10.1007/s11947-016-1701-6

Chan, H., Leh, C. P., Bhat, R., Senan, C., Williams, P. A., & Karim, A. A. (2011). Molecular structure, rheological and thermal characteristics of ozone-oxidized starch. *Food Chemistry*, *126*(3), 1019–1024. https://doi.org/10.1016/j.foodchem.2010.11.113

Chan, H. T., Bhat, R., & Karim, A. A. (2009). Physicochemical and functional properties of ozone-oxidized starch. *Journal of Agricultural and Food Chemistry*, *57*(13), 5965–5970. https://doi.org/10.1021/jf9008789

Chang, L., Wang, L., Peng, C., Tong, Z., Wang, D., Ding, G., Xiao, J., Guo, A., & Wang, X. (2019). The chloroplast proteome response to drought stress in cassava leaves. *Plant Physiology and Biochemistry*, *142*, 351–362. https://doi.org/10.1016/j.plaphy.2019.07.025

Chang, Y. P., Abd Karim, A., & Seow, C. C. (2006). Interactive plasticizing–antiplasticizing effects of water and glycerol on the tensile properties of tapioca starch films. *Food Hydrocolloids*, *20*(1), 1–8. https://doi.org/10.1016/j.foodhyd.2005.02.004

Chantaro, P., & Pongsawatmanit, R. (2010). Influence of sucrose on thermal and pasting properties of tapioca starch and xanthan gum mixtures. *Journal of Food Engineering*, *98*(1), 44–50. https://doi.org/10.1016/j.jfoodeng.2009.12.006

Charoenphon, A., Thanachit, S., Anusontpornperm, S., & Kheoruenromne, I. (2020). Dissolution of mg fertilizer and its availability in cassava in tropical upland soils. *Communications in Soil Science and Plant Analysis*, *51*(2), 236–249. https://doi.org/10.1080/00103624.2019.1705327

Chatterjee, D., Brambila, G. S., Bowker, B. C., & Zhuang, H. (2019). Effect of tapioca flour on physicochemical properties and sensory descriptive profiles of chicken breast meat patties. *Journal of Applied Poultry Research*, *28*(3), 598–605. https://doi.org/10.3382/japr/pfy076

Chavalparit, O., & Ongwandee, M. (2009). Clean technology for the tapioca starch industry in Thailand. *Journal of Cleaner Production*, *17*(2), 105–110. https://doi.org/10.1016/j.jclepro.2008.03.001

Chávez, A., Sánchez, T., Ceballos, H., Rodriguez-Amaya, D., Nestel, P., Tohme, J., & Ishitani, M. (2007). Retention of carotenoids in cassava roots submitted to different processing methods. *Journal of the Science of Food and Agriculture*, *87*(3), 388–393. https://doi.org/10.1002/jsfa.2704

Chen, H., Fu, X., & Luo, Z. (2015). Effect of gum arabic on freeze-thaw stability, pasting and rheological properties of tapioca starch and its derivatives. *Food Hydrocolloids*, *51*, 355–360. https://doi.org/10.1016/j.foodhyd.2015.05.034

Cherdthong, A., Khonkhaeng, B., Seankamsorn, A., Supapong, C., Wanapat, M., Gunun, N., Gunun, P., Chanjula, P., & Polyorach, S. (2018). Effects of feeding fresh cassava root with high-sulfur feed block on feed utilization, rumen fermentation, and blood metabolites in Thai native cattle. *Tropical Animal Health and Production*, *50*(6), 1365–1371. https://doi.org/10.1007/s11250-018-1569-8

Cherdthong, A., Wanapat, M., & Wachirapakorn, C. (2011). Effects of urea–calcium mixture in concentrate containing high cassava chip on feed intake, rumen fermentation and performance of lactating dairy cows fed on rice straw. *Livestock Science*, *136*(2–3), 76–84. https://doi.org/10.1016/j.livsci.2010.08.002

Chevance, F. F. V., Farmer, L. J., Desmond, E. M., Novelli, E., Troy, D. J., & Chizzolini, R. (2000). Effect of some fat replacers on the release of volatile aroma compounds from low-fat meat products. *Journal of Agricultural and Food Chemistry*, *48*(8), 3476–3484. https://doi.org/10.1021/jf991211u

Chikoti, P. C., Mulenga, R. M., Tembo, M., & Sseruwagi, P. (2019). Correction to: Cassava mosaic disease: a review of a threat to cassava production in Zambia. *Journal of Plant Pathology*, *101*(3), 479–479. https://doi.org/10.1007/s42161-019-00267-w

Chillo, S., Flores, S., Mastromatteo, M., Conte, A., Gerschenson, L., & Del Nobile, M. A. (2008). Influence of glycerol and chitosan on tapioca starch-based edible film properties. *Journal of Food Engineering*, *88*(2), 159–168. https://doi.org/10.1016/j.jfoodeng.2008.02.002

Chisenga, S. M., Workneh, T. S., Bultosa, G., & Laing, M. (2019). Proximate composition, cyanide contents, and particle size distribution of cassava flour from cassava varieties in Zambia. *AIMS AGRICULTURE AND FOOD*, *4*(4), 869–891. https://doi.org/10.3934/agrfood.2019.4.869

Chisté, R. C., Silva, P. A., Lopes, A. S., & da Silva Pena, R. (2012). Sorption isotherms of tapioca flour: Hygroscopic behaviour of tapioca flour. *International*

Journal of Food Science & Technology, *47*(4), 870–874. https://doi.org/10.1111/j.1365-2621.2011.02900.x

Chiwona-Karltun, T. Tylleskar, J. M, L. (2000). Low dietary cyanogen exposure from frequent consumption of potentially toxic cassava in Malawi. *International Journal of Food Sciences and Nutrition*, *51*(1), 33–43. https://doi.org/10.1080/096374800100886

Chua, M. F., Youbee, L., Oudthachit, S., Khanthavong, P., Veneklaas, E. J., & Malik, A. I. (2020). Potassium fertilisation is required to sustain cassava yield and soil fertility. *Agronomy*, *10*(8), 1103. https://doi.org/10.3390/agronomy10081103

Cozzolino, D. (2016). The use of the rapid visco analyser (Rva) in breeding and selection of cereals. *Journal of Cereal Science*, *70*, 282–290. https://doi.org/10.1016/j.jcs.2016.07.003

Cressey, P., & Reeve, J. (2019). Metabolism of cyanogenic glycosides: A review. *Food and Chemical Toxicology*, *125*, 225–232. https://doi.org/10.1016/j.fct.2019.01.002

Deeyai, P., Suphantharika, M., Wongsagonsup, R., & Dangtip, S. (2013). Characterization of modified tapioca starch in atmospheric argon plasma under diverse humidity by ftir spectroscopy. *Chinese Physics Letters*, *30*(1), 018103. https://doi.org/10.1088/0256-307X/30/1/018103

Desai, P. M., Liew, C. V., & Heng, P. W. S. (2016). Review of disintegrants and the disintegration phenomena. *Journal of Pharmaceutical Sciences*, *105*(9), 2545–2555. https://doi.org/10.1016/j.xphs.2015.12.019

Deshpande, C. V., Nandy, T., & Kaul, S. N. (1994). Studies on treatment of wastewater from tapioca based sago industry. *Journal of Environmental Science and Health . Part A: Environmental Science and Engineering and Toxicology*, *29*(10), 2255–2268. https://doi.org/10.1080/10934529409376178

Desmond, E. M., Troy, D. J., & Buckley, D. J. (1998). The effects of tapioca starch, oat fibre and whey protein on the physical and sensory properties of low-fat beef burgers. *LWT - Food Science and Technology*, *31*(7–8), 653–657. https://doi.org/10.1006/fstl.1998.0415

Diamantino, V. R., Costa, M. S., Taboga, S. R., Vilamaior, P. S. L., Franco, C. M. L., & Penna, A. L. B. (2019). Starch as a potential fat replacer for application in cheese: Behaviour of different starches in casein/starch mixtures and in the casein matrix. *International Dairy Journal*, *89*, 129–138. https://doi.org/10.1016/j.idairyj.2018.08.015

Domian, E., Cenkier, J., Górska, A., & Brynda-Kopytowska, A. (2018). Effect of oil content and drying method on bulk properties and stability of powdered emulsions with OSA starch and linseed oil. *LWT*, *88*, 95–102. https://doi.org/10.1016/j.lwt.2017.09.043

Donkor, E., Onakuse, S., Bogue, J., & de Los Rios Carmenado, I. (2017). The impact of the presidential cassava initiative on cassava productivity in Nigeria: Implication for sustainable food supply and food security. *Cogent Food & Agriculture*, *3*(1), 1368857. https://doi.org/10.1080/23311932.2017.1368857

El-Sharkawy, M. A. (1993). Drought-tolerant cassava for africa, asia, and latin america. *BioScience*, *43*(7), 441–451. https://doi.org/10.2307/1311903

Failla, M. L., Chitchumroonchokchai, C., Siritunga, D., De Moura, F. F., Fregene, M., Manary, M. J., & Sayre, R. T. (2012). Retention during processing and bioaccessibility of β-carotene in high β-carotene transgenic cassava root. *Journal of Agricultural and Food Chemistry*, *60*(15), 3861–3866. https://doi.org/10.1021/jf204958w

Famá, L., Rojas, A. M., Goyanes, S., & Gerschenson, L. (2005). Mechanical properties of tapioca-starch edible films containing sorbates. *LWT - Food Science and Technology*, *38*(6), 631–639. https://doi.org/10.1016/j.lwt.2004.07.024

Fan, M., Huang, Q., Zhong, S., Li, X., Xiong, S., Xie, J., Yin, T., Zhang, B., & Zhao, S. (2019). Gel properties of myofibrillar protein as affected by gelatinization and retrogradation behaviors of modified starches with different crosslinking and acetylation degrees. *Food Hydrocolloids*, *96*, 604–616. https://doi.org/10.1016/j.foodhyd.2019.05.045

Febrianta, H., Yunianto, V. D., Nurwantoro, N., & Bintoro, V. P. (2020). Freeze-drying microencapsulation of turmeric (Curcuma longa l.) using an amorphous matrix of maltodextrin, modified cassava flour and skim milk. *The Annals of the University Dunarea de Jos of Galati Fascicle VI – Food Technology*, *44*(2), 26–42. https://doi.org/10.35219/foodtechnology.2020.2.02

Fermont, A. M., van Asten, P. J. A., & Giller, K. E. (2008). Increasing land pressure in East Africa: The changing role of cassava and consequences for sustainability of farming systems. *Agriculture, Ecosystems & Environment*, *128*(4), 239–250. https://doi.org/10.1016/j.agee.2008.06.009

Fernandes, J. B. M., Celestino, M. T., Tavares, M. I. B., Freitas, Z. M. F., Santos, E. P. D., Ricci Júnior, E., & Monteiro, M. S. S. B. (2019). The development and characterization of Propranolol Tablets using Tapioca starch as excipient. *Anais Da Academia Brasileira de Ciências*, *91*(1), e20180094. https://doi.org/10.1590/0001-3765201920180094

Fessi, H., Puisieux, F., Devissaguet, J. Ph., Ammoury, N., & Benita, S. (1989). Nanocapsule formation by interfacial polymer deposition following solvent displacement. *International Journal of Pharmaceutics*, *55*(1), R1–R4. https://doi.org/10.1016/0378-5173(89)90281-0

Fettig, J., Pick, V., Austermann-Haun, U., Blumberg, M., & Phuoc, N. V. (2013). Treatment of tapioca starch wastewater by a novel combination of physical and biological processes. *Water Science and Technology*, *68*(6), 1264–1270. https://doi.org/10.2166/wst.2013.354

Flores, S., Conte, A., Campos, C., Gerschenson, L., & Del Nobile, M. (2007b). Mass transport properties of tapioca-based active edible films. *Journal of Food Engineering*, *81*(3), 580–586. https://doi.org/10.1016/j.jfoodeng.2006.12.010

Flores, S., Famá, L., Rojas, A. M., Goyanes, S., & Gerschenson, L. (2007a). Physical properties of tapioca-starch edible films: Influence of filmmaking and potassium sorbate. *Food Research International*, *40*(2), 257–265. https://doi.org/10.1016/j.foodres.2006.02.004

Fondong, V. N., Thresh, J. M., & Zok, S. (2002). Spatial and temporal spread of cassava mosaic virus disease in cassava grown alone and when intercropped with maize and/or cowpea. *Journal of Phytopathology*, *150*(7), 365–374. https://doi.org/10.1046/j.1439-0434.2002.00775.x

Franco, C. M. L., Preto, S. J. D., & Ciacco, C. F. (1987). Studies on the susceptibility of granular cassava and com starches to enzymatic attack part i: Study of the conditions of hydrolysis. *Starch - Stärke*, *39*(12), 432–435. https://doi.org/10.1002/star.19870391207

Frewer, L. J., van der Lans, I. A., Fischer, A. R. H., Reinders, M. J., Menozzi, D., Zhang, X., van den Berg, I., & Zimmermann, K. L. (2013). Public perceptions of agri-food applications of genetic modification – A systematic review and meta-analysis. *Trends in Food Science & Technology*, 30(2), 142–152. https://doi.org/10.1016/j.tifs.2013.01.003

Fu, Z., Luo, S.-J., BeMiller, J. N., Liu, W., & Liu, C.-M. (2015b). Effect of high-speed jet on flow behavior, retrogradation, and molecular weight of rice starch. *Carbohydrate Polymers*, *133*, 61–66. https://doi.org/10.1016/j.carbpol.2015.07.006

Fu, Z., Luo, S.-J., BeMiller, J. N., Liu, W., & Liu, C.-M. (2015a). Influence of high-speed jet on solubility, rheological properties, morphology and crystalline structure of rice starch: High-speed jet on rice starch. *Starch - Stärke*, *67*(7–8), 595–603. https://doi.org/10.1002/star.201400256

Fukuzawa, S., Ogawa, T., Nakagawa, K., & Adachi, S. (2016). Moisture profiles of wheat noodles containing hydroxypropylated tapioca starch. *International Journal of Food Science & Technology*, *51*(6), 1516–1522. https://doi.org/10.1111/ijfs.13108

Garcia, M., & Dale, N. (1999). Cassava root meal for poultry. *Journal of Applied Poultry Research*, *8*(1), 132–137. https://doi.org/10.1093/japr/8.1.132

Garlotta, D. (2001). [No title found]. *Journal of Polymers and the Environment*, *9*(2), 63–84. https://doi.org/10.1023/A:1020200822435

Ge, S., Xiong, L., Li, M., Liu, J., Yang, J., Chang, R., Liang, C., & Sun, Q. (2017). Characterizations of Pickering emulsions stabilized by starch nanoparticles: Influence of starch variety and particle size. *Food Chemistry*, *234*, 339–347. https://doi.org/10.1016/j.foodchem.2017.04.150

Gharsallaoui, A., Roudaut, G., Chambin, O., Voilley, A., & Saurel, R. (2007). Applications of spray-drying in microencapsulation of food ingredients: An overview. *Food Research International*, *40*(9), 1107–1121. https://doi.org/10.1016/j.foodres.2007.07.004

Ghozali, M., Meliana, Y., & Chalid, M. (2021). Synthesis and characterization of bacterial cellulose by Acetobacter xylinum using liquid tapioca waste. *Materials Today: Proceedings*, *44*, 2131–2134. https://doi.org/10.1016/j.matpr.2020.12.274

Gleadow, R., Pegg, A., & Blomstedt, C. K. (2016). Resilience of cassava (*manihot esculenta* crantz) to salinity: Implications for food security in low-lying regions. *Journal of Experimental Botany*, *67*(18), 5403–5413. https://doi.org/10.1093/jxb/erw302

Gujral, N. (2012). Celiac disease: Prevalence, diagnosis, pathogenesis and treatment. *World Journal of Gastroenterology*, *18*(42), 6036. https://doi.org/10.3748/wjg.v18.i42.6036

Gunasekar, V., Reshma, K. R., Treesa, G., Gowdhaman, D., & Ponnusami, V. (2014). Xanthan from sulphuric acid treated tapioca pulp: Influence of acid concentration on xanthan fermentation. *Carbohydrate Polymers*, *102*, 669–673. https://doi.org/10.1016/j.carbpol.2013.11.006

Gupta, B., Revagade, N., & Hilborn, J. (2007). Poly(Lactic acid) fiber: An overview. *Progress in Polymer Science*, *32*(4), 455–482. https://doi.org/10.1016/j.progpolymsci.2007.01.005

Han, H. L., & Sosulski, F. W. (1998). Cationization of potato and tapioca starches using an aqueous alcoholic-alkaline process. *Starch - Stärke*, *50*(11–12), 487–492. https://doi.org/10.1002/(SICI)1521-379X(199812)50:11/12<487::AID-STAR487>3.0.CO;2-P

Han, Z., Zeng, X. A., Fu, N., Yu, S. J., Chen, X. D., & Kennedy, J. F. (2012). Effects of pulsed electric field treatments on some properties of tapioca starch. *Carbohydrate Polymers*, *89*(4), 1012–1017. https://doi.org/10.1016/j.carbpol.2012.02.053

Hao, O. J., Chien-Jen, S., Cheng-Fang, L., Fu-Tien, J., & Zen-Chyuan, C. (1996). Use of microtox tests for screening industrial wastewater toxicity. *Water Science and Technology*, *34*(10), 43–50. https://doi.org/10.2166/wst.1996.0237

Harimawan, A., Devianto, H., Al-Aziz, Rd., Shofinita, D., & Setiadi, T. (2018, December 29). *Influence of electrode distance on electrical energy production of microbial fuel cell using tapioca wastewater*. https://doi.org/10.5614/j.eng.technol.sci.2018.50.6.7

Harsono, A., & Pratiwi, H. (2017). The increase of Ultisol productivity based on intercropping cassava with peanut and soybean. *Nusantara Bioscience*, *9*(2), 157–163. https://doi.org/10.13057/nusbiosci/n090209

Hasanudin, U., Kustyawati, M. E., Iryani, D. A., Haryanto, A., & Triyono, S. (2019). Estimation of energy and organic fertilizer generation from small scale tapioca industrial waste. *IOP Conference Series: Earth and Environmental Science*, *230*, 012084. https://doi.org/10.1088/1755-1315/230/1/012084

Hedayati, S., Niakousari, M., & Mohsenpour, Z. (2020). Production of tapioca starch nanoparticles by nanoprecipitation-sonication treatment. *International Journal of Biological Macromolecules*, *143*, 136–142. https://doi.org/10.1016/j.ijbiomac.2019.12.003

Hermiati, E., Azuma, J., Tsubaki, S., Mangunwidjaja, D., Sunarti, T. C., Suparno, O., & Prasetya, B. (2012). Improvement of microwave-assisted hydrolysis of cassava pulp and tapioca flour by addition of activated carbon. *Carbohydrate Polymers*, *87*(1), 939–942. https://doi.org/10.1016/j.carbpol.2011.08.033

Hizukuri, S. (1986). Polymodal distribution of the chain lengths of amylopectins, and its significance. *Carbohydrate Research*, *147*(2), 342–347. https://doi.org/10.1016/S0008-6215(00)90643-8

Hofman, D. L., van Buul, V. J., & Brouns, F. J. P. H. (2016). Nutrition, health, and regulatory aspects of digestible maltodextrins. *Critical Reviews in Food Science and Nutrition*, *56*(12), 2091–2100. https://doi.org/10.1080/10408398.2014.940415

Hong, Y., Liu, G., Zhou, S., Gu, Z., Cheng, L., Li, Z., & Li, C. (2016). Influence of guar gum on the in vitro digestibility of tapioca starch: Guar gum tapioca starch digestibility. *Starch - Stärke*, *68*(3–4), 339–347. https://doi.org/10.1002/star.201500142

Hong, Y., Zhu, L., & Gu, Z. (2014). Effects of sugar, salt and acid on tapioca starch and tapioca starch-xanthan gum combinations. *Starch - Stärke*, *66*(5–6), 436–443. https://doi.org/10.1002/star.201300168

Horstmann, S., Belz, M., Heitmann, M., Zannini, E., & Arendt, E. (2016). Fundamental study on the impact of gluten-free starches on the quality of gluten-free model breads. *Foods*, *5*(4), 30. https://doi.org/10.3390/foods5020030

Howe, J. A., Maziya-Dixon, B., & Tanumihardjo, S. A. (2009). Cassava with enhanced β-carotene maintains adequate vitamin A status in Mongolian gerbils (*meriones unguiculatus*) despite substantial *cis* -isomer content. *British Journal of Nutrition*, *102*(3), 342–349. https://doi.org/10.1017/S0007114508184720

Howeler, R. H. (1991). Long-term effect of cassava cultivation on soil productivity. *Field Crops Research*, *26*(1), 1–18. https://doi.org/10.1016/0378-4290(91)90053-X

Howeler, R. H., & Cadavid, L. F. (1990). Short-and long-term fertility trials in Colombia to determine the nutrient requirements of cassava. *Fertilizer Research*, *26*(1–3), 61–80. https://doi.org/10.1007/BF01048744

Hridya, A. C., Byju, G., & Misra, R. S. (2014). Effects of microbial inoculations on soil chemical, biochemical and microbial biomass carbon of cassava (*manihot esculenta* crantz) growing Vertisols. *Archives of Agronomy and Soil Science*, *60*(2), 239–249. https://doi.org/10.1080/03650340.2013.791023

Huang, J., Wei, M., Ren, R., Li, H., Liu, S., & Yang, D. (2017). Morphological changes of blocklets during the gelatinization process of tapioca starch. *Carbohydrate Polymers*, *163*, 324–329. https://doi.org/10.1016/j.carbpol.2017.01.083

Hughes, E., Mullen, A. M., & Troy, D. J. (1998). Effects of fat level, tapioca starch and whey protein on frankfurters formulated with 5% and 12% fat. *Meat Science*, *48*(1–2), 169–180. https://doi.org/10.1016/S0309-1740(97)00087-9

Iakovchenko, N. V., & Arseneva, T. P. (2016). Tapioca maltodextrin in the production of soft unripened cheese. *Acta Scientiarum Polonorum Technologia Alimentaria*, *15*(1), 47–56. https://doi.org/10.17306/J.AFS.2016.1.5

Iglesias, C., Mayer, J., Chavez, L.´ıa, & Calle, F. (1997). Genetic potential and stability of carotene content in cassava roots. *Kluwer Academic Publishers*.

Imakumbili, M. L. E., Semu, E., Semoka, J. M. R., Abass, A., & Mkamilo, G. (2019). Soil nutrient adequacy for optimal cassava growth, implications on cyanogenic glucoside production: A case of konzo-affected Mtwara region, Tanzania. *PLOS ONE*, *14*(5), e0216708. https://doi.org/10.1371/journal.pone.0216708

Isabirye, M., Ruysschaert, G., Vanlinden, L., Poesen, J., Magunda, M., & Deckers, J. (2007). Soil losses due to cassava and sweet potato harvesting: A case study from low input traditional agriculture. *Soil and Tillage Research*, *92*(1–2), 96–103. https://doi.org/10.1016/j.still.2006.01.013

Jaszczak, E., Polkowska, Ż., Narkowicz, S., & Namieśnik, J. (2017). Cyanides in the environment—Analysis—Problems and challenges. *Environmental Science and Pollution Research*, *24*(19), 15929–15948. https://doi.org/10.1007/s11356-017-9081-7

Jensen, E. S., Carlsson, G., & Hauggaard-Nielsen, H. (2020). Intercropping of grain legumes and cereals improves the use of soil N resources and reduces the requirement for synthetic fertilizer N: A global-scale analysis. *Agronomy for Sustainable Development*, *40*(1), 5. https://doi.org/10.1007/s13593-020-0607-x

John, K. S., Venugopal, V. K., & Saraswathi, P. (2007). Yield maximization in cassava through a systematic approach in fertilizer use. *Communications in Soil Science and Plant Analysis*, *38*(5–6), 779–794. https://doi.org/10.1080/00103620701220783

Jones, D. M., Trim, D. S., Bainbridge, Z. A., & French, L. (1994). Influence of selected process variables on the elimination of cyanide from cassava. *Journal* *of the Science of Food and Agriculture*, *66*(4), 535–542. https://doi.org/10.1002/jsfa.2740660418

Kamaldeen, O. S., Ariahu, C. C., & Yusufu, M. I. (2020). Application of soy protein isolate and cassava starch based film solutions as matrix for ionic encapsulation of carrot powders. *Journal of Food Science and Technology*, *57*(11), 4171–4181. https://doi.org/10.1007/s13197-020-04455-w

Kang, L., Liang, Q., Jiang, Q., Yao, Y., Dong, M., He, B., & Gu, M. (2020). Screening of diverse cassava genotypes based on nitrogen uptake efficiency and yield. *Journal of Integrative Agriculture*, *19*(4), 965–974. https://doi.org/10.1016/S2095-3119(19)62746-2

Karim, A., Norziah, M. H., & Seow, C.C. (2000). Methods for the study of starch retrogradation. *Food Chemistry*, *71*(1), 9–36. https://doi.org/10.1016/S0308-8146(00)00130-8

Kasemsuwan, T., Bailey, T., & Jane, J. (1998). Preparation of clear noodles with mixtures of tapioca and high-amylose starches1Journal Paper J-16546 of the Iowa Agriculture and Home Economics Experiment Station, Ames. Project 3258.1. *Carbohydrate Polymers*, *36*(4), 301–312. https://doi.org/10.1016/S0144-8617(97)00256-7

Kashala-Abotnes, E., Okitundu, D., Mumba, D., Boivin, M. J., Tylleskär, T., & Tshala-Katumbay, D. (2019). Konzo: A distinct neurological disease associated with food (Cassava) cyanogenic poisoning. *Brain Research Bulletin*, *145*, 87–91. https://doi.org/10.1016/j.brainresbull.2018.07.001

Kato, R., Tachibe, M., Sugano, S., Kishida, T., & Ebihara, K. (2009). High-hydroxypropylated tapioca starch improves insulin resistance in genetically diabetic kkay mice. *Journal of Food Science*, *74*(3), H89–H96. https://doi.org/10.1111/j.1750-3841.2009.01083.x

Kaulpiboon, J., Rudeekulthamrong, P., Watanasatitarpa, S., Ito, K., & Pongsawasdi, P. (2015). Synthesis of long-chain isomaltooligosaccharides from tapioca starch and an in vitro investigation of their prebiotic properties. *Journal of Molecular Catalysis B: Enzymatic*, *120*, 127–135. https://doi.org/10.1016/j.molcatb.2015.07.004

Keatkrai, J., Lumdubwong, N., Chaiseri, S., & Jirapakkul, W. (2017). Characteristics of menthone encapsulated complex by mungbean, tapioca, and rice starches. *International Journal of Food Properties*, *20*(4), 810–820. https://doi.org/10.1080/10942912.2016.1183129

Kemdirim, O. C., Chukwu, O. A., & Achinewhu, S. C. (1995). Effect of traditional processing of cassava on the cyanide content of gari and cassava flour. *Plant Foods for Human Nutrition*, *48*(4), 335–339. https://doi.org/10.1007/BF01088492

Kengkanna, J., Jakaew, P., Amawan, S., Busener, N., Bucksch, A., & Saengwilai, P. (2019). Phenotypic variation of cassava root traits and their responses to drought. *Applications in Plant Sciences*, *7*(4). https://doi.org/10.1002/aps3.1238

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. https://doi.org/10.1016/j.foodhyd.2014.04.008

Kim, S. R. B., Choi, Y.-G., Kim, J.-Y., & Lim, S.-T. (2015). Improvement of water solubility and humidity stability of tapioca starch film by incorporating various gums. *LWT - Food Science and Technology*, *64*(1), 475–482. https://doi.org/10.1016/j.lwt.2015.05.009

Kim, S., Yang, S.-Y., Chun, H. H., & Song, K. B. (2018). High hydrostatic pressure processing for the preparation of buckwheat and tapioca starch films. *Food Hydrocolloids*, *81*, 71–76. https://doi.org/10.1016/j.foodhyd.2018.02.039

Kimaryo, V. M., Massawe, G. A., Olasupo, N. A., & Holzapfel, W. H. (2000). The use of a starter culture in the fermentation of cassava for the production of “kivunde”, a traditional Tanzanian food product. *International Journal of Food Microbiology*, *56*(2–3), 179–190. https://doi.org/10.1016/S0168-1605(00)00159-8

Kishida, T., Nakai, Y., & Ebihara, K. (2001). Hydroxypropyl-distarch phosphate from tapioca starch reduces zinc and iron absorption, but not calcium and magnesium absorption, in rats. *The Journal of Nutrition*, *131*(2), 294–300. https://doi.org/10.1093/jn/131.2.294

Koh, J. J., Zhang, X., & He, C. (2018). Fully biodegradable Poly(Lactic acid)/Starch blends: A review of toughening strategies. *International Journal of Biological Macromolecules*, *109*, 99–113. https://doi.org/10.1016/j.ijbiomac.2017.12.048

Kolapo, A. L., & Sanni, M. O. (2009). A comparative evaluation of the macronutrient and micronutrient profiles of soybean-fortified gari and tapioca. *Food and Nutrition Bulletin*, *30*(1), 90–94. https://doi.org/10.1177/156482650903000110

Korus, J., Witczak, M., Ziobro, R., & Juszczak, L. (2009). The impact of resistant starch on characteristics of gluten-free dough and bread. *Food Hydrocolloids*, *23*(3), 988–995. https://doi.org/10.1016/j.foodhyd.2008.07.010

Kulicke, W.-M., & Heinze, T. (2005). Improvements in polysaccharides for use as blood plasma expanders. *Macromolecular Symposia*, *231*(1), 47–59. https://doi.org/10.1002/masy.200590024

La Frano, M. R., Woodhouse, L. R., Burnett, D. J., & Burri, B. J. (2013). Biofortified cassava increases β-carotene and vitamin A concentrations in the TAG-rich plasma layer of American women. *British Journal of Nutrition*, *110*(2), 310–320. https://doi.org/10.1017/S0007114512005004

Lamanna, M., Morales, N. J., García, N. L., & Goyanes, S. (2013). Development and characterization of starch nanoparticles by gamma radiation: Potential application as starch matrix filler. *Carbohydrate Polymers*, *97*(1), 90–97. https://doi.org/10.1016/j.carbpol.2013.04.081

Larrea-Wachtendorff, D., Sousa, I., & Ferrari, G. (2020). Starch-based hydrogels produced by high-pressure processing (Hpp): Effect of the starch source and processing time. *Food Engineering Reviews*. https://doi.org/10.1007/s12393-020-09264-7

Latif, M. A., Ghufran, R., Wahid, Z. A., & Ahmad, A. (2011). Integrated application of upflow anaerobic sludge blanket reactor for the treatment of wastewaters. *Water Research*, *45*(16), 4683–4699. https://doi.org/10.1016/j.watres.2011.05.049

Le, Q.-T., Lee, C.-K., Kim, Y.-W., Lee, S.-J., Zhang, R., Withers, S. G., Kim, Y.-R., Auh, J.-H., & Park, K.-H. (2009). Amylolytically-resistant tapioca starch modified by combined treatment of branching enzyme and maltogenic amylase. *Carbohydrate Polymers*, *75*(1), 9–14. https://doi.org/10.1016/j.carbpol.2008.06.001

Lee, S. W., Said, N. S., & Sarbon, N. M. (2021). The effects of zinc oxide nanoparticles on the physical, mechanical and antimicrobial properties of chicken skin gelatin/tapioca starch composite films in food packaging. *Journal of Food Science and Technology*, *58*(11), 4294–4302. https://doi.org/10.1007/s13197-020-04904-6

Levi, M., & Jonge, E. de. (2007). Clinical relevance of the effects of plasma expanders on coagulation. *Seminars in Thrombosis and Hemostasis*, *33*(8), 810–815. https://doi.org/10.1055/s-2007-1000370

Li, H., Ji, J., Yang, L., Lei, N., Wang, J., & Sun, B. (2020). Structural and physicochemical property changes during pyroconversion of native maize starch. *Carbohydrate Polymers*, *245*, 116560. https://doi.org/10.1016/j.carbpol.2020.116560

Li, X., Fan, M., Huang, Q., Zhao, S., Xiong, S., Zhang, B., & Yin, T. (2020). Effect of wet-media milling on the physicochemical properties of tapioca starch and their relationship with the texture of myofibrillar protein gel. *Food Hydrocolloids*, *109*, 106082. https://doi.org/10.1016/j.foodhyd.2020.106082

Liakopoulou-Kyriakides, M., Psomas, S. K., & Kyriakidis, D. A. (1999). Xanthan gum production by xanthomonas campestris w. T. Fermentation from chestnut extract. *Applied Biochemistry and Biotechnology*, *82*(3), 175–184. https://doi.org/10.1385/ABAB:82:3:175

Lian, F., Huang, X., Lin, Y., Xia, W., Fu, T., Wang, F., He, D., Zhou, W., & Li, J. (2021). A highly efficient nanoscale tapioca starch prepared by high‐speed jet for Cu $^{2+}$ removal in simulated industrial effluent. *Journal of the Science of Food and Agriculture*, *101*(10), 4298–4307. https://doi.org/10.1002/jsfa.11069

Liew, K. C., De Ting, P. B., & Tan, Y. F. (2018). Physico-mechanical properties of particleboard made from seaweed adhesive and tapioca starch flour. *Journal of the Indian Academy of Wood Science*, *15*(2), 199–203. https://doi.org/10.1007/s13196-018-0226-1

Lin, Z. J. D., Taylor, N. J., & Bart, R. (2019). Engineering disease-resistant cassava. *Cold Spring Harbor Perspectives in Biology*, *11*(11), a034595. https://doi.org/10.1101/cshperspect.a034595

Lithourgidis, A. S., Dordas, C. A., Damalas, C. A., & Vlachostergios, D. N. (2011). Annual intercrops: An alternative pathway for sustainable agriculture. *Australian Journal of Crop Science*, *5*(4), 396–410.

Liu, P.-L., Zhang, Q., Shen, Q., Hu, X., & Wu, J.-H. (2012). Effect of high hydrostatic pressure on modified noncrystalline granular starch of starches with different granular type and amylase content. *LWT*, *47*(2), 450–458. https://doi.org/10.1016/j.lwt.2012.02.005

Lobato-Calleros, C., Ramírez-Santiago, C., Vernon-Carter, E. J., & Alvarez-Ramirez, J. (2014). Impact of native and chemically modified starches addition as fat replacers in the viscoelasticity of reduced-fat stirred yogurt. *Journal of Food Engineering*, *131*, 110–115. https://doi.org/10.1016/j.jfoodeng.2014.01.019

Loksuwan, J. (2007). Characteristics of microencapsulated β-carotene formed by spray drying with modified tapioca starch, native tapioca starch and maltodextrin. *Food Hydrocolloids*, *21*(5–6), 928–935. https://doi.org/10.1016/j.foodhyd.2006.10.011

Loo, C. P. Y., & Sarbon, N. M. (2020a). Chicken skin gelatin films with tapioca starch. *Food Bioscience*, *35*, 100589. https://doi.org/10.1016/j.fbio.2020.100589

Loo, C. P. Y., & Sarbon, N. M. (2020b). Chicken skin gelatin films with tapioca starch. *Food Bioscience*, *35*, 100589. https://doi.org/10.1016/j.fbio.2020.100589

López-Gómez, J. P., Alexandri, M., Schneider, R., & Venus, J. (2019). A review on the current developments in continuous lactic acid fermentations and case studies utilising inexpensive raw materials. *Process Biochemistry*, *79*, 1–10. https://doi.org/10.1016/j.procbio.2018.12.012

Louarn, G., Bedoussac, L., Gaudio, N., Journet, E.-P., Moreau, D., Steen Jensen, E., & Justes, E. (2021). Plant nitrogen nutrition status in intercrops– a review of concepts and methods. *European Journal of Agronomy*, *124*, 126229. https://doi.org/10.1016/j.eja.2021.126229

Lozano-Vazquez, G., Lobato-Calleros, C., Escalona-Buendia, H., Chavez, G., Alvarez-Ramirez, J., & Vernon-Carter, E. J. (2015). Effect of the weight ratio of alginate-modified tapioca starch on the physicochemical properties and release kinetics of chlorogenic acid containing beads. *Food Hydrocolloids*, *48*, 301–311. https://doi.org/10.1016/j.foodhyd.2015.02.032

Lu, W., Kelly, A. L., & Miao, S. (2016). Emulsion-based encapsulation and delivery systems for polyphenols. *Trends in Food Science & Technology*, *47*, 1–9. https://doi.org/10.1016/j.tifs.2015.10.015

Luang-ni, P., Chatpun, S., Wansuksri, R., Lertpanich, S., & Piyachornkwan, K. (2015). Preparation and characterization of physically and chemically modified tapioca starch-based plasma expanders. *2015 8th Biomedical Engineering International Conference (BMEiCON)*, 1–4. https://doi.org/10.1109/BMEiCON.2015.7399553

Lyons, P. H., Kerry, J. F., Morrissey, P. A., & Buckley, D. J. (1999). The influence of added whey protein/carrageenan gels and tapioca starch on the textural properties of low fat pork sausages. *Meat Science*, *51*(1), 43–52. https://doi.org/10.1016/S0309-1740(98)00095-3

Makmoon, T., Foungfuchat, A., & Jiratumnukul, N. (2013). Modified tapioca starch as a rheology modifier in acrylic dispersion system. *Progress in Organic Coatings*, *76*(6), 959–962. https://doi.org/10.1016/j.porgcoat.2012.10.021

Manchun, S., Piriyaprasarth, S., Patomchaiviwat, V., Limmatvapirat, S., & Sriamornsak, P. (2012). Effect of physical aging on physical properties of pregelatinized tapioca starch. *Advanced Materials Research*, *506*, 35–38. https://doi.org/10.4028/www.scientific.net/AMR.506.35

Maniglia, B. C., Pataro, G., Ferrari, G., Augusto, P. E. D., Le-Bail, P., & Le-Bail, A. (2021). Pulsed electric fields (Pef) treatment to enhance starch 3D printing application: Effect on structure, properties, and functionality of wheat and cassava starches. *Innovative Food Science & Emerging Technologies*, *68*, 102602. https://doi.org/10.1016/j.ifset.2021.102602

Maphalla, T. G., & Emmambux, M. N. (2016). Functionality of maize, wheat, teff and cassava starches with stearic acid and xanthan gum. *Carbohydrate Polymers*, *136*, 970–978. https://doi.org/10.1016/j.carbpol.2015.09.004

Maran, J. P., Sivakumar, V., Sridhar, R., & Thirugnanasambandham, K. (2013). Development of model for barrier and optical properties of tapioca starch based edible films. *Carbohydrate Polymers*, *92*(2), 1335–1347. https://doi.org/10.1016/j.carbpol.2012.09.069

Marvizadeh, M. M., Oladzadabbasabadi, N., Mohammadi Nafchi, A., & Jokar, M. (2017). Preparation and characterization of bionanocomposite film based on tapioca starch/bovine gelatin/nanorod zinc oxide. *International Journal of Biological Macromolecules*, *99*, 1–7. https://doi.org/10.1016/j.ijbiomac.2017.02.067

Marzouk, N., Hassan, N., Fawzy, Z., & El-Ramady, H. (2020). Cassava cultivars response to different levels of potassium fertilization under drip irrigation and sandy soil conditions. *Egyptian Journal of Soil Science*, *60*(3), 317–334. https://doi.org/10.21608/ejss.2020.34054.1367

Melini, V., & Melini, F. (2019). Gluten-free diet: Gaps and needs for a healthier diet. *Nutrients*, *11*(1), 170. https://doi.org/10.3390/nu11010170

Meng, R., Wu, Z., Xie, H.-Q., Xu, G.-X., Cheng, J.-S., & Zhang, B. (2020). Preparation, characterization, and encapsulation capability of the hydrogel cross-linked by esterified tapioca starch. *International Journal of Biological Macromolecules*, *155*, 1–5. https://doi.org/10.1016/j.ijbiomac.2020.03.141

Milde, L. B., Ramallo, L. A., & Puppo, M. C. (2012). Gluten-free bread based on tapioca starch: Texture and sensory studies. *Food and Bioprocess Technology*, *5*(3), 888–896. https://doi.org/10.1007/s11947-010-0381-x

Miles, D., Jansson, E., Mai, M. C., Azer, M., Day, P., Shadbolt, C., Stitt, V., Kiermeier, A., & Szabo, E. (2011). A survey of total hydrocyanic acid content in ready-to-eat cassava-based chips obtained in the australian market in 2008. *Journal of Food Protection*, *74*(6), 980–985. https://doi.org/10.4315/0362-028X.JFP-10-557

Miles, M. J., Morris, V. J., Orford, P. D., & Ring, S. G. (1985). The roles of amylose and amylopectin in the gelation and retrogradation of starch. *Carbohydrate Research*, *135*(2), 271–281. https://doi.org/10.1016/S0008-6215(00)90778-X

Mimura, K., Kanada, K., Uchida, S., Yamada, M., & Namiki, N. (2011). Formulation study for orally disintegrating tablet using partly pregelatinized starch binder. *Chemical and Pharmaceutical Bulletin*, *59*(8), 959–964. https://doi.org/10.1248/cpb.59.959

Minakawa, A. F. K., Faria-Tischer, P. C. S., & Mali, S. (2019). Simple ultrasound method to obtain starch micro- and nanoparticles from cassava, corn and yam starches. *Food Chemistry*, *283*, 11–18. https://doi.org/10.1016/j.foodchem.2019.01.015

Mishra, S., & Rai, T. (2006). Morphology and functional properties of corn, potato and tapioca starches. *Food Hydrocolloids*, *20*(5), 557–566. https://doi.org/10.1016/j.foodhyd.2005.01.001

Miyazaki, M., Maeda, T., & Morita, N. (2008). Bread quality of frozen dough substituted with modified tapioca starches. *European Food Research and Technology*, *227*(2), 503–509. https://doi.org/10.1007/s00217-007-0747-0

Mocumbi, A. O. H., Yacoub, M. H., Yokohama, H., & Ferreira, M. B. (2009). Right ventricular endomyocardial fibrosis. *Cardiovascular Pathology*, *18*(1), 64–65. https://doi.org/10.1016/j.carpath.2007.12.009

Monroy-Rivera, J. A., Angulo, O., Sanchez, T., & Lebert, A. (1996). Elimination of cyabogebic compounds of cassava during solar drying. *Drying Technology*, *14*(10), 2371–2385. https://doi.org/10.1080/07373939608917210

Moore, G. R. P., Canto, L. R. do, Amante, E. R., & Soldi, V. (2005). Cassava and corn starch in maltodextrin production. *Química Nova*, *28*(4), 596–600. https://doi.org/10.1590/S0100-40422005000400008

Moura, W. S., Oliveira, E. E., Haddi, K., Corrêa, R. F. T., Piau, T. B., Moura, D. S., Santos, S. F., Grisolia, C. K., Ribeiro, B. M., & Aguiar, R. W. S. (2021). Cassava starch-based essential oil microparticles preparations: Functionalities in mosquito control and selectivity against non-target organisms. *Industrial Crops and Products*, *162*, 113289. https://doi.org/10.1016/j.indcrop.2021.113289

Muhammad, K., Kusnandar, F., Mat Hashim, D., & Rahman, R. AbD. (1999). Application of native and phosphorylated tapioca starches in potato starch noodle. *International Journal of Food Science & Technology*, *34*(3), 275–280. https://doi.org/10.1046/j.1365-2621.1999.00262.x

Muller, J., González-Martínez, C., & Chiralt, A. (2017). Combination of poly(Lactic) acid and starch for biodegradable food packaging. *Materials*, *10*(8), 952. https://doi.org/10.3390/ma10080952

Mungray, A. K., Murthy, Z. V. P., & Tirpude, A. J. (2010). Post treatment of up-flow anaerobic sludge blanket based sewage treatment plant effluents: A review. *Desalination and Water Treatment*, *22*(1–3), 220–237. https://doi.org/10.5004/dwt.2010.1788

Murali, S., Kar, A., Mohapatra, D., & Kalia, P. (2015). Encapsulation of black carrot juice using spray and freeze drying. *Food Science and Technology International*, *21*(8), 604–612. https://doi.org/10.1177/1082013214557843

Mutsaers, H. J. W., Ezumah, H. C., & Osiru, D. S. O. (1993). Cassava-based intercropping: A review. *Field Crops Research*, *34*(3–4), 431–457. https://doi.org/10.1016/0378-4290(93)90125-7

Mutter, T. C., Ruth, C. A., & Dart, A. B. (2013). Hydroxyethyl starch (Hes) versus other fluid therapies: Effects on kidney function. *Cochrane Database of Systematic Reviews*. https://doi.org/10.1002/14651858.CD007594.pub3

Naz, M. Y., Sulaiman, S. A., Ariff, Mohd. H. B. Mohd., & Ariwahjoedi, B. (2014). *Urea encapsulation in modified starch matrix for nutrients retention*. 316–321. https://doi.org/10.1063/1.4898485

Nguyen, H., Schoenau, J. J., Van Rees, K. C. J., Nguyen, D., & Qian, P. (2001). Long-term nitrogen, phosphorus and potassium fertilization of cassava influences soil chemical properties in North Vietnam. *Canadian Journal of Soil Science*, *81*(4), 481–488. https://doi.org/10.4141/S00-048

Nhassico, D., Muquingue, H., Cliff, J., Cumbana, A., & Bradbury, J. H. (2008). Rising African cassava production, diseases due to high cyanide intake and control measures. *Journal of the Science of Food and Agriculture*, *88*(12), 2043–2049. https://doi.org/10.1002/jsfa.3337

Nisar, M., Chatli, M. K., & Sharma, D. K. (2009). Efficacy of Tapioca Starch As a Fat Replacer in Low-fat Buffalo Meat Patties. *Buffalo Bulletin*, *28*(1), 18.

Nuwamanya, E., Chiwona-Karltun, L., Kawuki, R. S., & Baguma, Y. (2012). Bio-ethanol production from non-food parts of cassava(Manihot esculenta Crantz). *AMBIO*, *41*(3), 262–270. https://doi.org/10.1007/s13280-011-0183-z

Nwaobiala, C. U. (2018). Farmers' adoption of cassava agronomic practices and intercrop technologies in Abia and Imo States, Nigeria. *Journal of Agricultural Extension*, *22*(2). https://doi.org/10.4314/jae.v22i2.8

Oda, Y., Namba, S., Yoshitake, H., & Tatsumi, T. (2002). Mesoporous carbon structure directed by mesostructured cellular foam silica. *Electrochemistry*, *70*(12), 953–955. https://doi.org/10.5796/electrochemistry.70.953

Odedina, J., Ojeniyi, S., & Odedina, S. (2012). Integrated nutrient management for sustainable cassava production in South Western Nigeria. *Archives of Agronomy and Soil Science*, *58*(sup1), S132–S140. https://doi.org/10.1080/03650340.2012.695865

Ofman, M. H., Campos, C. A., & Gerschenson, L. N. (2004). Effect of preservatives on the functional properties of tapioca starch: Analysis of interactions. *LWT - Food Science and Technology*, *37*(3), 355–361. https://doi.org/10.1016/j.lwt.2003.09.010

Ofori, C. S. (1973). Decline in fertility status of a tropical forest ochrosol under continuous cropping. *Experimental Agriculture*, *9*(1), 15–22. https://doi.org/10.1017/S0014479700023620

Ogata, F., Nagai, N., Ueta, E., Nakamura, T., & Kawasaki, N. (2018). Biomass potential of virgin and calcined tapioca (Cassava starch) for the removal of sr(Ii) and cs(I) from aqueous solutions. *Chemical and Pharmaceutical Bulletin*, *66*(3), 295–302. https://doi.org/10.1248/cpb.c17-00873

Oguntoyinbo, F. A., & Dodd, C. E. R. (2010). Bacterial dynamics during the spontaneous fermentation of cassava dough in gari production. *Food Control*, *21*(3), 306–312. https://doi.org/10.1016/j.foodcont.2009.06.010

Oh, H. E., Pinder, D. N., Hemar, Y., Anema, S. G., & Wong, M. (2008). Effect of high-pressure treatment on various starch-in-water suspensions. *Food Hydrocolloids*, *22*(1), 150–155. https://doi.org/10.1016/j.foodhyd.2007.01.028

Okogbenin, E., Setter, T. L., Ferguson, M., Mutegi, R., Ceballos, H., Olasanmi, B., & Fregene, M. (2013). Phenotypic approaches to drought in cassava: Review. *Frontiers in Physiology*, *4*. https://doi.org/10.3389/fphys.2013.00093

Okoli, I. C., Okparaocha, C. O., Chinweze, C. E., & Udedibie, A. B. I. (2012). Physicochemical and hydrogen cyanide content of three processed cassava products used for feeding poultry in nigeria. *Asian Journal of Animal and Veterinary Advances*, *7*(4), 334–340. https://doi.org/10.3923/ajava.2012.334.340

Olasantan, F. O. (2005). Cassava cultivation management for sustainable vegetable production in intercropping with okra. *Journal of Sustainable Agriculture*, *27*(2), 53–68. https://doi.org/10.1300/J064v27n02_05

Olasantan, F. O., Ezumah, H. C., & Lucas, E. O. (1996b). Effects of intercropping with maize on the micro-environment, growth and yield of cassava. *Agriculture, Ecosystems & Environment*, *57*(2–3), 149–158. https://doi.org/10.1016/0167-8809(96)01019-5

Olasantan, F. O., Ezumah, H. C., & Lucas, E. O. (1996a). Response of cassava and maize to fertilizer application, and a comparison of the factors affecting their growth during intercropping. *Nutrient Cycling in Agroecosystems*, *46*(3), 215–223. https://doi.org/10.1007/BF00420556

Oliveira, E. J. de, Morgante, C. V., de Tarso Aidar, S., de Melo Chaves, A. R., Antonio, R. P., Cruz, J. L., & Filho, M. A. C. (2017). Evaluation of cassava germplasm for drought tolerance under field conditions. *Euphytica*, *213*(8), 188. https://doi.org/10.1007/s10681-017-1972-7

Olszewska-Widdrat, A., Alexandri, M., López-Gómez, J. P., Schneider, R., & Venus, J. (2020). Batch and continuous lactic acid fermentation based on a multi-substrate approach. *Microorganisms*, *8*(7), 1084. https://doi.org/10.3390/microorganisms8071084

Oluwole, O. S. A. (2000). Persistence of tropical ataxic neuropathy in a Nigerian community. *Journal of Neurology, Neurosurgery & Psychiatry*, *69*(1), 96–101. https://doi.org/10.1136/jnnp.69.1.96

Oluwole, O. S. A. (2008). Cyanogenicity of cassava varieties and risk of exposure to cyanide from cassava food in Nigerian communities. *Journal of the Science of Food and Agriculture*, *88*(6), 962–969. https://doi.org/10.1002/jsfa.3174

Ordoñez, M., & Herrera, A. (2014). Morphologic and stability cassava starch matrices for encapsulating limonene by spray drying. *Powder Technology*, *253*, 89–97. https://doi.org/10.1016/j.powtec.2013.11.005

Orek, C., Gruissem, W., Ferguson, M., & Vanderschuren, H. (2020). Morpho-physiological and molecular evaluation of drought tolerance in cassava (Manihot esculenta Crantz). *Field Crops Research*, *255*, 107861. https://doi.org/10.1016/j.fcr.2020.107861

Osonubi, O., Atayese, M. O., & Mulongoy, K. (1995). The effect of vesicular-arbuscular mycorrhizal inoculation on nutrient uptake and yield of alley-cropped cassava in a degraded Alfisol of southwestern Nigeria. *Biology and Fertility of Soils*, *20*(1), 70–76. https://doi.org/10.1007/BF00307844

Othman, S. H., Majid, N. A., Tawakkal, I. S. M. A., Basha, R. K., Nordin, N., & Shapi'I, R. A. (2019). Tapioca starch films reinforced with microcrystalline cellulose for potential food packaging application. *Food Science and Technology*, *39*(3), 605–612. https://doi.org/10.1590/fst.36017

Owi, W. T., Lin, O. H., Sam, S. T., Mern, C. K., Villagracia, A. R., Santos, G. N. C., & Akil, H. M. (2017). *A comparative study of green composites based on tapioca starch and celluloses*. 040019. https://doi.org/10.1063/1.4993361

Padalino, L., Mastromatteo, M., De Vita, P., Maria Ficco, D. B., & Del Nobile, M. A. (2013). Effects of hydrocolloids on chemical properties and cooking quality of gluten-free spaghetti. *International Journal of Food Science & Technology*, *48*(5), 972–983. https://doi.org/10.1111/ijfs.12049

Padmaja, G., George, M., & Moorthy, S. N. (1993). Detoxification of cassava during fermentation with a mixed culture inoculum. *Journal of the Science of Food and Agriculture*, *63*(4), 473–481. https://doi.org/10.1002/jsfa.2740630415

Pandia, S., Tanata, S., Rachel, M., Octiva, C., & Sialagan, N. (2018). Effect of fermentation time of mixture of solid and liquid wastes from tapioca industry to percentage reduction of TSS (Total suspended solids). *IOP Conference Series: Materials Science and Engineering*, *309*, 012086. https://doi.org/10.1088/1757-899X/309/1/012086

Panghal, A., Munezero, C., Sharma, P., & Chhikara, N. (2021). Cassava toxicity, detoxification and its food applications: A review. *Toxin Reviews*, *40*(1), 1–16. https://doi.org/10.1080/15569543.2018.1560334

Pardales Jr., J. R., & Esquisel, C. B. (1996). Effect of drought during the establishment period on the root system development of cassava. *Japanese Journal of Crop Science*, *65*(1), 93–97. https://doi.org/10.1626/jcs.65.93

Park, B. K., Lee, D. K., Ahn, J. S., Park, J. K., Kim, M. J., Son, G. H., & Shin, J. S. (2019). Effects of dietary levels of tapioca residue on growth performance and carcass characteristics in Hanwoo steers. *Asian-Australasian Journal of Animal Sciences*, *32*(8), 1128–1136. https://doi.org/10.5713/ajas.18.0753

Parmar, A., Fikre, A., Sturm, B., & Hensel, O. (2018). Post-harvest management and associated food losses and by-products of cassava in southern Ethiopia. *Food Security*, *10*(2), 419–435. https://doi.org/10.1007/s12571-018-0774-7

Parmar, A., Sturm, B., & Hensel, O. (2017). Crops that feed the world: Production and improvement of cassava for food, feed, and industrial uses. *Food Security*, *9*(5), 907–927. https://doi.org/10.1007/s12571-017-0717-8

Patel, J. R., Patel, A. A., & Singh, A. K. (2016). Production of a protein-rich extruded snack base using tapioca starch, sorghum flour and casein. *Journal of Food Science and Technology*, *53*(1), 71–87. https://doi.org/10.1007/s13197-015-2012-z

Patil, B. L., Legg, J. P., Kanju, E., & Fauquet, C. M. (2015). Cassava brown streak disease: A threat to food security in Africa. *Journal of General Virology*, *96*(5), 956–968. https://doi.org/10.1099/jgv.0.000014

Pei, Y. L., Chun Chen, T., Yu Lin, F., Yau Doong, J., Lee Chen, W., Kamoshita, S., Kartiko Sari, I., Takeichi, H., & Yamamoto, S. (2018). The effect of limiting tapioca milk tea on added sugar consumption in taiwanese young male and female subjects. *The Journal of Medical Investigation*, *65*(1.2), 43–49. https://doi.org/10.2152/jmi.65.43

Perera, C. O. (2009). Removal of cyanogenic glycoside from cassava during controlled drying. *Drying Technology*, *28*(1), 68–72. https://doi.org/10.1080/07373930903430710

Pérez, P. F., Ollé Resa, C. P., Gerschenson, L. N., & Jagus, R. J. (2021). Addition of zein for the improvement of physicochemical properties of antimicrobial tapioca starch edible film. *Food and Bioprocess Technology*, *14*(2), 262–271. https://doi.org/10.1007/s11947-020-02565-z

Phengvichith, V., & Ledin, I. (2007). Effects of supplementing gamba grass (Andropogon gayanus) with cassava (Manihot esculenta Crantz) hay and cassava root chips on feed intake, digestibility and growth in goats. *Asian-Australasian Journal of Animal Sciences*, *20*(5), 725–732. https://doi.org/10.5713/ajas.2007.725

Pickering, S. U. (1907). Cxcvi. —Emulsions. *J. Chem. Soc., Trans.*, *91*(0), 2001–2021. https://doi.org/10.1039/CT9079102001

Pitigraisorn, P., Srichaisupakit, K., Wongpadungkiat, N., & Wongsasulak, S. (2017). Encapsulation of Lactobacillus acidophilus in moist-heat-resistant multilayered microcapsules. *Journal of Food Engineering*, *192*, 11–18. https://doi.org/10.1016/j.jfoodeng.2016.07.022

Polthanee, A. (2018). Cassava as an insurance crop in a changing climate: The changing role and potential applications of cassava for smallholder farmers in Northeastern Thailand. *Forest and Society*, *2*(2), 121. https://doi.org/10.24259/fs.v2i2.4275

Polyorach, S., & Wanapat, M. (2013). Enrichment of protein content in cassava (Manihot esculenta Crantz) bysupplementing with yeast for use as animal feed. *Emirates Journal of Food and Agriculture*, *25*(2), 142. https://doi.org/10.9755/ejfa.v25i2.10649

Pongsawatmanit, R., & Srijunthongsiri, S. (2008). Influence of xanthan gum on rheological properties and freeze–thaw stability of tapioca starch. *Journal of Food Engineering*, *88*(1), 137–143. https://doi.org/10.1016/j.jfoodeng.2008.02.009

Pongsawatmanit, R., Temsiripong, T., Ikeda, S., & Nishinari, K. (2006). Influence of tamarind seed xyloglucan on rheological properties and thermal stability of tapioca starch. *Journal of Food Engineering*, *77*(1), 41–50. https://doi.org/10.1016/j.jfoodeng.2005.06.017

Pongsawatmanit, R., Temsiripong, T., & Suwonsichon, T. (2007). Thermal and rheological properties of tapioca starch and xyloglucan mixtures in the presence of sucrose. *Food Research International*, *40*(2), 239–248. https://doi.org/10.1016/j.foodres.2006.10.013

Prazeres, I. C. dos, Carvalho, A. V., Domingues, A. F. N., & Abreu, L. F. (2020). Preparing multicomponent snack bars based on tapioca flour, Brazil nut, and regional fruits. *Revista Chilena de Nutrición*, *47*(2), 190–199. https://doi.org/10.4067/S0717-75182020000200190

Promkot, C., Nitipot, P., Piamphon, N., Abdullah, N., & Promkot, A. (2017). Cassava root fermented with yeast improved feed digestibility in Brahman beef cattle. *Animal Production Science*, *57*(8), 1613. https://doi.org/10.1071/AN15685

Prudencio, Y. C., & Al-Hassan, R. (1994). The food security stabilization roles of cassava in Africa. *Food Policy*, *19*(1), 57–64. https://doi.org/10.1016/0306-9192(94)90008-6

Purcell, S., Wang, Y.-J., & Seo, H.-S. (2014). Application of oxidized starch in bake-only chicken nuggets: Bake-only chicken nuggets …. *Journal of Food Science*, *79*(5), C810–C815. https://doi.org/10.1111/1750-3841.12466

Putthacharoen, S., Howeler, R. H., Jantawat, S., & Vichukit, V. (1998). Nutrient uptake and soil erosion losses in cassava and six other crops in a Psamment in eastern Thailand. *Field Crops Research*, *57*(1), 113–126. https://doi.org/10.1016/S0378-4290(97)00119-6

Qin, Y., Liu, C., Jiang, S., Xiong, L., & Sun, Q. (2016). Characterization of starch nanoparticles prepared by nanoprecipitation: Influence of amylose content and starch type. *Industrial Crops and Products*, *87*, 182–190. https://doi.org/10.1016/j.indcrop.2016.04.038

Rahim, S. N. A., Sulaiman, A., Hamzah, F., Hamid, K. H. K., Rodhi, M. N. M., Musa, M., & Edama, N. A. (2013). Enzymes encapsulation within calcium alginate-clay beads: Characterization and application for cassava slurry saccharification. *Procedia Engineering*, *68*, 411–417. https://doi.org/10.1016/j.proeng.2013.12.200

Ramasami, A. K., Raja Naika, H., Nagabhushana, H., Ramakrishnappa, T., Balakrishna, G. R., & Nagaraju, G. (2015). Tapioca starch: An efficient fuel in gel-combustion synthesis of photocatalytically and anti-microbially active ZnO nanoparticles. *Materials Characterization*, *99*, 266–276. https://doi.org/10.1016/j.matchar.2014.11.017

Ratnayake, W. S., & Jackson, D. S. (2007). A new insight into the gelatinization process of native starches. *Carbohydrate Polymers*, *67*(4), 511–529. https://doi.org/10.1016/j.carbpol.2006.06.025

Ravindran, V. (1993). Cassava leaves as animal feed: Potential and limitations. *Journal of the Science of Food and Agriculture*, *61*(2), 141–150. https://doi.org/10.1002/jsfa.2740610202

Ravishankar, S., Zhang, H., & Kempkes, M. L. (2008). Pulsed electric fields. *Food Science and Technology International*, *14*(5), 429–432. https://doi.org/10.1177/1082013208100535

Reincke, K., Vilvert, E., Fasse, A., Graef, F., Sieber, S., & Lana, M. A. (2018). Key factors influencing food security of smallholder farmers in Tanzania and the role of cassava as a strategic crop. *Food Security*, *10*(4), 911–924. https://doi.org/10.1007/s12571-018-0814-3

Ren, F., & Wang, S. (2019). Effect of modified tapioca starches on the gelling properties of whey protein isolate. *Food Hydrocolloids*, *93*, 87–91. https://doi.org/10.1016/j.foodhyd.2019.02.025

Resa, C. P. O., Jagus, R. J., & Gerschenson, L. N. (2014). Effect of natamycin, nisin and glycerol on the physicochemical properties, roughness and hydrophobicity of tapioca starch edible films. *Materials Science and Engineering: C*, *40*, 281–287. https://doi.org/10.1016/j.msec.2014.04.005

Rodriguez-Sandoval, E., Cortes-Rodriguez, M., & Manjarres-Pinzon, K. (2015). Effect of hydrocolloids on the pasting profiles of tapioca starch mixtures and the baking properties of gluten-free cheese bread: Hydrocolloids on gluten-free cheese bread. *Journal of Food Processing and Preservation*, *39*(6), 1672–1681. https://doi.org/10.1111/jfpp.12398

Rohman, S., Kaewtatip, K., Kantachote, D., & Tantirungkij, M. (2021). Encapsulation of *Rhodopseudomonas palustris* KTSSR54 using beads from alginate/starch blends. *Journal of Applied Polymer Science*, *138*(12), 50084. https://doi.org/10.1002/app.50084

Ruksakulpiwat, Y., & Ruksakulpiwat, C. (2016). The modification of tapioca starch by esterification techniques. *SURANAREE JOURNAL OF SCIENCE AND TECHNOLOGY*, *23*(2), 157–165.

Rusike, J., Mahungu, N. M., Jumbo, S., Sandifolo, V. S., & Malindi, G. (2010). Estimating impact of cassava research for development approach on productivity, uptake and food security in Malawi. *Food Policy*, *35*(2), 98–111. https://doi.org/10.1016/j.foodpol.2009.10.004

Sacks, F. M., Lichtenstein, A. H., Wu, J. H. Y., Appel, L. J., Creager, M. A., Kris-Etherton, P. M., Miller, M., Rimm, E. B., Rudel, L. L., Robinson, J. G., Stone, N. J., & Van Horn, L. V. (2017). Dietary fats and cardiovascular disease: A presidential advisory from the american heart association. *Circulation*, *136*(3). https://doi.org/10.1161/CIR.0000000000000510

Saediman, H., Aisa, S., Zani, M., Limi, M. A., & Yusria, W. O. (2019). Food security status of households in a cassava-growing village in southeast sulawesi, indonesia. *Journal of Agricultural Extension*, *23*(1), 199. https://doi.org/10.4314/jae.v23i1.17

Sae-kang, V., & Suphantharika, M. (2006). Influence of pH and xanthan gum addition on freeze-thaw stability of tapioca starch pastes. *Carbohydrate Polymers*, *65*(3), 371–380. https://doi.org/10.1016/j.carbpol.2006.01.029

Said, N. S., Howell, N. K., & Sarbon, N. M. (2021). A review on potential use of gelatin-based film as active and smart biodegradable films for food packaging application. *Food Reviews International*, 1–23. https://doi.org/10.1080/87559129.2021.1929298

Saka, J., Mhone, A., Mkambira, J., Brimer, L., Bokanga, M., Mahungu, N., Chiwona-Karltun, L., & Rosling, H. (1998). Correlation between cyanogenic glucoside content and taste of fresh cassava roots. *Tropical Agriculture*, *75*(1–2), 169–173.

Sallenave, R., & Fomin, A. (1997). Some advantages of the duckweed test to assess the toxicity of environmental samples. *Acta Hydrochimica et Hydrobiologica*, *25*(3), 135–140. https://doi.org/10.1002/aheh.19970250304

Sandoval-Castilla, O., Lobato-Calleros, C., Aguirre-Mandujano, E., & Vernon-Carter, E. J. (2004). Microstructure and texture of yogurt as influenced by fat replacers. *International Dairy Journal*, *14*(2), 151–159. https://doi.org/10.1016/S0958-6946(03)00166-3

Sanglard, P., Adamo, V., Bourgeois, J.-P., Chappuis, T., & Vanoli, E. (2012). Poly(Lactic acid) synthesis and characterization. *CHIMIA International Journal for Chemistry*, *66*(12), 951–954. https://doi.org/10.2533/chimia.2012.951

Sanjurjo, K., Flores, S., Gerschenson, L., & Jagus, R. (2006). Study of the performance of nisin supported in edible films. *Food Research International*, *39*(6), 749–754. https://doi.org/10.1016/j.foodres.2006.01.016

Santacruz, S., & Castro, M. (2018). Viability of free and encapsulated Lactobacillus acidophilus incorporated to cassava starch edible films and its application to Manaba fresh white cheese. *LWT*, *93*, 570–572. https://doi.org/10.1016/j.lwt.2018.04.016

Santos, A., Veiga, F., & Figueiras, A. (2019). Dendrimers as pharmaceutical excipients: Synthesis, properties, toxicity and biomedical applications. *Materials*, *13*(1), 65. https://doi.org/10.3390/ma13010065

Schmitz, C. S., de Simas, K. N., Santos, K., Joao, J. J., de Mello Castanho Amboni, R. D., & Amante, E. R. (2006). Cassava starch functional properties by etherification—Hydroxypropylation. *International Journal of Food Science and Technology*, *41*(6), 681–687. https://doi.org/10.1111/j.1365-2621.2005.01136.x

Seetapan, N., Fuongfuchat, A., Gamonpilas, C., Methacanon, P., Pongjaruwat, W., & Limparyoon, N. (2013). Effect of modified tapioca starch and xanthan gum on low temperature texture stability and dough viscoelasticity of a starch-based food gel. *Journal of Food Engineering*, *119*(3), 446–453. https://doi.org/10.1016/j.jfoodeng.2013.06.010

Sezi, C. L. (1996). Effect of protein deficient cassava diet on Cercopithecus aethiops hearts and its possible role in the aetiology and pathogenesis of endomyocardial fibrosis in man. *East Afr Med J .* https://pubmed.ncbi.nlm.nih.gov/8756020/

Shan, Z., Luo, X., Wei, M., Huang, T., Khan, A., & Zhu, Y. (2018). Physiological and proteomic analysis on long-term drought resistance of cassava (Manihot esculenta Crantz). *Scientific Reports*, *8*(1), 17982. https://doi.org/10.1038/s41598-018-35711-x

Shariffa, Y. N., Karim, A. A., Fazilah, A., & Zaidul, I. S. M. (2009). Enzymatic hydrolysis of granular native and mildly heat-treated tapioca and sweet potato starches at sub-gelatinization temperature. *Food Hydrocolloids*, *23*(2), 434–440. https://doi.org/10.1016/j.foodhyd.2008.03.009

Sigüenza-Andrés, T., Gallego, C., & Gómez, M. (2021). Can cassava improve the quality of gluten free breads? *LWT*, *149*, 111923. https://doi.org/10.1016/j.lwt.2021.111923

Silva, M. C. A. da, Leite, J. S. F., Barreto, B. G., Neves, M. V. dos A., Silva, A. S., Viveiros, K. M. de, Passos, R. S. F. T., Costa, N. P., Silva, R. V. da, & Cavalheiro, C. P. (2021). The impact of innovative gluten-free coatings on the physicochemical, microbiological, and sensory characteristics of fish nuggets. *LWT*, *137*, 110409. https://doi.org/10.1016/j.lwt.2020.110409

Silva, P. de A., de Carvalho, G. G. P., Pires, A. J. V., Santos, S. A., dos Santos Pina, D., Silva, R. R., Rodrigues, C. S., de Matos, L. H. A., Eiras, C. E., Novais-Eiras, D., & Nunes, W. S. (2018). Feeding behavior of feedlot lambs fed diets containing levels of cassava wastewater. *Tropical Animal Health and Production*, *50*(4), 721–726. https://doi.org/10.1007/s11250-017-1487-1

Singh, A., Geveke, D. J., & Yadav, M. P. (2017). Improvement of rheological, thermal and functional properties of tapioca starch by using gum arabic. *LWT*, *80*, 155–162. https://doi.org/10.1016/j.lwt.2016.07.059

Sipahioglu, O., Alvarez, V. B., & Solano-Lopez, C. (1999). Structure, physico-chemical and sensory properties of feta cheese made with tapioca starch and lecithin as fat mimetics. *International Dairy Journal*, *9*(11), 783–789. https://doi.org/10.1016/S0958-6946(99)00150-8

Siritunga, D., & Sayre, R. (2004). Engineering cyanogen synthesis and turnover in cassava (Manihot esculenta). *Plant Molecular Biology*, *56*(4), 661–669. https://doi.org/10.1007/s11103-004-3415-9

Sivakumar, R., Elayaperumal, A., & Saravanan, R. (2017). Drying and energy aspects of tapioca sago processing-an experimental field study. *Journal of Mechanical Science and Technology*, *31*(6), 3035–3042. https://doi.org/10.1007/s12206-017-0547-9

Slaughter, S. L., Ellis, P. R., & Butterworth, P. J. (2001). An investigation of the action of porcine pancreatic α-amylase on native and gelatinised starches. *Biochimica et Biophysica Acta (BBA) - General Subjects*, *1525*(1–2), 29–36. https://doi.org/10.1016/S0304-4165(00)00162-8

Soccol, C. R., Marin, B., Raimbault, M., & Lebeault, J.-M. (1994). Breeding and growth of Rhizopus in raw cassava by solid state fermentation. *Applied Microbiology and Biotechnology*, *41*(3), 330–336. https://doi.org/10.1007/BF00221228

Sommai, S., Ampapon, T., Mapato, C., Totakul, P., Viennasay, B., Matra, M., & Wanapat, M. (2020). Replacing soybean meal with yeast-fermented cassava pulp (Yfcp) on feed intake, nutrient digestibilities, rumen microorganism, fermentation, and N-balance in Thai native beef cattle. *Tropical Animal Health and Production*, *52*(4), 2035–2041. https://doi.org/10.1007/s11250-020-02228-3

Sommart, K., Wanapat, M., Rowlinson, P., Parker, D. S., Climee, P., & Panishying, S. (2000). The use of cassava chips as an energy source for lactating dairy cows fed with rice straw. *Asian-Australasian Journal of Animal Sciences*, *13*(8), 1094–1101. https://doi.org/10.5713/ajas.2000.1094

Song, M., Choi, S., Kim, H., Kim, B., & Baik, M. (2015). Efficiency of high hydrostatic pressure in preparing amorphous granular starches. *Starch - Stärke*, *67*(9–10), 790–801. https://doi.org/10.1002/star.201500002

Song, M.-R., Choi, S.-H., Oh, S.-M., Kim, H., Bae, J.-E., Park, C.-S., Kim, B.-Y., & Baik, M.-Y. (2017). Characterization of amorphous granular starches prepared by high hydrostatic pressure (Hhp). *Food Science and Biotechnology*, *26*(3), 671–678. https://doi.org/10.1007/s10068-017-0106-2

Soraya, N. W., El Hadi, R. M., Chumaidiyah, E., & Tripiawan, W. (2017). Feasibility study analysis for multi-function dual energy oven (Case study: Tapioca crackers small medium enterprise). *IOP Conference Series: Materials Science and Engineering*, *277*, 012075. https://doi.org/10.1088/1757-899X/277/1/012075

Stredansky, M., & Conti, E. (1999). Xanthan production by solid state fermentation. *Process Biochemistry*, *34*(6–7), 581–587. https://doi.org/10.1016/S0032-9592(98)00131-9

Sugih, A. K., Santoso, I. V., & Kristijarti, A. P. (2015). *Effect of tapioca starch and amyloglucosidase concentration on very high gravity simultaneous saccharification and fermentation (Vhg-ssf) of bioethanol*. 030008. https://doi.org/10.1063/1.4938293

Sun, J., Zhao, R., Zeng, J., Li, G., & Li, X. (2010). Characterization of destrins with different dextrose equivalents. *Molecules*, *15*(8), 5162–5173. https://doi.org/10.3390/molecules15085162

Takeda, Y., Shirasaka, K., & Hizukuri, S. (1984). Examination of the purity and structure of amylose by gel-permeation chromatography. *Carbohydrate Research*, *132*(1), 83–92. https://doi.org/10.1016/0008-6215(84)85066-1

Tamimi, N., Mohammadi Nafchi, A., Hashemi‐Moghaddam, H., & Baghaie, H. (2021). The effects of nano‐zinc oxide morphology on functional and antibacterial properties of tapioca starch bionanocomposite. *Food Science & Nutrition*, *9*(8), 4497–4508. https://doi.org/10.1002/fsn3.2426

Tang, M. C., & Copeland, L. (2007). Investigation of starch retrogradation using atomic force microscopy. *Carbohydrate Polymers*, *70*(1), 1–7. https://doi.org/10.1016/j.carbpol.2007.02.025

Tawali, A. B., Wakiah, N., Ramli, A. R., Mahendradatta, M., Tawali, S., & Made, S. (2018). Premix formulation for making the Indonesian otak-otak. *IOP Conference Series: Earth and Environmental Science*, *157*, 012033. https://doi.org/10.1088/1755-1315/157/1/012033

Temsiripong, T., Pongsawatmanit, R., Ikeda, S., & Nishinari, K. (2005). Influence of xyloglucan on gelatinization and retrogradation of tapioca starch. *Food Hydrocolloids*, *19*(6), 1054–1063. https://doi.org/10.1016/j.foodhyd.2005.02.005

Tester, R. F., Qi, X., & Karkalas, J. (2006). Hydrolysis of native starches with amylases. *Animal Feed Science and Technology*, *130*(1–2), 39–54. https://doi.org/10.1016/j.anifeedsci.2006.01.016

Thang, C. M., Ledin, I., & Bertilsson, J. (2010). Effect of feeding cassava and/or Stylosanthes foliage on the performance of crossbred growing cattle. *Tropical Animal Health and Production*, *42*(1), 1–11. https://doi.org/10.1007/s11250-009-9378-8

Thirathumthavorn, D., & Charoenrein, S. (2007). Aging effects on sorbitol- and non-crystallizing sorbitol-plasticized tapioca starch films. *Starch - Stärke*, *59*(10), 493–497. https://doi.org/10.1002/star.200700626

Thirumdas, R., Kadam, D., & Annapure, U. S. (2017). Cold plasma: An alternative technology for the starch modification. *Food Biophysics*, *12*(1), 129–139. https://doi.org/10.1007/s11483-017-9468-5

Tonon, R. V., Brabet, C., Pallet, D., Brat, P., & Hubinger, M. D. (2009). Physicochemical and morphological characterisation of açai (*euterpe oleraceae* mart.) powder produced with different carrier agents. *International Journal of Food Science & Technology*, *44*(10), 1950–1958. https://doi.org/10.1111/j.1365-2621.2009.02012.x

Toraya-Avilés, R., Segura-Campos, M., Chel-Guerrero, L., & Betancur-Ancona, D. (2016). Effects of pyroconversion and enzymatic hydrolysis on indigestible starch content and physicochemical properties of cassava (*manihot esculenta*) starch: Pyroconversion and enzymatic hydrolysis of cassava s(*manihot esculenta*)tarch. *Starch - Stärke*, *69*(5–6), 1600267. https://doi.org/10.1002/star.201600267

Toraya-Avilés, R., Segura-Campos, M., Chel-Guerrero, L., & Betancur-Ancona, D. (2017). Some nutritional characteristics of enzymatically resistant maltodextrin from cassava (Manihot esculenta Crantz) starch. *Plant Foods for Human Nutrition*, *72*(2), 149–155. https://doi.org/10.1007/s11130-017-0599-0

Trakarnpaiboon, S., Srisuk, N., Piyachomkwan, K., Yang, S.-T., & Kitpreechavanich, V. (2017). L-lactic acid production from liquefied cassava starch by thermotolerant rhizopus microsporus: Characterization and optimization. *Process Biochemistry*, *63*, 26–34. https://doi.org/10.1016/j.procbio.2017.08.019

Tripathi, M. K., & Giri, S. K. (2014). Probiotic functional foods: Survival of probiotics during processing and storage. *Journal of Functional Foods*, *9*, 225–241. https://doi.org/10.1016/j.jff.2014.04.030

Triyono, A., Erwan Andriansyah, R. C., Luthfiyanti, R., & Rahman, T. (2017a). Development of modified starch technology (*maltodextrin*) from commercial tapioca on semi production scale using oil heater dextrinator. *IOP Conference Series: Earth and Environmental Science*, *101*, 012026. https://doi.org/10.1088/1755-1315/101/1/012026

Triyono, A., Erwan Andriansyah, R. C., Luthfiyanti, R., & Rahman, T. (2017b). Development of modified starch technology (*maltodextrin*) from commercial tapioca on semi production scale using oil heater dextrinator. *IOP Conference*

Series: Earth and Environmental Science, *101*, 012026. https://doi.org/10.1088/1755-1315/101/1/012026

Troy, D. J., Desmond, E. M., & Buckley, D. J. (1999). Eating quality of low-fat beef burgers containing fat-replacing functional blends. *Journal of the Science of Food and Agriculture*, *79*(4), 507–516. https://doi.org/10.1002/(SICI)1097-0010(19990315)79:4<507::AID-JSFA209>3.0.CO;2-6

Tsou, C.-H., Suen, M.-C., Yao, W.-H., Yeh, J.-T., Wu, C.-S., Tsou, C.-Y., Chiu, S.-H., Chen, J.-C., Wang, R., Lin, S.-M., Hung, W.-S., De Guzman, M., Hu, C.-C., & Lee, K.-R. (2014). Preparation and characterization of bioplastic-based green renewable composites from tapioca with acetyl tributyl citrate as a plasticizer. *Materials*, *7*(8), 5617–5632. https://doi.org/10.3390/ma7085617

Tukomane, T., Leerapongnun, P., Shobsngob, S., & Varavinit, S. (2007). Preparation and characterization of annealed-enzymatically hydrolyzed tapioca starch and the utilization in tableting. *Starch - Stärke*, *59*(1), 33–45. https://doi.org/10.1002/star.200600524

Tunnarut, D., & Pongsawatmanit, R. (2017). Quality enhancement of tapioca starch gel using sucrose and xanthan gum. *International Journal of Food Engineering*, *13*(8). https://doi.org/10.1515/ijfe-2017-0009

Turyagyenda, L. F., Kizito, E. B., Ferguson, M., Baguma, Y., Agaba, M., Harvey, J. J. W., & Osiru, D. S. O. (2013). Physiological and molecular characterization of drought responses and identification of candidate tolerance genes in cassava. *AoB Plants*, *5*(0), plt007–plt007. https://doi.org/10.1093/aobpla/plt007

Uhumwangho, M., & Okor, R. (2004). Anomalous effect of compression pressure on the brittle fracture tendency of ?-cellulose tablets. *International Journal of Pharmaceutics*, *284*(1–2), 69–74. https://doi.org/10.1016/j.ijpharm.2004.07.002

Umar, S., Kamarudin, M. S., & Ramezani-Fard, E. (2013). Physical properties of extruded aquafeed with a combination of sago and tapioca starches at different moisture contents. *Animal Feed Science and Technology*, *183*(1–2), 51–55. https://doi.org/10.1016/j.anifeedsci.2013.03.009

Umeh, S. I., & Mbah, B. N. (2010). Measuring the benefits of biological nitrogen fixation of soybean (Glycine max (l.) Merrill) in cassava (Manihot esculenta crantz) and soybean intercrop. *African Journal of Agricultural Research* , *5*(24), 3354–3359.

Utsumi, Y., Utsumi, C., Tanaka, M., Ha, C. V., Takahashi, S., Matsui, A., Matsunaga, T. M., Matsunaga, S., Kanno, Y., Seo, M., Okamoto, Y., Moriya, E., & Seki, M. (2019). Acetic acid treatment enhances drought avoidance in cassava(Manihot esculenta Crantz). *Frontiers in Plant Science*, *10*, 521. https://doi.org/10.3389/fpls.2019.00521

Uzokwe, V. N. E., Mlay, D. P., Masunga, H. R., Kanju, E., Odeh, I. O. A., & Onyeka, J. (2016). Combating viral mosaic disease of cassava in the Lake Zone of Tanzania by intercropping with legumes. *Crop Protection*, *84*, 69–80. https://doi.org/10.1016/j.cropro.2016.02.013

Van den Eynde, M., & Van Puyvelde, P. (2017). 3d printing of poly(Lactic acid). In M. L. Di Lorenzo & R. Androsch (Eds.), *Industrial Applications of Poly(lactic acid)* (Vol. 282, pp. 139–158). Springer International Publishing. https://doi.org/10.1007/12_2017_28

Vandegeer, R., Miller, R. E., Bain, M., Gleadow, R. M., & Cavagnaro, T. R. (2013). Drought adversely affects tuber development and nutritional quality of the staple crop cassava (Manihot esculenta Crantz). *Functional Plant Biology*, *40*(2), 195. https://doi.org/10.1071/FP12179

Varavinit, S., Anuntavuttikul, S., & Shobsngob, S. (2000). Influence of Freezing and Thawing Techniques on Stability of Sago and Tapioca Starch Pastes. *Starch/Stärke*, *52*, 214–217.

Varga-Visi, É., & Toxanbayeva, B. (2017). Application of fat replacers and their effect on quality of comminuted meat products with low lipid content: A review. *Acta Alimentaria*, *46*(2), 181–186. https://doi.org/10.1556/066.2016.0008

Vásconez, M. B., Flores, S. K., Campos, C. A., Alvarado, J., & Gerschenson, L. N. (2009). Antimicrobial activity and physical properties of chitosan–tapioca starch based edible films and coatings. *Food Research International*, *42*(7), 762–769. https://doi.org/10.1016/j.foodres.2009.02.026

Villanueva, M., Pérez-Quirce, S., Collar, C., & Ronda, F. (2018). Impact of acidification and protein fortification on rheological and thermal properties of wheat, corn, potato and tapioca starch-based gluten-free bread doughs. *LWT*, *96*, 446–454. https://doi.org/10.1016/j.lwt.2018.05.069

Villanueva, M., Ronda, F., Moschakis, T., Lazaridou, A., & Biliaderis, C. G. (2018). Impact of acidification and protein fortification on thermal properties of rice, potato and tapioca starches and rheological behaviour of their gels. *Food Hydrocolloids*, *79*, 20–29. https://doi.org/10.1016/j.foodhyd.2017.12.022

Violalita, F., Evawati, Syahrul, S., Yanti, H. F., & Fahmy, K. (2020). Characteristics of gluten-free wet noodles substituted with soy flour. *IOP Conference Series: Earth and Environmental Science*, *515*, 012047. https://doi.org/10.1088/1755-1315/515/1/012047

Visses, F. de A., Sentelhas, P. C., & Pereira, A. B. (2018). Yield gap of cassava crop as a measure of food security—An example for the main Brazilian producing regions. *Food Security*, *10*(5), 1191–1202. https://doi.org/10.1007/s12571-018-0831-2

Vittadini, E., Carini, E., Chiavaro, E., Rovere, P., & Barbanti, D. (2008). High pressure-induced tapioca starch gels: Physico-chemical characterization and stability. *European Food Research and Technology*, *226*(4), 889–896. https://doi.org/10.1007/s00217-007-0611-2

Wanapat, M. (2003). Manipulation of cassava cultivation and utilization to improve protein to energy biomass for livestock feeding in the tropics. *Asian-Australasian Journal of Animal Sciences*, *16*(3), 463–472. https://doi.org/10.5713/ajas.2003.463

Wanapat, M. (2009). Potential uses of local feed resources for ruminants. *Tropical Animal Health and Production*, *41*(7), 1035–1049. https://doi.org/10.1007/s11250-008-9270-y

Wanapat, M., & Kang, S. (2015). Cassava chip (Manihot esculenta Crantz) as an energy source for ruminant feeding. *Animal Nutrition*, *1*(4), 266–270. https://doi.org/10.1016/j.aninu.2015.12.001

Wanapat, M., & Khampa, S. (2006). Effect of cassava hay in high-quality feed block as anthelmintics in steers grazing on ruzi grass. *Asian-Australasian Journal of Animal Sciences*, *19*(5), 695–698. https://doi.org/10.5713/ajas.2006.695

Wanapat, M., Puramongkon, T., & Siphuak, W. (2000). Feeding of cassava hay for lactating dairy cows. *Asian-Australasian Journal of Animal Sciences*, *13*(4), 478–482. https://doi.org/10.5713/ajas.2000.478

Wang, S., Li, C., Copeland, L., Niu, Q., & Wang, S. (2015). Starch retrogradation: A comprehensive review: starch retrogradation…. *Comprehensive Reviews in Food Science and Food Safety*, *14*(5), 568–585. https://doi.org/10.1111/1541-4337.12143

Wang, X., Lu, M., Pei, Y., Lu, X., & Du, X. (2015). Two mesoporous cellular foams materials and their adsorption properties to brominated flame retardants. *Journal of Porous Materials*, *22*(1), 83–90. https://doi.org/10.1007/s10934-014-9875-7

Wang, Y., & Zhang, G. (2021). The preparation of modified nano-starch and its application in food industry. *Food Research International*, *140*, 110009. https://doi.org/10.1016/j.foodres.2020.110009

Wapnir, R. A., Wingertzahn, M. A., Moyse, J., & Teichberg, S. (1998). Proabsorptive effects of modified tapioca starch as an additive of oral rehydration solutions: *Journal of Pediatric Gastroenterology & Nutrition*, *27*(1), 17–22. https://doi.org/10.1097/00005176-199807000-00004

Wee, Y.-J., Reddy, L. V. A., & Ryu, H.-W. (2008). Fermentative production of L(+)-lactic acid from starch hydrolyzate and corn steep liquor as inexpensive nutrients by batch culture of *Enterococcus faecalis* RKY1. *Journal of Chemical Technology & Biotechnology*, *83*(10), 1387–1393. https://doi.org/10.1002/jctb.1953

Weerarathne, L. V. Y., Marambe, B., & Chauhan, B. S. (2017). Does intercropping play a role in alleviating weeds in cassava as a non-chemical tool of weed management? – A review. *Crop Protection*, *95*, 81–88. https://doi.org/10.1016/j.cropro.2016.08.028

Weil, W., Weil, R. C., Keawsompong, S., Sriroth, K., Seib, P. A., & Shi, Y.-C. (2021). Pyrodextrins from waxy and normal tapioca starches: Molecular structure and in vitro digestibility. *Carbohydrate Polymers*, *252*, 117140. https://doi.org/10.1016/j.carbpol.2020.117140

Whitney, K., Reuhs, B. L., Ovando Martinez, M., & Simsek, S. (2016). Analysis of octenylsuccinate rice and tapioca starches: Distribution of octenylsuccinic anhydride groups in starch granules. *Food Chemistry*, *211*, 608–615. https://doi.org/10.1016/j.foodchem.2016.05.096

Wilson, M. C., Mutka, A. M., Hummel, A. W., Berry, J., Chauhan, R. D., Vijayaraghavan, A., Taylor, N. J., Voytas, D. F., Chitwood, D. H., & Bart, R. S. (2017). Gene expression atlas for the food security crop cassava. *New Phytologist*, *213*(4), 1632–1641. https://doi.org/10.1111/nph.14443

Wongsagon, R., Shobsngob, S., & Varavinit, S. (2005). Preparation and physicochemical properties of dialdehyde tapioca starch. *STARCH - ST�RKE*, *57*(3–4), 166–172. https://doi.org/10.1002/star.200400299

Wongsagonsup, R., Pujchakarn, T., Jitrakbumrung, S., Chaiwat, W., Fuongfuchat, A., Varavinit, S., Dangtip, S., & Suphantharika, M. (2014). Effect of cross-linking on physicochemical properties of tapioca starch and its application in soup product. *Carbohydrate Polymers*, *101*, 656–665. https://doi.org/10.1016/j.carbpol.2013.09.100

Wu, M., Wang, J., Ge, Q., Yu, H., & Xiong, Y. L. (2018). Rheology and microstructure of myofibrillar protein–starch composite gels: Comparison of native and modified starches. *International Journal of Biological Macromolecules*, *118*, 988–996. https://doi.org/10.1016/j.ijbiomac.2018.06.173

Xia, W., Chen, J., He, D., Wang, Y., Wang, F., Zhang, Q., Liu, Y., Cao, Y., Fu, Y., & Li, J. (2019). Changes in physicochemical and structural properties of tapioca starch after high speed jet degradation. *Food Hydrocolloids*, *95*, 98–104. https://doi.org/10.1016/j.foodhyd.2019.04.025

Xia, W., He, D., Fu, Y., Wei, X., Liu, H., Ye, J., Liu, Y., & Li, J. (2017). Advanced technology for nanostarches preparation by high speed jet and its mechanism analysis. *Carbohydrate Polymers*, *176*, 127–134. https://doi.org/10.1016/j.carbpol.2017.08.072

Xia, W., Wang, F., Li, J., Wei, X., Fu, T., Cui, L., Li, T., & Liu, Y. (2015). Effect of high speed jet on the physical properties of tapioca starch. *Food Hydrocolloids*, *49*, 35–41. https://doi.org/10.1016/j.foodhyd.2015.03.010

Xie, X., Machikowa, T., & Wonprasaid, S. (2020). Fertigation based on a nutrient balance model for cassava production in two different textured soils. *Plant Production Science*, *23*(4), 407–416. https://doi.org/10.1080/1343943X.2020.1743189

Xu, Z., Li, C., Zhang, C., Yu, Y., van der Werf, W., & Zhang, F. (2020). Intercropping maize and soybean increases efficiency of land and fertilizer nitrogen use; A meta-analysis. *Field Crops Research*, *246*, 107661. https://doi.org/10.1016/j.fcr.2019.107661

Yagishita, T., Ito, K., Yokomizo, E., Endo, S., & Takahashi, K. (2011). Physicochemical properties of monosodium glutamate-compounded tapioca starch exceeds those of simple heat-moisture treated starch. *Journal of Food Science*, *76*(7), C980–C984. https://doi.org/10.1111/j.1750-3841.2011.02285.x

Yamamoto, K. (2017). Food processing by high hydrostatic pressure. *Bioscience, Biotechnology, and Biochemistry*, *81*(4), 672–679. https://doi.org/10.1080/09168451.2017.1281723

Yang, J., Chang, R., Ge, S., Zhao, M., Liang, C., Xiong, L., & Sun, Q. (2016). The inhibition effect of starch nanoparticles on tyrosinase activity and its mechanism. *Food & Function*, *7*(12), 4804–4815. https://doi.org/10.1039/C6FO01228K

Ye, P., An, J., Zhang, G., Wang, L., Wang, P., & Xie, Y. (2018). Preparation of particleboard using dialdehyde starch and corn stalk. *BioResources*, *13*(4), 8930–8942. https://doi.org/10.15376/biores.13.4.8930-8942

Yin, T., Park, J. W., & Xiong, S. (2015). Physicochemical properties of nano fish bone prepared by wet media milling. *LWT - Food Science and Technology*, *64*(1), 367–373. https://doi.org/10.1016/j.lwt.2015.06.007

Yulianto, K., Sukardi, Indrasti, N. S., & Raharja, S. (2020). Situational analysis and prospect of interest-free financing in tapioca agro-industry. *IOP Conference Series: Earth and Environmental Science*, *472*, 012051. https://doi.org/10.1088/1755-1315/472/1/012051

Zeng, C., Ding, Z., Zhou, F., Zhou, Y., Yang, R., Yang, Z., Wang, W., & Peng, M. (2017). The discrepant and similar responses of genome-wide transcriptional profiles between drought and cold stresses in cassava. *International Journal of Molecular Sciences*, *18*(12), 2668. https://doi.org/10.3390/ijms18122668

Zeng, J., Wu, C., Wang, C., Liao, F., Mo, J., Ding, Z., Tie, W., Yan, Y., & Hu, W. (2020). Genomic analyses of heat stress transcription factors (Hsfs) in simulated drought stress response and storage root deterioration after harvest in cassava. *Molecular Biology Reports*, *47*(8), 5997–6007. https://doi.org/10.1007/s11033-020-05673-3

Zhang, C., & Lim, S.-T. (2021). Physical modification of various starches by partial gelatinization and freeze-thawing with xanthan gum. *Food Hydrocolloids*, *111*, 106210. https://doi.org/10.1016/j.foodhyd.2020.106210

Zhang, R., Zhou, K., Xie, C., & Qin, S. (2018). Experimental study on minimum ignition energy of tapioca starch. *IOP Conference Series: Earth and Environmental Science*, *208*, 012037. https://doi.org/10.1088/1755-1315/208/1/012037

Zhang, W., Zhang, J., & Xia, W. (2012). The preparation of chitosan nanoparticles by wet media milling: **Media milling to get chitosan nanoparticles**. *International Journal of Food Science & Technology*, *47*(11), 2266–2272. https://doi.org/10.1111/j.1365-2621.2012.03097.x

Zhang, X., Zhu, W., Tong, Q., & Ren, F. (2012). Rheological, thermal properties, and gelatinization kinetics of tapioca starch-trehalose blends studied by non-isothermal DSC technology. *Starch - Stärke*, *64*(12), 996–1002. https://doi.org/10.1002/star.201200111

Zhang, Z., Zhang, R., Zou, L., & McClements, D. J. (2016). Protein encapsulation in alginate hydrogel beads: Effect of pH on microgel stability, protein retention and protein release. *Food Hydrocolloids*, *58*, 308–315. https://doi.org/10.1016/j.foodhyd.2016.03.015

Zhao, P., Liu, P., Shao, J., Li, C., Wang, B., Guo, X., Yan, B., Xia, Y., & Peng, M. (2015). Analysis of different strategies adapted by two cassava cultivars in response to drought stress: Ensuring survival or continuing growth. *Journal of Experimental Botany*, *66*(5), 1477–1488. https://doi.org/10.1093/jxb/eru507

Zhu, F. (2015). Composition, structure, physicochemical properties, and modifications of cassava starch. *Carbohydrate Polymers*, *122*, 456–480. https://doi.org/10.1016/j.carbpol.2014.10.063

Zhu, F. (2017). Encapsulation and delivery of food ingredients using starch based systems. *Food Chemistry*, *229*, 542–552. https://doi.org/10.1016/j.foodchem.2017.02.101

Zhu, F. (2018). Modifications of starch by electric field based techniques. *Trends in Food Science & Technology*, *75*, 158–169. https://doi.org/10.1016/j.tifs.2018.03.011

Zia-ud-Din, Xiong, H., & Fei, P. (2017). Physical and chemical modification of starches: A review. *Critical Reviews in Food Science and Nutrition*, *57*(12), 2691–2705. https://doi.org/10.1080/10408398.2015.1087379