Canrea Journal: Food Technology, Nutritions, and Culinary, 2024; 7 (2): 213–229

OPEN ACCESS

e-ISSN : 2621-9468

Type of the Paper (Review)

Production, biological activities and functional food of modified cassava flour (mocaf)

Yuniar Khasanah[1,2], Anastasia Wheni Indrianingsih[2], Priyanto Triwitono[1*], and Agnes Murdiati[1]

[1] Faculty of Agricultural Technology, Universitas Gadjah Mada, Yogyakarta, 55281, Indonesia
[2] Research Center for Food Technology and Processing, National Research and Innovation Agency, Yogyakarta, 55861, Indonesia

Abstract

Cassava is predominantly produced in tropical regions, including Asia, Africa, and South America. In the developing countries, cassava includes in the big four comestibles with other commodities such as rice, wheat, and maize. It offers several advantages over other crops, such as affordability, ease of consumption, drought tolerance, the ability to grow on in marginal land at lower cost, and beeing the biggest producer of carbohydrates per hectare. However, cassava tuber is quickly perishable, because of its high-water content, making it more susceptible to rotting. To extend their shelf life, one approach is the production of modified cassava flour (mocaf). Mocaf is typically produced through a fermentation process by microorganism involving lactic acid bacteria. Studies have demonstrated that mocaf can serve as the primary ingredients for various food and various foods and snacks, such as cookies, cake, noodles, and others food traditionally made with wheat flour or starch-based material. Compared to regular cassava flour, mocaf offers improved flavor and color and is also more cost-effective than wheat flour. The use of mocaf is promising since several studies also showed the use of mocaf to produce functional foods for human health. The purpose of this review was to elaborate the published articles on the production, biological activities, and functional food from modified cassava flour. The promising potential of mocaf is summarized, along with data on its biological activities in food and health contexts. Furthermore, recommendations for future research on the industrial applications of mocaf are provided.

Article History
Received March 15, 2024
Accepted December 25, 2024
Published December 31, 2025

Keywords
Cassava,
Fermentation,
Modified Cassava Flour,
Antioxidant,
Functional Food.

1. Introduction

Manihot esculenta Crantz, family of Euphorbiaceae also named “*manioc*” or “*yucca*” in America, “*ubi kayu*”, “*ketela pohon*” or “*singkong*” in Indonesia, “*gbaguda*” or “*imidaka*” in Nigeria; “*eyabya*” in Tanzania, “*kamoteng kahoy*” or “*balanghoy*” in the Phillippines; “*singkong*”, “*tapioca*” in Frech, “*mandioca*” in Portuguese (1–3). Cassava is also recognized as an important tuber crop and a significant source of carbohydrates, alongside rice, in tropical countries. It serves as a staple food for many regions in Asia and Africa, providing the primary dietary source for over 500 million people. The fact is that cassava is a starchy tuber plant and is a cheap source of calories, able to grow in ability under conditions considered as suboptimal. Furthermore, it can be harvested at any time and offers several advantages, including affordability, ease of consumption, drought tolerance, the ability to grow on marginal land at a lower cost, and the highest carbohydrate yield per hectare (1,4).

* Correspondence : **Priyanto Triwitono** triwitono@ugm.ac.id

ISSN 2621-9468 online, DOI 10.20956/canrea.v7i2.1280

Originating from Central America, cassava was likely introduced to Asia during Dutch colonization and saw extensive cultivation in the 20th century in countries such as the Philippines, India, and Indonesia and expanded throughout Asia such as Malaysia, Thailand, Vietnam and China for smallholder farmers (1,5). In developing countries, cassava is included in the top four staple foods. Alongside rice, wheat, and maize, due to its high carbohydrate content (over 70%). In 2017, global cassava production was estimated to be more than 291 million tonnes, with the crop predominantly cultivated in Asia, South America, and West Africa. Africa accounted for over 60% of global cassava production, and Nigeria is the biggest cassava producing country (20.4%) and the largest area harvested in the world (6 million Ha or 26%), followed by Kongo (10.83%), Thailand (10.61%) and Indonesia (6.52%). In Nigeria and other African countries, cassava is a crucial staple food, providing over 90% of households with a primary calorie source. Most cassava produced is consumed locally as traditional meals, with approximately 10% used for industrial purposes and less than 1% designated for export (3,6–8). In contrast, Thailand become the leading country in the world as exporter of cassava despite producing less than Nigeria. Cassava is one of Thailand's major economic crops, with an export value of $1.9 billion in 2017 (6). The country exported 9.5 million tonnes of cassava flour and starch, 12.2 million tonnes of chips, and pellets in the same year. In the Laos People’s Democratic Republic, cassava plantation areas have expanded significantly, from 20,000 hectares to 115,000 hectares by 2021, driven by rising demand from China, Vietnam, and Thailand (9).

In addition to being a vital food source rich in vitamins and minerals, cassava offers significant economic and industrial potentials such as animal feed, industrial applications and fuel production. For instance, cassava is used in the production of bioethanol and biofuel, as well as in industrial processes such as the manufacture of high-quality cassava flour (HQCF), modified starch, modified flour, pharmaceuticals, sweeteners, and starch (6,7).

Cassava is highly perishable and prone to rapid deterioration after harvest compared to other tubers. This decline occurs due to physiological and microbiological changes. This condition results in changes in the color of the tubers so that they cannot be consumed or used as raw material for the food industry. Therefore, efforts to extend the shelf life of these plants are crucial, particularly by developing value-added products that positively impact economic aspects. The simplest methods of consuming cassava tuber is typically by boiling or frying (1,10). However, cassava tuber is quickly perishable because of its high -water content, making it more susceptible to rotting. Several methods, such as fermentation and starch production, have been conducted to prolong the shelf-life of cassava tuber. One effective approach is the production of cassava flour, tapioca flour, and modified cassava flour (mocaf).

Mocaf is typically produced through a fermentation process by microorganisms, usually lactic acid bacteria, yeast, and mould, to change cassava’s cells (11). The microorganisms produce cellulolytic and pectinolytic enzymes that destroy the cellulose and disrupt the starch granules in cassava (12). The production of mocaf was like cassava flour production, except that it undergoes a fermentation process, followed by drying and milling into mocaf. The production process of mocaf is similar to that of cassava flour, with the additional step of fermentation, followed by drying and milling. Mocaf exhibits distinct characteristics compared to original cassava flour, including improved viscosity, rehydration capability, gelation properties, and solubility (13).

The flavor of mocaf also differs from cassava flour since the organic acid resulting by the fermentation process may affect the flour’s characteristics (14). Modifying cassava flour aims to improve its properties, such as reducing its tendency to gelatinize, enhancing texture, increasing transparency, and improving stability (15). Previous studies have isolated several phenolic compounds and flavonoids from cassava, which demonstrated strong antioxidant effects (10,16). Additionally, cassava contains terpenoids, reducing sugars, alkaloids, steroids, carotenoids, fatty acids, and benzoic acid derivatives (2). Given that mocaf is derived from cassava, it is likely to also contain numerous bioactive compounds worth further exploration. However, cassava had been regarded as a secondary crop due to its low protein and starch digestibility, as well as the presence of cyanogenic glucoside which act as anti-nutritional agent and reduce its nutritional value. As the result, cassava has received less attention than other crops, such as rice, wheat, and maize.

This review summarizes published articles on the production, biological activities, and functional food from modified cassava flour through fermentation. The promising potential of mocaf was reviewed and suggested. Additionally, data on the biological activity of mocaf in food and health are presented, and future research on its industrial applications is recommended.

2. The Production of Mocaf

Cassava tuber can typically be consumed directly for a few days. To prolong its shelf life and add value for economic value, cassava tubers are processed into cassava flour. This processing also includes the production of modified cassava flour (mocaf), which serves various purposes, such as preservation, detoxification, and modification (14,17). Some traditional methods for producing cassava flour are often resulting in poor quality products, making them unsuitable for substituting wheat flour.

The commercialization of mocaf is very promising, especially for countries that can only grow cassava because of its climate. It can be variedly used as a cost-effective substitute for wheat flour, with the added benefit of being abundant and readily available. The general procedures for producing mocaf are illustrated in Figures 1 and 2. Typically the process of making mocaf includes the stages of weighing, sorting, peeling, washing, shredding/slicing, fermentation (soaking), pressing, draining, and drying. The following process is milling/flouring, sifting, packaging, and storage (18). Modifications during the mocaf production process aims to maintain the beta carotene content, namely combining the use of starter with the use of sodium metabisulfite (19).

Mocaf has potential as a substitute for wheat on its gluten-free product, such as bread, cake, noodle, and traditional snack (20–23). Although mocaf has a low protein content, it is gluten-free, making it a safer option for individuals with diabetes, autism, or hypercholesterolemia. Foods containing gluten and casein may not be properly digested by the digestive systems of children with autism. The protein content mocaf is low (1%), significantly lower than that of wheat (24,25). It is related to the nature of gluten found in the processed product. Food product from mocaf are also known to exhibit antioxidant activity and are also low on the glycemic index (26) .

A report highlighted the inconsistency in the quality of fermented cassava products (14). The quality of mocaf is determined by many factors, including the genotype/variety of cassava (27), the age of harvest, the thickness of slicing (28), the type of fermentation, the temperature of fermentation, bacteria and the different methods of production (17,29–31) fermentation (type of fermentation and the duration of soaking fermentation) (11), the starter (32).

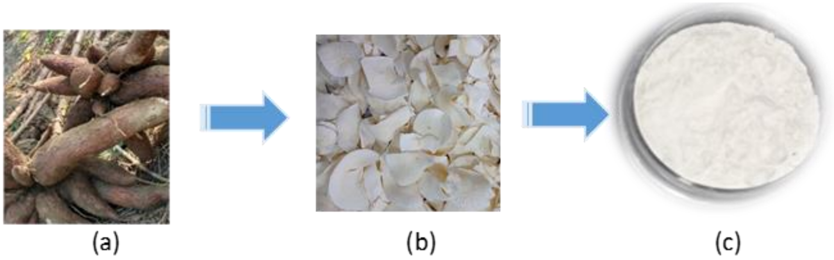

Figure 1. (a) Cassava root; (b) Cassava slices; (c) Mocaf

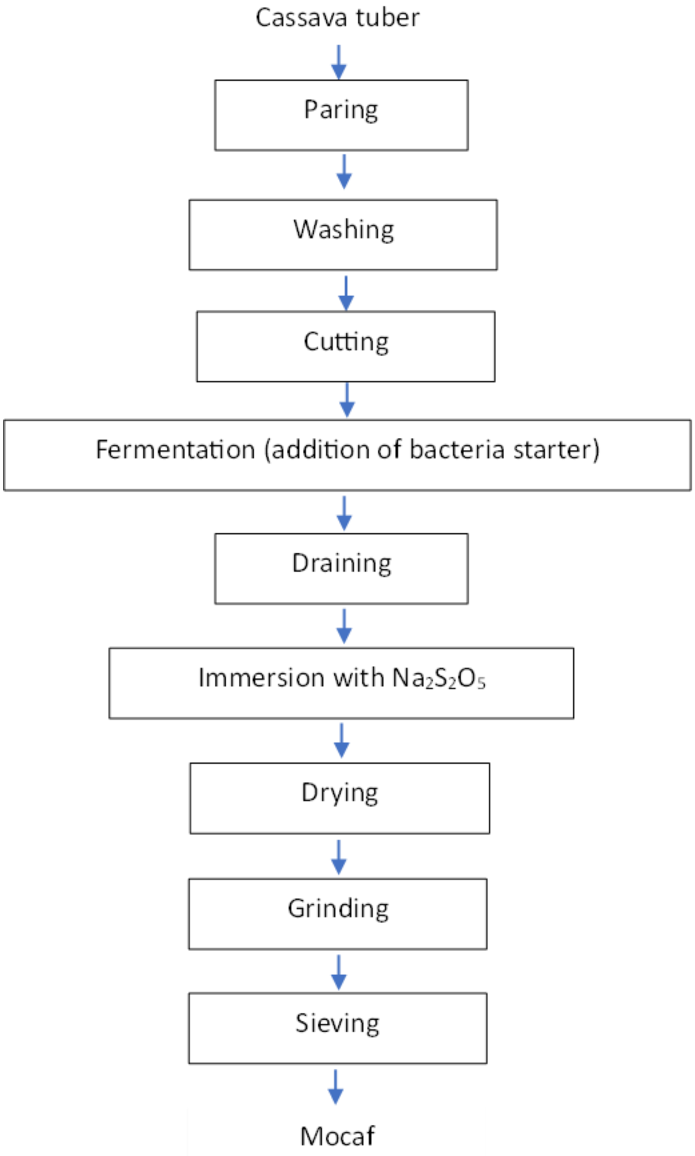

Figure 2. Flow chart of the making process of mocaf generally

Fermentation is critical step in mocaf production, whether spontaneous fermentation or controlled fermentation with the addition of specific microbes (23). This process affects the differences in characteristics between mocaf and other cassava flours, such as viscosity, gelation ability, rehydration capacity, ease of dissolution, color, aroma, physicochemical properties, digestibility, reduced toxicity, yield, and bioactive components (18). Table 1 shows several processes for making mocaf and their influence on the characteristics of the mocaf produced. The changes in the characteristics of mocaf as a result of modifications have contributed to its increasing and varied applications.

Cassava fermentation naturally involves many specific microbes, including *lactic acid bacteria* (LAB), *Bacillus sp*., *cellulolytic bacteria*, and *amylolytic yeast* (33,34). Microbes commonly used in mocaf flour production include *Acetobacter xylinum*, *Rhizopus oryzae*, *Saccharomyces cerevisiae*, *Lactobacillus plantarum* and *Lactobacillus casei* (35). Among these, *lactic acid bacteria* are the predominant microorganism and yeast. In cassava fermentation 54.6% of isolates was identified as *Lactobacillus plantarum*. These bacteria generally used as a starter for the spontaneous fermentation process of cassava and can reduce the levels of cyanogenic compounds during fermentation (36). During fermentation, both chemical and sensory changes increase protein content, and cyanogenic glucoside decreases. Yeast and *lactic acid bacteria* (LAB) are microbial strains that have been frequently associated with the production of an enzyme for HCN reduction during cassava fermentation, as well as the development of flavor (14,25).

3. Biological Activities and Functional Food Potential of Modified Cassava Flour

3.1. Antioxidant Activity

Infection of cassava roots by fungi or cutting, triggers phenolic compound accumulation such as scopoletin, scopoline and diterpenoid compounds (29,30,37,38). Isolation of several bioactive compounds from the stem of cassava such as phenols (isovanillin, ficusol, syringaldehyde, ethamivan), coumarin (scopoletin), and phenylpropanoids (p-coumaric acid, coniferaldehyde) also studied (16).

The antioxidant activity of ethyl acetate fraction and butanol fraction of cassava stem extracts exhibited good IC50 of 0.52 and 0.62 mg/mL, respectively. Additionally, the petroleum ether fraction showed smaller value. Among the isolated compounds, the highest antioxidant activity was observed in pinoresol, followed by coniferaldehyde, ficusol, ethamivan, and balanophonin. Another antioxidant evaluation using ABTS assay revealed that the ethyl acetate fractions also showed the highest value with an IC50 of 0.26 mg/mL. Furthermore, the phenolic compounds with the highest ABTS scavenging activity were syringaldehyde, followed by p-coumaric acid and coniferaldehyde (16).

Our previous study utilized modified cassava flour (MOCAF) to make functional food in the form of cookies by adding pumpkin flour (39). The results indicated that of the three formulations used, the formulation with a mocaf-pumpkin flour ratio of 77.5:22.5% had the highest antioxidant activity with an activity of 14.03% at 1000 ppm. Sensory tests from mocaf-pumpkin cookies also showed that the mocaf-pumpkin flour with 77.5:22.5% formula was most acceptable to the panellists. These findings suggest that the combination of mocaf and pumpkin flour has the potential to produce functional food that is safe for human health as a source of natural antioxidants. Previous research also developed functional crackers using mocaf and part of pumpkin flour i.e. peel, seeds and flesh of pumpkin (40,41). The crackers with mocaf and various of flesh flour ratio showed that the highest antioxidant was obtained by adding pumpkin flesh flour as of 42%. Furthermore, crackers made with mocaf flour and pumpkin seed flour exhibited the highest antioxidant activity, reaching 35.59% when evaluated using the DPPH method.

Another study used utilized cassava flour to create composite flour by adding garden egg and sorghum flour. The results obtained showed that the composite flour obtained increased its antioxidant activity. Various variations of composites from these three mixtures have antioxidant activity using the FRAP method in the range of 16.54 -26.17 mg/g, antioxidant activity using the ABTS method in the range of 70.39-88.07%, and antioxidant activity using the DPPH method of 50-70%. The best composite flour is obtained with the formulation of cassava: garden egg: sorghum with a ratio of 85:7.5:7.5 (42). Another study used cassava starch as a bio-composite, incorporating grape skin and grape acerola residues. The antioxidant analysis revealed that the cassava bio-composite containing 10.0 wt% grape acerola residue exhibited the highest antioxidant activity against DPPH free radicals (43).

A previous study examining the effects of processing cassava flour using through roasting and sun-drying methods showed differences in biological activity from the effects of cassava flour processing. The antioxidant activity test using the ATBS method showed EC50 values of 58.46 and 99.92 mmol TEAC/g for roasted cassava flour and sun-dried flour, respectively. The antioxidant activity test with reducing power was yielded values of 59.86 and 96.21 mmol/AAEg, respectively, and the antioxidant activity test using the DPPH method was 0.72 mg/ml and 0.56 mg/ml, for roasted cassava flour and sundried flour, respectively. In general, processing cassava flour by roasting is more recommended than processing by sundried to produce cassava flour with better biological activity (44).

A study on Sri Lankan cassava flour from 5 varieties called MU51, Shani, Swarna, Suranimala and Kirikawadi demonstrated antioxidant activity ranging from 31.45% to 72.01% in the DPPH assay. The antioxidant activity using the FRAP method ranged from 0.83 to 0.93 mol GAE/100 g dry weight. Among the varieties, cassava flour from the Swarna variety had the highest antioxidant content. These results highlight the potential of cassava flour for use in various food and edible film industries (10).

Table 1. Mocaf processing condition and its quality

Parameter	Condition	Mocaf quality	Reference
Root age	Age of harvesting	Proximate and mineral composition, functional and physicochemical properties, peak and breakdown viscosities, and yield	(45,46)
Variety/genotype	• Local Variety: *Mentega, Karet, Kaspro, Cimanggu, Adira-1*, (Malaysia genotype and *Merah/Gondoruwo*)	• Variety effect on moisture, lipid, lightness, and yield	(27,47,48)
	• Breeading cassava	• Cassava genotype has different physicochemical composition (yield,	(49)

		carbohydrate, protein, ash, fat, white degree, water content, HCN)	
Shredding/slicing	Slice thickness: 0.5 cm, 1 cm, and 1.5 cm	Slice thickness had a significant effect on water content and swelling power	(28)
Fermentation	Time fermentation:		
	• 0 h – 24 h	• Fermentation process influenced by pH, water holding capacity, swelling power, syneresis, and morphology properties	(50)
	• 24 h - 72 h	• Increasing fermentation time decreased yield, moisture content, ash, protein, pH, HCN, and crude fiber and increased swelling power and solubility	(14,35,46)
	• 24 h – 120 h	• Time of fermentation affected on yield, water content, protein, HCN, starch content	(51)
	Bacteria		
	• *Lactobacillus. Paracasei*	• Mocaf contain high protein; low fat; low carbohydrate; high whiteness index and low acidity	(12)
	• *Lactobacillus plantarum*	• Higher lactic acid bacteria population, high reduction level of HCN, and higher protein	(36,47,49)
	• *Lactobacillus casei*	• Stater concentration increased protein, solubility, swelling power, And carboxylic	(52)
	• *Acetobacter Xylinum concentration: 5%, 10%, 15%, 20%, and 25%*	• Stater concentration decreased yield, moisture, ash, acidity, HCN, and crude fiber	(35)
	Fungi		
	• *Rhizopus oryzae*	• Fermentation using *Rhizopus oryzae* increasing protein levels and decreasing HCN levels	(32,49)
	• *Saccharomyces cerevisiae*	• Fermentation using *Saccharomyces cerevisiae* increasing protein levels and decreasing HCN levels	(32,49)

	Spontaneous fermentation	fermentation period effect moisture content, carbohydrate, water absorption capacity, swelling and solubility index	(53)
	Commercial culture		
	• *Ragi (tempe and tapai)*	• Commercial ragi increased protein and lipid; and decrease moisture, fiber and carbohydrate	(54)
	• Yoghurt (10%)	• Fermentation using yoghurt as inoculum increased moisture, starch, fiber, and calcium; and also decreased ash, Fe, fosfor, and HCN	(24)
Drying	Time: 8 h, 12 h, and 24 h; temperature: 50°C, 70°C, 80°C	Time and temperature drying affect moisture, protein, lipid, carbohydrate, and color	(55)
Milling/flouring	Wet and dry milling	Milling effect on pH, water holding capacity, swelling power, syneresis, and morphology properties	(50)

3.2. Antidiabetic Activity

Lack of insulin production or insulin resistance leads to diabetes mellitus (DM), particularly type 2 DM, which is caused by insulin resistance. This conditions also accelerates diseases such as cardiovascular disease (56). A previous study revealed that the Glucagon-like peptide-1 (GLP-1) pathway can stimulate insulin production, reduce glucagon secretion, and protect β-pancreatic cells, thus increasing insulin sensitivity and control blood glucose (24,54). Meanwhile, resistant starch (RS) increase the GLP-1 secretion (57,58). A study by Firdaus et.al. (59) showed that modified cassava flour (MOCAF) and its resistant starch-3 (RS3), made by fermentation process of lactic acid bacteria had an ability improve insulin resistance in diabetes-induced mice. The mice consumed 20 g of either mocaf, RS3, or a standard diets per day for 4 weeks. Blood samples were collected to evaluate the blood glucose, plasma insulin, and plasma GLP-1. The results revealed that consuming mocaf decreased fasting blood glucose from 446 mg/dL to 105 mg/dL, while consuming RS3 decreased it from 494 mg/dL to 97 mg/dL. Postprandial blood glucose also decreased, with mocaf consumption reducing it from 485 mg/dL to 136 mg/dL and RS3 from 526 mg/dL to 96 mg/dL.

Previous research on composite flour mixtures, with cassava as the main ingredient, also explored its antidiabetic activity. The findings revealed that composite cassava, garden egg, and sorghum exhibited antidiabetic properties, as indicated by the α-amylase inhibitor test, with activity levels ranging from 41.13% to 60.34% (42). Research on analog rice made from flour mixtures using cassava flour as a basic ingredient in formulation was done. The results obtained showed that the best optimal formulation included 5% of *Rhizophora mucronata* (mangrove fruit) flour and 5% *Eucheuma cottonii* (seaweed) flour. This combination demonstrated α-glucosidase inhibitory activity with an IC50 value of 185.59 ppm (60).

Another study evaluated the antidiabetic activity of analog rice made from mocaf, kidney beans, and arrowroot. The study involved 24 Wistar rats which were divided into 4 treatment groups for 4 weeks of intervention. The results obtained showed that diabetic rats (Streptozotocin-Nicotinamide (STZ-NA) induced diabetic rats) treated with rice analogues of mocaf, kidney beans and arrowroot had the greatest reduction of blood glucose at 55.07%. These findings indicate that analog rice made from mocaf, kidney beans, and arrowroot possesses significant antidiabetic properties, likely influenced by the resistant starch and dietary fiber present in its ingredients (61).

Another study investigated the effects of processing methods on the manufacture of cassava flour. The findings revealed that making flour using roasted cassava exhibit superior properties in terms of antidiabetic activity compared to the sun-dried cassava flour process. The α-glucosidase inhibitor activity test showed an EC50 value of 0.17 mg/ml and 0.28 mg/ml for roasted cassava flour and sundried cassava flour, respectively. Meanwhile, the α-amylase activity test result was 0.64 mg/ml and 0.59 mg/ml, for roasted cassava flour and sundried cassava flour, respectively. Furthermore, roasted cassava flour demonstrated a higher content of bioactive compounds including gallic acid, cathechin, kampferol, qercetin and caffeic acids (44).

An antidiabetic snack bar was developed using modified cassava flour (mocaf) and chia seed flour was developed. The findings showed that the a greater the proportion of mocaf resulted in a brighter color in the final product. Apart from that, the combination of mocaf and chia seeds has a hypoglycaemic function which correlates with lowering blood sugar levels by decreasing AMP-activated protein kinase (AMPK) and increasing insulin sensitivity, thereby reducing the risk of diabetes mellitus (62). A study explored the diversification of traditional Indonesian foods made from cassava, including analog rice*,* *instant tiwul*, and *oyek*. The glycemic index evaluation revealed that these diversified cassava-based products have a moderate glycemic index, ranging from 56 to 63, with the lowest glycemic index observed in cassava-based analog rice. These findings suggest that the food processing methods applied to cassava significantly affects the glycaemic index by influencing absorption and digestibility (63).

3.3. Anticancer Activity

In addition to being the primary source of carbohydrate content, cassava also produced other constituents, such as niacin, riboflavin, calcium, thiamine, and dietary fibers (64,65). In addition, the extract of cassava has been used as traditional medicine in China (66), while previous study reported the anticancer potential of methanol extract of cassava. A study by Idibie et. al. (67), highlighted the cytotoxic effects of linamarin, a compound derived from cassava extract on HL-60 cells, MT-29 and MCF-7 cells using MTT assay. The isolation of linamarin involved activated carbon treatment followed by ultrafiltration, yielding approximately 2.8% of purified compound from the crude extract. The results indicated a concentration-dependent increase in the cytotoxic activity of linamarin against HL-60 cells. These findings suggest that mocaf may also contain active compounds with potential anticancer or antitumor properties.

Previous research about has computationally examined the biological activity of cassava extract as an anti-cancer. Linamarin glucoside, which is abundant in cassava, undergoes hydrolysis to produce hydrogen cyanide, a compound with cytotoxic properties that could potentially target cancer cells. Computational studies have shown that certain linamarin derivatives exhibit lower activation barriers and faster hydrolysis kinetics, suggesting an enhanced potential as anticancer agents. However, laboratory experiments are necessary to validate these computational findings (68).

Another study revealed demonstrated that cassava cyanide extract had good anti-proliferative activity in adenocarcinoma human alveolar basal epithelial cell (A549) at 400 ppm. This was determined using the neutral red uptake assay and MTT assay (69). Additionally, maesculentins A and B, isolated from cassava stem extract, showed cytotoxic activity against the HGC-27 tumor cell line. While the exact mechanism of action remains unclear, it is hypothesized that the unsaturation of chemical structure probably have a positive correlation with the anti-cancer properties.

3.4. Alternative Culture Media for Microorganism Growth

Experiments involving bacteria or microbes in the laboratory require culture media to support their growth. Commercially available growth media are often expensive, prompting the exploration of natural resources as cost-effective alternatives. Previous studies have investigated the use of natural sources such as cassava, cereals, and potatoes as affordable alternatives for microbial growth media (70). Other studies have reported use of cassava flour, vegetable waste (potato skins, cauliflower stalks) and fruit waste (orange peels) to replace traditional culture media (71,72). Furthermore, mocaf has been explored as an alternative culture medium for bacterial growth. A study demonstrated that amounts of mocaf (of 1 - 8 grams) can be used for culture media for *Escherichia coli* and *Bacillus cereus* bacteria. It showed that by using 8 grams of mocaf, the *E. coli* bacteria concentrations was 81x105 CFU/ml while for B. cereus as of 197.8 x 105 CFU/ml. Conversely, the lowest concentration for the bacteria was 1 gram of mocaf flour as culture media with *E. coli* concentration was 7.2 x 105 CFU/ml and 2 grams of mocaf with *B. cereus* concentration was 27x 105 CFU/ml. This study showed the potential use of mocaf as a cheaper alternative medium for microorganism growth (73).

3.5. Functional Food from Mocaf

In a tropical country where wheat was cannot be cultivated, there is an urgent need for a cost-effective alternative carbohydrate source with similar functionality. Mocaf is one of the candidates since cassava as the source of mocaf was in a lower price than wheat flour. A previous study reported that mocaf has a similar composition to cassava flour in terms of protein content (1.2%) but exhibits lower water content (6.9%), higher starch content (87.3%), and slightly higher fiber and fat content compared to cassava flour (74). On the other hand, when compared to wheat flour, mocaf had lower protein and fat content while higher in starch and fiber content. Thus, in using mocaf for functional food, commonly another ingredient was added to increase its nutrients.

A previous study investigated the production of cakes using mocaf and carrot puree in six different formulations: 50%:50%, 60%:40%, 70%:30%, 80%:20%, 90%:10%, and 100%:0%. It was revealed that cake made from mocaf and carrot puree with ratio of 50% mocaf :50% carrot puree had the best properties with ash content 1.24%, water content 33.24%, beta-carotene 0.065 mg/g, crude fiber 9.55%, and antioxidant activity of 2.88%. Additionally, sensory tests indicated that, the aroma, texture, taste, and overall acceptance were good (75). Mocaf is also suitable for noodles production. As famously known, noodles are staple food in Asia countries such as South Korea, China and Japan and it also gained popularity globally in the world (76,77). A study found that a noodle formula using a mocaf-to-wheat flour ratio of 15%:35% was good for noodle production. Several treatments were varied with addition with basil leaf extract (5%) and addition with both spirulina (2%) and basil leaf extract (2%). The results showed that the addition of spirulina and basil leaf extract improved noodle color and overall quality. Sensory tests confirmed that mocaf-based noodles were acceptable to consumers (78).

The combination of mocaf and spirulina was also explored for in the production of an Indonesian traditional pastry called mocaf-milk pie with addition of local fruits like pineapple and grapes (74). The best formulation for the pie was found to be with the inclusion of 0.5% w/w spirulina. Sensory testing revealed that both the mocaf-pie with pineapple and grape variations were well-liked by consumers, meeting the criteria for pastry quality. The inclusion of vegetables such as moringa (*Moringa oleifera*), *kale* (*Brassica oleracea*) and *katuk* (*Sauropus androgynus*) was found to enhance the fat, protein, and mineral content of cookies made from mocaf. Mocaf-moringa cookies had the highest crude fiber and fat content as of 1.4% and 38.1%, respectively. The highest protein content was shown by mocaf-*kale* cookies with 5.1% while the highest mineral content was observed in mocaf-*kale* cookies with calcium as of 82.3 mg/100g, potassium of 202 mg/100g and magnesium of 97.7 mg/100g, respectively. Furthermore, sensory tests indicated that the taste, aroma, and color of the mocaf-vegetable cookies were still acceptable to panelists (79).

Mocaf also had been used in biscuit formulation with the addition of soybean flour ranging from 10% to 20% of w/w (80). The aim of adding of soybean flour was to increase its protein content. The result showed that the highest protein content of mocaf-soybean biscuit was achieved using 20% of soybean flour addition as of 14.27%. Meanwhile the mocaf-soybean biscuit hardness was affected by the particle size of soybean flour. The previous study also produced crackers from pumpkin-mocaf based (40,41). It revealed that the addition of pumpkin could hance the antioxidant activity of crackers. The pumpkin seed flour-mocaf showed the highest antioxidant activity of 35.6% at 800 ppm, while the pumpkin rind flour-mocaf showed the highest total phenolic content as of 283.1 mg GAE/g. Additionally, HPLC analysis also presented the beta-carotene detection in pumpkin-mocaf crackers as of 8.9%. This findings suggest that pumpkin-mocaf based formulation have potential for further exploration and commercialization.

4. Conclusions

It is necessary to study more comprehensively about mocaf and all its potential. Mocaf possesses unique characteristics, offering several advantages, such as competitive prices, easy manufacture, and the content of useful active compounds that are especially beneficial for health. However, it is necessary to standardize the processes and methods used so that good quality mocaf is obtained. To further enhance the nutritional profile, functional food products made from mocaf can also be fortified with additional ingredients to increase their function, bioavalability and effectiveness as functional food. If mocaf and its derivative products gain global recognition, it could significantly boost the economies of developing countries, particularly those where cassava production is well-suited to the local climate. It is necessary to continue efforts by all parties including researchers, local government, food industries and consumers to increase productivity, quality and product variations from mocaf with good nutritional content, health benefits and consumer acceptance.

Acknowledgements

The authors would like to thank the National Research and Innovation Agency (BRIN), Indonesia, for its facilities in the preparation of this article.

Author Contributions

Y.K and P.T. has designed and writing concept; Y.K and A.W data collection and manuscript writing; A.M has reviewed manuscript.

Funding

This research has been funded by Degree by Research program – National Research and Innovation Agency (DBR BRIN)

Institutional Review Board Statement

Not applicable

Data Availability Statement

Invalid

Conflicts of Interest

Authors declare no conflict of interest.

References

1. Uthpala TGG, Wanniarachchi PC, Nikagolla DN, Thibbotuwawa A. Cassava : A Potential Food Source for Value-added Product Developments in Sri Lanka. Adv Agric Life Sci. 2021;(7):57–78.
2. Mohidin SRNSP, Moshawih S, Hermansyah A, Asmuni MI, Shafqat N, Ming LC. Cassava (Manihot esculenta Crantz): A Systematic Review for the Pharmacological Activities, Traditional Uses, Nutritional Values, and Phytochemistry. J Evidence-Based Integr Med. 2023;28.
3. Uchechukwu-Agua AD, Caleb OJ, Opara UL. Postharvest Handling and Storage of Fresh Cassava Root and Products: a Review. Food Bioprocess Technol. 2015;8(4):729–48.
4. Bayata A. Review on Nutritional Value of Cassava for Use as a Staple Food. Sci J Anal Chem. 2019;7(4):83.
5. Malik AI, Kongsil P, Nguyễn VA, Ou W, Sholihin, Srean P, et al. Cassava breeding and agronomy in Asia: 50 years of history and future directions. Vol. 70, Breeding Science. 2020. p. 145–66.
6. A Otekunrin O, Sawicka B. Cassava, a 21st Century Staple Crop: How can Nigeria Harness Its Enormous Trade Potentials? Acta Sci Agric. 2019;3(8):194–202.
7. Zhu F. Composition, structure, physicochemical properties, and modifications of cassava starch. Carbohydr Polym. 2015;122:456–80.
8. Onyenwoke CA, Simonyan KJ. Cassava post-harvest processing and storage in Nigeria : A review. African J Agric Res. 2014;9(53):3853–63.
9. Food and Agriculture Organization of the United Nations. Special Report – 2022 FAO/WFP Crop and Food Security Assessment Mission (CFSAM) to the Lao People's Democratic Republic. Special Report – 2022 FAO/WFP Crop and Food Security

Assessment Mission (CFSAM) to the Lao People's Democratic Republic. Rome; 2023.
10. Nilusha RAT, Jayasinghe JMJK, Perera ODAN, Perera PIP, Jayasinghe CVL. Proximate Composition, Physicochemical, Functional, and Antioxidant Properties of Flours from Selected Cassava (Manihot esculenta Crantz) Varieties. Int J Food Sci. 2021;2021.
11. Emmanuel OA, Clement A, Agnes SB, Chiwona-Karltun L, Drinah BN. Chemical composition and cyanogenic potential of traditional and high yielding CMD resistant cassava (Manihot esculenta crantz) varieties. Int Food Res J. 2012;19(1):175–81.
12. Seveline S, Heldyana R, Kurniawati S. The Use of Three Species of Lactic Acid Bacteria in the Mocaf (Modified Cassava Flour) Production. Ind J Teknol dan Manaj Agroindustri. 2020;9(3):163–72.
13. Putri NA, Subagio A, Diniyah N. Pasting Properties of Mocaf (Modified Cassava Flour) Using Rapid Visco Analyzer With Variations of pH Solution. Food Sci J. 2022;4(1):18.
14. Sulistyo J, Nakahara K. Cassava Flour Modification by Microorganism. 1st Int Symp Microb Technol Food Energy Secur Kasetsart Univ. 2013;(November 2013).
15. Oboh G, Akindahunsi AA. Nutritional and toxicological evaluation of Saccharomyces cerevisae fermented cassava flour. J Food Compos Anal. 2005;18(7):731–8.
16. Yi B, Hu L, Mei W, Zhou K, Wang H, Luo Y, et al. Antioxidant phenolic compounds of cassava (Manihot esculenta) from Hainan. Molecules. 2011;16(12):10157–67.
17. Akingbala JO, Oguntimein GB, Abass AB. Effect of processing methods on quality and acceptability of fufu from low cyanide cassava. J Sci Food Agric. 1991;57(1):151–4.
18. Helmi RL, Khasanah Y, Damayanti E, Kurniadi M, Mahelingga DE. Modified Cassava Flour (Mocaf): Optimalisasi Proses dan Potensi Pengembangan Industri Berbasis UMKM. Modified Cassava Flour (Mocaf): Optimalisasi Proses dan Potensi Pengembangan Industri Berbasis UMKM. Jakarta: LIPI Press; 2020.
19. Hartati, Fathoni A, Kurniawati S, Hartati NS, Sudarmonowati E. Technological innovation in the protection of beta carotene on MOCAF production which is rich in beta carotene. Nusant Biosci. 2017;9(1):6–11.
20. Sigüenza-Andrés T, Gallego C, Gómez M. Can cassava improve the quality of gluten free breads? Lwt. 2021;149(March).
21. Widanti YA, Nur'Aini V, Wulandari YW, Sari EEK. Gluten-free cake formulation using mocaf and several types of flour from local food ingredients. IOP Conf Ser Earth Environ Sci. 2021;828(1).
22. Andiani R, Rosida DF, Kurnianto MA. Chemical Characteristics of Gluten-Free Noodle Made from Mocaf and Porang Flour. AJARCDE (Asian J Appl Res Community Dev Empower. 2023;7(3):124–8.
23. Khasanah Y, Nurhayati R, Ariani D, Kurniadi M. Characteristics and consumer acceptance of product based on modified cassava flour (mocaf) produced by SME in Gunungkidul. IOP Conf Ser Earth Environ Sci. 2020;462(1).
24. Wulandari YW, Mustofa A. Chemical Charateristic of mocaf flour with variation fermentation by spontaneous and youghurt as inoculum starter. 2001;1(1):18–22.
25. Afifah DN, Ma'ruf A, Putri RN, Hamad A, Santosa AP. Production of High Protein MOCAF (Modified Cassava Flour) Using Papain and Lactic Acid Bacteria. Molekul. 2024;19(1):152–61.
26. Widanti Y, Putro E, Ayuningtyas P. Glycemic Index and Glycemic Load of Gluten-free Brownies Made from Combination of Mocaf and Black Glutinous Rice Flour. 2020;(18):139–45.

27. Kardhinata EH, Purba E, Suryanto D, Rusmarilin H. Modified cassava flour (MOCAF) content of cassava (Manihot esculenta CRANTZ) in North Sumatera. IOP Conf Ser Earth Environ Sci. 2019;260(1).
28. Assalam S, Asmoro NW, Tari AIN, Hartati S. Pengaruh Ketebalan Irisan Chips Singkong Dan Lama Fermentasi Terhadap Sifat Fisiko Kimia Tepung Mocaf (Modified Cassava Flour). AGRISAINTIFIKA J Ilmu-Ilmu Pertan. 2019;3(1):31.
29. ALMAZAN AM. Influence of Cassava Variety and Storage on Gari Quality. Trop Agric. 1992;69(4):386–90.
30. Idowu MA, Akindele SA. Effect of storage of cassava roots on the chemical composition and sensory qualities of gari and fufu. Food Chem. 1994;51(4):421–4.
31. Blanshard AFJ, Dahniya MT, Poulter NH, Taylor AJ. Fermentation of cassava into foofoo: Effect of time and temperature on processing and storage quality. J Sci Food Agric. 1994;66(4):485–92.
32. Gunawan S, Widjaja T, Zullaikah S, Ernawati L, Istianah N, Aparamarta HW, et al. Effect of fermenting cassava with Lactobacillus plantarum, Saccharomyces cereviseae, and Rhizopus oryzae on the chemical composition of their flour. Int Food Res J. 2015;22(3):1280–7.
33. Oyewole OB. Characteristics and significance of yeasts’ involvement in cassava fermentation for “fufu” production. Int J Food Microbiol. 2001;65(3):213–8.
34. Achi OK, Akomas NS. Comparative assessment of fermentation techniques in the processing of fufu, a traditional fermented cassava product. Pakistan J Nutr. 2006;5(3):224–9.
35. Mauroh DA, Hasanah YR, Mulyadi AH. Effect of Starter Concentration and Fermentation Time on the Characteristics of Modified of Cassava Flour (Mocaf). Res Chem Eng. 2023;2(1):23–8.
36. Damayanti E, Kurniadi M, Helmi RL, Frediansyah A. Single starter Lactobacillus plantarum for modified cassava flour (mocaf) fermentation. IOP Conf Ser Earth Environ Sci. 2020;462(1):2–8.
37. Sakai T, Nakagawa Y. Diterpenic stress metabolites from cassava roots. Phytochemistry. 1988;27(12):3769–79.
38. Buschmann H, Rodriguez MX, Tohme J, Beeching JR. Accumulation of hydroxycoumarins during post-harvest deterioration of tuberous roots of Cassava (Manihot esculenta Crantz). Ann Bot. 2000;86(6):1153–60.
39. Indrianingsih AW. Physicochemical properties, antioxidant activities, β carotene content, and.pdf. Bioact Carbohydrates Diet Fibre. 2024;31:1–8.
40. Indrianingsih AW, Apriyana W, Nisa K, Rosyida VT, Hayati SN, Darsih C, et al. Antiradical activity and physico-chemical analysis of crackers from cucurbita moschata and modified cassava flour. Food Res. 2019;3(5):484–90.
41. Indrianingsih AW, Rosyida VT, Apriyana W, Darsih C, Kusumaningrum A, Hayati SN, et al. Antioxidant, physicochemical, and sensory properties of crackers prepared from beta carotene rich-modified cassava (Manihot esculenta) flour (BCR-mocaf) and pumpkin (Cucurbita moschata) seed, rind, or flesh flour. AIP Conf Proc. 2022;2493(December).
42. Aderinola TA, Makinwa OJ, Aderehinwo OM. Proximate composition, functional and bioactive properties of cassava, garden egg and sorghum residue composite flours. Food Humanit. 2023;1(November):1576–83.

43. Reinaldo JS, Milfont CHR, Gomes FPC, Mattos ALA, Medeiros FGM, Lopes PFN, et al. Influence of grape and acerola residues on the antioxidant, physicochemical and mechanical properties of cassava starch biocomposites. Polym Test. 2021;93.
44. Adefegha SA, Okeke BM, Oyeleye SI, Oboh G. Effects of processing on starch composition, glycemic indices, phenolic profile, and possible antidiabetic properties of cassava (Manihot esculenta) flours. J Food Process Preserv. 2021;45(7):1–9.
45. Adeola AA, Idowu MA, Oyatogun RM, Adebowale A-RA, Afolabi WAO, Adigbo SO. Quality of cassava flour as affected by age at harvest, cropping system and variety. Agric Trop Subtrop. 2020;53(4):187–98.
46. Enesi RO, Hauser S, Pypers P, Kreye C, Tariku M, Six J. Understanding changes in cassava root dry matter yield by different planting dates, crop ages at harvest, fertilizer application and varieties. Eur J Agron. 2022;133:126448.
47. Amanu FN, Susanto WH. MOCAF Production in Madura (Study of Varieties and Plantation Sites) Toward Quality and Yield. J Pangan Dan Agroindustri. 2014;2(3):161–9.
48. Diniyah N, Subagio A, Nur Lutfian Sari R, Gita Vindy P, Ainur Rofiah A. Effect of Fermentation Time and Cassava Varieties on Water Content and the Yield of Starch from Modified Cassava Flour (MOCAF). Indones J Pharm Sci Technol. 2018;5(2):71.
49. Wa ode N, Darmawati E, Suro Mardjan S, Khumaida N. Komposisi Fisikokimia Tepung Ubi Kayu dan Mocaf dari Tiga Genotipe Ubi Kayu Hasil Pemuliaan. J Keteknikan Pertan. 2021;8(3):97–104.
50. Putri NA, Herlina H, Subagio A. Karakterisasi mocaf (Modified Cassava Flour)berdasarkan metode penggilingan dan lama fermentasi. J Agroteknologi. 2018;12(01):79.
51. Kurniati LI, Aida N, Gunawan S, Widjaja T. Pembuatan Mocaf (Modified Cassava Flour) Dengan Proses Fermentasi menggunakan Lactobacillus plantarum, Saccharomyces cereviseae, dan Rhizopus oryzae. 2012;1(1):1–6.
52. Darmawan MR, Andreas P, Jos B, Sumardiono S. Modifikasi Ubi Kayu dengan Proses Fermentasi Menggunakan Starter Lactobacillus casei Untuk Produk Pangan. 2013;2(4):137–45.
53. Odey GN, Lee WY. Evaluation of the quality characteristics of flour and pasta from fermented cassava roots. Int J Food Sci Technol. 2020;55(2):813–22.
54. Amri E, Pratiwi P. Pembuatan Mocaf (Modified Cassafa Flour) Dengan Proses Fermentasi Menggunakan Beberapa Jenis Ragi. J Pelangi. 2015;6(2).
55. Aisah A, Harini N, Damat D. Pengaruh Waktu dan Suhu Pengeringan Menggunakan Pengering Kabinet dalam Pembuatan MOCAF (Modified Cassava Flour) dengan Fermentasi Ragi Tape. Food Technol Halal Sci J. 2021;4(2):172–91.
56. DeFronzo RA. Insulin resistance, lipotoxicity, type 2 diabetes and atherosclerosis: The missing links. The Claude Bernard Lecture 2009. Diabetologia. 2010;53(7):1270–87.
57. Shimotoyodome A, Suzuki J, Fukuoka D, Tokimitsu I, Hase T. RS4-type resistant starch prevents high-fat diet-induced obesity via increased hepatic fatty acid oxidation and decreased postprandial GIP in C57BL/6J mice. Am J Physiol - Endocrinol Metab. 2010;298(3):652–62.
58. Tachibe M, Kato R, Sugano S, Kishida T, Ebihara K. Hydroxypropylated tapioca starch retards the development of insulin resistance in KKAy mice, a type 2 diabetes model, fed a high-fat diet. J Food Sci. 2009;74(7):232–6.

59. Firdaus J, Sulistyaningsih E, Subagio A. Resistant Starch Modified Cassava Flour (MOCAF) improves insulin resistance. Asian J Clin Nutr. 2018;10(1):32–6.
60. Hardoko, Hafidz YA, Sasmito BB, Halim Y. Antidiabetic Potency and Characteristics of Corn Flour and Cassava Flour-Based Rice Analog Added with R. mucronata Mangrove Fruit Flour and E. cottonii Seaweed Flour. 2020;194(FANRes 2019):199–204.
61. Wahjuningsih SB, Haslina, Untari S, Wijanarka A. Hypoglycemic effect of analog rice made from modified cassava flour (Mocaf), arrowroot flour and kidney bean flour on STZ-NA induced diabetic rats. Asian J Clin Nutr. 2018;10(1):8–15.
62. Maharani SR, Pamela VY, Kusumasari S. the Review of Snack Bar From Chia - Mocaf As an Antidiabetic Food. Food Sci J. 2021;3(1):56.
63. Wylis Arief R, Novitasari E, Asnawi R. Food Diversification of Cassava as Functional Food Instead of Rice in Lampung. Planta Trop J Agro Sci. 2018;6(2):62–9.
64. Oke OL. The role of hydrocyanic acid in nutrition. Vol. 11, World review of nutrition and dietetics. 1969. p. 170–98.
65. Rao P V., Hahn SK. An automated enzymic assay for determining the cyanide content of cassava (Manihot esculenta crantz) and cassava products. J Sci Food Agric. 1984;35(4):426–36.
66. Yeoh HH, Tatsuma T, Oyama N. Monitoring the cyanogenic potential of cassava: The trend towards biosensor development. TrAC - Trends Anal Chem. 1998;17(4):234–40.
67. Idibie CA, Davids H, Iyuke SE. Cytotoxicity of purified cassava linamarin to a selected cancer cell lines. Bioprocess Biosyst Eng. 2007;30(4):261–9.
68. Joseph T, Sreejith S, Joseph, Sangeetha VP, Prajitha N, Vandana U, et al. Effect of cyanide ions (CN-) extracted from cassava (Manihotesculenta Crantz) on Alveolar Epithelial Cells (A549 cells). Toxicology. 2021;464(November):153019.
69. Pan YM, Zou T, Chen YJ, Chen JY, Ding X, Zhang Y, et al. Two new pentacyclic triterpenoids from the stems of Manihot esculenta. Phytochem Lett. 2015;12:273–6.
70. Adesemoye AO, Adedire CO. Use of cereals as basal medium for the formulation of alternative culture media for fungi. World J Microbiol Biotechnol. 2005;21(3):329–36.
71. Dabai YU, Muhammad S. Cassava starch as an alternative to agar-agar in microbiological media. African J Biotechnol. 2005;4(6):573–4.
72. Jadhav P, Sonne M, Kadam A, Patil S. “Formulation of Cost Effective Alternative Bacterial Culture Media Using Fruit and Vegetables Waste.” Int J Curr Res Rev. 2018;(January):5–15.
73. RIni CS, Saidi IA, Rohmah J. Modified Mocaf Flour (Modified Cassava Flour) As Alternative Culture Media for Growth Bacteria Escherichia coli and Bacillus cereus Modifikasi Tepung Mocaf (Modified Cassava Flour) Sebagai Media Kultur Alternatif Untuk Pertumbuhan Bakteri Escherichia col. Procedia Scoial Sci Humanit. 2022;3(c):867–71.
74. Ariani RP, Ekayani IAPH, Masdarini L. Processing mocaf into pie susu with the addition of super food “spirulina.” J Phys Conf Ser. 2021;1810(1).
75. Fardiaza GA, Timur Ina P, Pratiwi IDPK. Pengaruh Perbandingan Modified Cassava Flour (Mocaf) dan Puree Wortel (Daucus carota L.) Terhadap Karakteristik Cake. J Ilmu dan Teknol Pangan. 2021;10(3):513.
76. Wang L, Wang L, Zhang N, Li M, Li Z. Glucose metabolic effects of oat noodles with different processing in type 2 diabetic mice. J Cereal Sci. 2019;88(May):125–31.
77. Chen M, Wang L, Qian H, Zhang H, Li Y, Wu G, et al. The effects of phosphate salts on

the pasting, mixing and noodle-making performance of wheat flour. Food Chem. 2019;283(May 2018):353–8.

78. Ni’matullah Al-Baarri A, Widayat, Cahyono B, Baety Nirbaya A, Khairunnisa U, Pangestika W. The Color Analysis of Noodle Made from Modified Cassava Flour. IOP Conf Ser Earth Environ Sci. 2020;518(1):8–12.
79. Hasrini RF, Aviana T, Khoiriyah A. Fortification of Modified Cassava Flour (Mocaf) Cookies with Rich Nutrition Vegetable Powder. E3S Web Conf. 2021;232:3–10.
80. Ratnawati L, Desnilasari D, Kumalasari R, Surahman DN. Characterization of modified cassava flour (Mocaf)-based biscuits substituted with soybean flour at varying concentrations and particle sizes. Food Res. 2020;4(3):645–51.