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Extraction of mucilage from Ogbono (*Irvingia gabonnensis*), Okra (*Abelmosus esculentus(L) monech*) and Achi (*Brachystegia eurycoma*) using microwave assisted Method

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Abstract

This study investigated the extraction of mucilage from the plant seeds of Ogbono (Irvingia gabonnensis), Okra (Abelmosus esculentus(L) monarch), and Achi (Brachystegia eurycoma) using microwave-assisted extraction (MAE) method and the results compared to the conventional extraction method. Mucilage which is widely used in both food, cosmetic, and pharmaceutical industries as a thickener, binder, emulsifier, stabilizer, etc is mainly extracted using solvent extraction method (conventional method) but microwave assisted method has proven to be more efficient with higher yield and reduced boiling timet by this study. The plant has been extracted by conventional and microwave-assisted methods for the isolation of mucilage. Microwave extraction at 420W intensity and 5 minutes heating duration increased 15.69%, 32.66%, and 22.64% for Achi, Okra, and Ogbono respectively in the yield(%) of mucilage when compared to the 1-hour conventional heating method. The effects of four extraction variables such as seed-to-water ratios (1:10-1:60w/w), temperatures (30-100ºC), pH (3-11), and time (3-20minutes) for MAE, 30-120minutes for CE) on the yield of mucilage of the three seeds were also evaluated. . It was observed that the MAE recorded highest yield of mucilage of 20.669% for Achi , 51.31 for Ogbono and 37.885% for Okra. It was concluded that microwave heating is very effective for the extraction of mucilage from plant seeds by producing a better mucilage yield and reduced heating time It was also concluded that four process parameters investigated affect the yield of mucilage of the seeds studied. The microwave developed procedure can be recommended for both commercial and laboratory isolation of mucilage from plant seeds.

Keywords: Mucilage, Irvingia gabonnensis, Abelmosus esculentu, Brachystegia eurycoma, Mucuma.*spp. Microwave*

1. Introduction

In the recent past, the undesirable consequences of non-natural polymers on human health and the environment (non-biodegradability, non-biocompatibility, and cyst formation) have limited their usage in therapeutic and industrial applications (Lehner, et al,,2019). Therefore, interest in plant-derived viscous polysaccharides, including mucilage and gums, has been increasing in the food, pharmaceutical, and other industries due to their diverse functional properties, such as emulsifying, binding, coating, gelling, thickening, and stabilizing properties (Tosif, et al,, 2021). Furthermore, mucilage is an eco-friendly, cost-effective, edible polysaccharide and is mainly extracted from living organisms, e.g., bacteria, fungi, plants, animals, and algae (Chawla, et al,,2021). Among the plant kingdom flaxseed, Ogbono, chia seed, Achi seed, basil seed, Ukpo seeds, and Okra are the richest sources of mucilage.

Mucilage from plant seeds had been extensively used in food systems as additives, emulsifiers, stabilizers, gelling agents, and texture modifiers, due to the safety profile, ease of availability, low cost, and biodegradable nature of mucilage [Junior, et al,2013]. Mucilaginous materials are polysaccharides in nature and have been extensively used in every sphere of life (You, et al, 2022). Moreover, mucilage has been exploited in the human diet (as a food ingredient substitute or additive) (Dhama, et al, 2021.). Even at low concentrations, mucilage has excellent viscosity, water-holding capacity, oil-holding capacity, and antimicrobial activity. Thus, these remarkable functional properties make mucilage a promising ingredient with possible applications as a fat replacer (Ribes, et al,2021), gel former, thickener (Ma, et al, 2021), and emulsifier (Lise, et al, 2021.). Chemically, mucilage is a physiological product of plant metabolites and is composed of polysaccharide units of L-rhamnose, D-galactose, D-xylose, and L-arabinose. It also contains organic acids and a small number of proteins (Mansuri, et al.,2022).

The physicochemical, functional, and chemical compositions of mucilage are highly dependent upon the origin and the types of extraction and purification methods. For example, okra mucilage is composed of (1,2)-rhamnose and (1,4)-galacturonic acid residues with disaccharide side chains (Dantas, et al, 2021.). Similarly, psyllium mucilage is composed of β-D-1,4-linked xylol-pyranose components substituted by α′-L-arabino-furanose fractions with a xylose/arabinose ratio of 3:1 (Matus, et al, 2022.).Several investigations by Habtamu et al.,(2018), Nwakaudu et al.,(2017), and Okoro and Igbokwe (2023) have reported different functional properties of the mucilage from Ogbono, Okra and Achi, seeds, for example, Olusola et al.,(2020) reported the binding in tablet formulation and concluded that incorporation of Ogbono mucilage increased disintegration and dissolution times and as such could be used to modify drug release

Irvingia gabonnensis genus of African and southeast Asia trees belong to the family of Irvingiacea, sometimes known by the names, wild mango, African mango, bush mango, dika, or Ogbono. They bear mango-like fruit which are especially valued for their fat and protein-rich nut. They are grown for their fruits and kernels popularly known as Ugiri and Ogbono (Igbo language) respectively in Nigeria (Ohaeri, 2015). It has both edible (Irvingia gabonnensis) and non-edible fruits (irvingia wombolu). The edible is eaten fresh or used to make juice and the kernel when ground is used to make Ogbono soup but the non-edible is likely grown for the production of Ogbono from its kernel. Research by Ehiem and Simonnyan, (2012) show that the kernel powder can be used as ingredient in other sauces like tomatoes and groundnut for a sticky effect and taste. The seed of the plant contains lipids and polymeric constituents (Ogaji, et al., 2012). The lipids component of Ogbono seed has been traditionally extracted using n-hexane or solvent such as ethanol and enzymatic method (Shittu and Njinga, et al., 2018). Irvingia gabonnensis (Ogbono) seed consists of approximately 62.8% of fats and 19.79% of carbohydrates. Protein is about 8.9% dietary fiber 5.3% and ash 3.2% (Asori, et al., 2020). Similarly, Oluwaseun et al., (2015) showed that the nutritional composition of Irvingia Wombolu seed contains 8.65% protein,14.6% carbohydrate, 2.1% moisture, 1.4% crude fiber, 16.8% ash, and 38.9% dietary fiber.

Okra (Abelmosus esculentus(L) monarch) is a popular vegetable crop grown in most parts of Nigeria and other tropical countries. It is a member of the Malvaceae family (Misheha and Muhammed, 2018, Katung, 2019). The crop is usually grown in Nigeria for its mucilaginous content. The pods vary in length, color, and smoothness depending on the variety and it grows best in well-drained rich soils. Okra is an erect animal plant that may grow up to 2m in height: the stem is green, sometimes with red traces, hairy and woody when mature. The leaves are 10-20cm long and broad-lobed with 5-7 lobes. The flowers are 4-8cm in diameter. Pods which contain numerous seeds are long or cylindrical and shiny when cut, their size and shape vary, pods are hairy in the young stage, furrowed along length when ripe (Mishelia and Muhammed, 2018). Mucilaginous extract from Okra is reportedly useful in curing ulcers as well as relief of vitamins A and C and also traces of vitamin B (Mishelia and Muhammed, 2018). Okra provides a good source of calcium and other body-building minerals that contributes to healthy living. Okra fruits provide numerous health benefits which are useful in treating cardiovascular, coronary heart disease, diabetes disorders, and chronic dysentery (Abd Elmoneim, et al.,2021).

Brachystegia eurycoma (“Achi”) was naturally found in tropical and subtropical areas. (Bafor et al., 2017). Brachystegia eurycoma is locally known as “Achi” by the Igbo, “Akolodo” by Yoruba’, “Okweri” by the Benin: ‘Eku’ by the Isharis; “Ukung’ by the Efiks; ‘akpakpo’ by ijaws and ‘oyani’ by the kwales. Achi belongs to the same family Leguminosae as well as the same sub-family caesalpiniecea “Achi” is an important and economic source of protein, carbohydrates, and calories as well as certain vitamins and minerals (Nwakaudu et al.,2017) These nutrients are essential to human nutrition but the composition of this nutrient in them differs. The protein of these foods is rich in lysine but deficient in sulphur-containing amino acids, particularly cysteine, and methionine. Specifically, flour from ‘Achi’ has been found to be used in most states in Nigeria including Imo, Anambra, Enugu and other states as source of nutrient in food (Nwosu,2012). They are used as thickeners in traditional soup (for eating garri, pounded yam, or cocoyam and fufu). They are equally used as emulsifiers and flavouring agents in traditional soups due to their gum content. These gums are called the seed and food gums (Hydrocolloids). These are not true gums but are of simpler structure (Nwakaudu et al.,2017). These seed gums are extracted from their seeds when crushed into flour and, they have the ability to swell in water and these are able to influence the viscosity of the liquid. Apart from this culinary use, it is possible for these gums when used as addictive in other foods to impact desirable textural and functional properties of the finished food product particularly the ‘Convenience foods’ (Oladipo et al.,2013)

In recent time microwave heating has been found to be a comfortable source of energy in the kitchen and chemical laboratories for the extraction of various plant products (Roberto et al.,2017) Many of the most relevant eco-friendly chemistry are most appropriate for microwave techniques. Microwave is one of the elementary, rapid, clean, eco-friendly, and efficient methods of extraction. It saves energy, fuel, and electricity (Antonios and Spridon, 2013). A very short heating time and better yields of the products are the main benefits of microwave heating. Commercial microwave ovens are used to generate energy in chemical laboratories for efficient heating of water, moisture analysis, wet ash of biological and geological materials, waste material management, sterilization of pharmaceutical preparations, in activation of enzymes in food products, etc (Wahidn et al.,2014). In the recent past, a large use of this process is seen in the stimulation of organic reactions for rapid and green synthetic procedures (Zheng et al.,2018).

Extraction is one of the most important points in the logical chain in the effort of achieving a full recovery of target compounds. Lately, microwave energy is being used for the extraction of phyto-constituents from plants (Fongang et al.,2018). Microwave extraction has the same principle as that of maceration or percolation. The only diversity is simply the speed of disintegration of plant cells and plant tissues which is much higher (Iqra et al.,2019) in the former. Microwave-assisted isolation method require less time, fewer solvents, a higher extraction rate, and better products with lower costs. The microwave comprises a number of radiation cells in order to shape the required energy (Pravin et al.,2013). Presently, an ecological-friendly method like a microwave–assisted extraction “MAE” is commonly used to extract polysaccharides from various kinds of plant materials due to enhanced extraction efficiency, reduced both extraction time and solvent consumption, compared to other conventional methods (Lamia et al., 2015). Currently much work has not be carried on the extraction of mucilage from these plant seeds commonly found in South Eastern part of Nigeria using microwave-assisted method. Therefore the present study is aimed at comparing the mucilage extracts from three major plant seeds used as soup thickeners in Nigeria, obtained by conventional extraction ‘CE’ and microwave-assisted extraction ‘MAE” methods based on: (i) the determination of extraction yield, (ii) determination of the effects of process variables (solid-liquid ratio, heating duration temperature and pH) on the yield of mucilage

2.0 Material and methods

2.1. Material

The three seed samples (Achi, Ogbono and Okra) used for the extraction were purchased from local market (New Market) in Enugu, Nigeria. All the chemicals used are analytical grade and were purchased from Ogbete Main Market Enugu, Nigeria.

2.2. Methods

2.2.1 Preparation of seed samples

The seeds of the Achi, Ogbono, and Okra were dried at room temperature for one week for proper drying, and the dried samples were pulverized in a round machine operated with a 5 hp, 200kv electric motor. The pulverized samples were then stored in airtight plastic containers prior to the commencement of the extraction processes.

2.2.2. Isolation of mucilage by convectional procedure

50g of each powdered seed sample was soaked in distilled water (500ml) for 24 hrs in a round bottom flask. It was boiled at a temperature of 35ºC for 1 hr under reflux with seldom stirring and kept aside for 2 hrs for the release of mucilage into water. The pH was adjusted using acid (HCL) or alkaline (KOH) (Sandeep, et al., 2015). The above process was repeated at different levels of seed-to-water ratios (1; 10-1:60w/w), heating times (30-150mins), temperatures (30-100ºC), and pH (3-11). The material was filtered over a muslin bag and hot distilled water (100ml) was added through the sides of the marc and squeezed well in order to remove the mucilage completely (Lamia et al., (2015).

2.2.3. Isolation of mucilage by microwave procedure

The method approved by Balagani et al.,(2013) was used in this present study. Each seed flour sample (50g) was soaked in distilled water (500 ml) for 24 hours in a 1000 ml beaker. It was transferred into a microwave oven along with the glass tube to prevent jerking and subjected to microwave irradiation at 420W intensity at 35ºC for 5 minutes. The beaker was dislodged and reserved for 2 hours for the release of mucilage in water and it was filtered through a muslin bag with the addition of hot water through the sides of the mesh and later squeezed in order to extract the mucilage completely. The Extraction procedure was repeated at different levels of seed-to-water ratios (1:10-1:60w/w), microwave temperatures {30-100ºC), extraction times (5-30mins), and pH (3-11).

2.2.4. Precipitation of the isolated mucilage

The filtrate from both isolation methods was centrifuged at 500rpm for 20 minutes using centrifugation apparatus (SHARP R861 SLM, 900W). The supernatant was collected and cooled and the product was treated using 96% ethanol in a ratio of 1:5v/v for the precipitation of mucilage and the precipitate was washed several times using the same ethanol for total removal of unwanted impurities. The precipitate was then separated from the solvent and then dried in a hot air oven at 40ºC. The mucilage product was crushed and uniform particle size was obtained by sieving the mucilage powder. Percentage yield of mucilage was calculated using equation by Sandeep, et al.,(2015).

$$\%\ \text{yield (w/w)} = \frac{weight\ of\ extracted\ material\ (g)}{dry\ matter\ weight\ (g)} \times 100 \qquad (1)$$

3.0 Results and Discussions

The mucilage extracted by both methods were found to be identical in nature and will give positive results for the chemical analysis to be carried out.

3.1. Effect of process parameters on the extraction yield of mucilage from Achi, Ogbono and Okra seeds.

3.1.1. Effect of seed-to-water ratio(w/w) on the yield of mucilage.

The results of effect of process variables such as seed- to- water ratio, temperature, pH and time on the yield of mucilage for three seeds under study were shown in Figure 3.1a to 3.4c. The effect of seed –to- water ratio for Achi, Ogbono, and Okra (at microwave temperature of 70ºC, pH of 3, and heating time of 30 mins) as shown in Figure 3.1a, 3.1b, and 3.1c respectively revealed that as seed- to- water ratio increased from 1:10 to 1:50, for both microwave- assisted method and conventional method, the mucilage yield increased significantly and decreased as seed-water- ratio decreased. Initially seed-to-water ratio of 1:10 and 1:20 were tested on the extraction of Achi mucilage and it was discovered that insignificant mucilage yield was obtained but for Okra and Ogbono significant amounts were recorded, From the above results it has been established that a moderate seed-to-water ratio gave the highest mucilage yield for both extraction methods adopted in this study. These agree with the results of Syed et al., (2022) and Oladipo et al (2013) which revealed that higher mucilage yield of Mimosa Pudica and Lagenaria Siceraria respectively were obtained at the moderate seed–to–water ratio. This is due to the fact that increasing the seed-to-water ratio may increase the diffusivity of the solvent into cells and enhance the desorption of polysaccharides from the cells (Lamina et al.,2015).

Based on the principles of mass transfer, the concentration gradient between the bulk of the extracting solvent and the solid is the driving force for the material transfer. The concentration gradient will increase by increasing the quantity of solvent, and hence a higher extraction yield might be expected. At low seed/water ratios, a meager amount of solvent can reduce the solvent's ability to enter the seed matrix: hence, the extraction yield decreases. Contrarily, at high seed-to-water ratios, the extraction of unwanted compound from the seed matrix can be formed, consequently, the extraction yield and purity decreases (Manzar, et al.,2023). Also discovered in this present study is that the microwave extraction method produced higher yield when compared to the conventional method. From the results, it was recorded that the microwave method increased the yield by 15.69%, 32.66%, and 22.64% for Achi, Okra, and Ogbono respectively when compared to the conventional method. These agreed with the results of Antonios and Spyridon (2013) which recorded an 11.55% increase in mucilage yield of Abelmoschus Esculentus , and Abd Elmoniem et al (2021) which obtained between 20-30% increase in yield compared to conventional method.

Table 3.1a; Effect of seed/water ratio on mucilage yield of Achi Seed..

S/N	Seed/ water ratio (w/w)	Conventional Yield (%)	Microwave Yield (%)
1	1;30	15.345	16.046
2	1;40	17.660	18.431
3	1;50	17.197	20 .669
4	1;60	14.234	14.943
5	1;70	10.368	11.784

Table 3.1b: Effect of Seed-to-waterratio on mucilage yield of Ogbono

S/N	Seed/water (w/w)	Conventional Method	Microwave Method
1	1:10	4.63	-
2	1:20	19.89	2.745
3	1:30	19.77	18.095
4	1:40	13.10	24.245
5	1:50	10.284	24.245
6	1:60	8.382	11.418

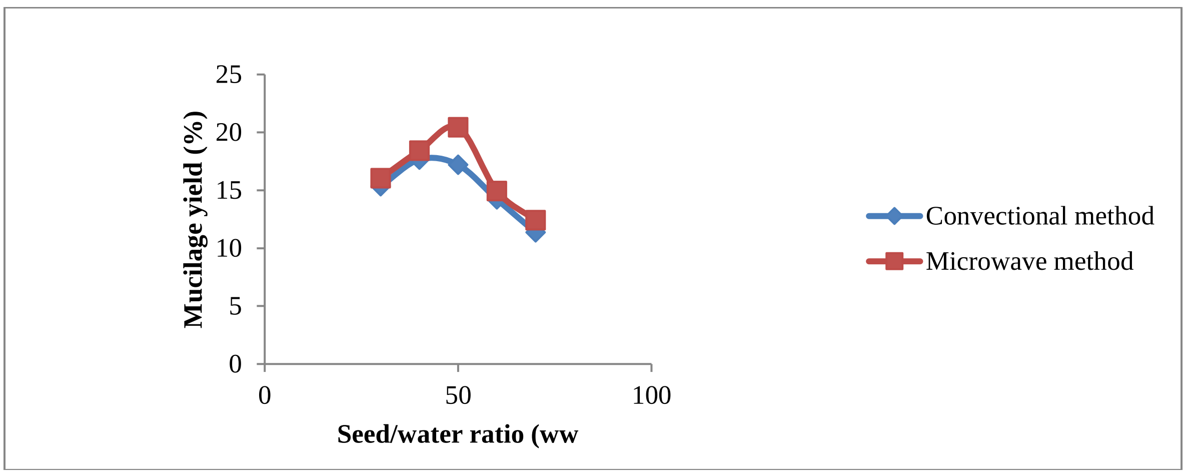


Figure 3.1(a) ; Effect of solid- to- water on the yield of Achi seed mucilage.

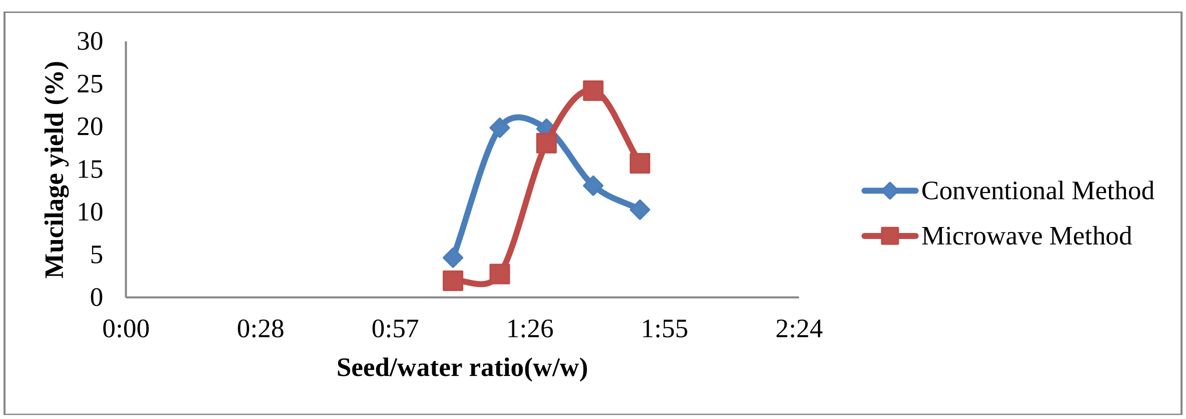


Figure 3.1b: Effect of seed-to-water ratio on mucilage yield of Ogbono seed

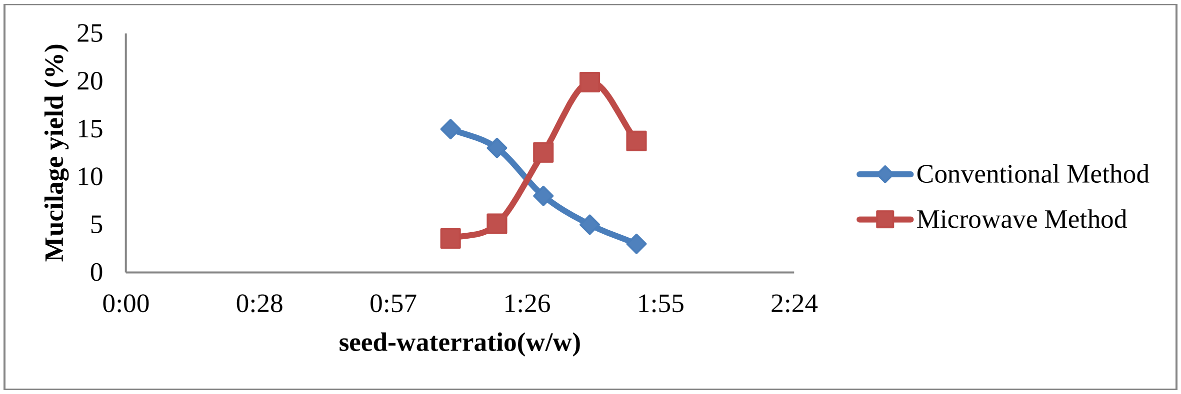


Figure 3.1(a); Effect seed-to-water ratio on the mucilage yield of Okra seed.

Table 3.1c:Effect of seed-water- ratio on mucilage yield of Okra seeds.

S/N	Seed/water (w/w)	Conventional Method	Microwave Method
1	1:10	15	3.538
2	1:20	13	5.083
3	1:30	8	12.546
4	1:40	5	19.899
5	1:50	3.	13.749
6	1:60	2.20	9.852

Table 3.2a; Effect of temperature on mucilage yield of Achi seed.

S/N	Microwave temperature (^{0}C)	Conventional Yield(%)	Microwave Yield(%)
1	30	4.98	8.345
2	50	5.44	12.013
3	70	7.22	8.570
4	90	9.03	7.358
5	100	5.675	6.213

3.1.2. Effect of temperature on the mucilage yield

The effect of temperature on mucilage yield was investigated in the range of 30 to 100 ºC, the results are shown in Figures 3.2a, 3.2b, and 3.2c for Achi, Ogbon, and Okra respectively. It was discovered that with an increase in temperature from 30 to 70ºC, the mucilage yield increased from 4.251 to 11.619% for Achi, 4.98 to 9,03% for Ogbono when the conventional method was used. Similarly, as the temperature increased from 30 to 50ºC, the mucilage yield increased from 8.345 to 12.013% for Achi, 36.310 to 51.310% for Ogbono with microwave extraction method.. Further increase in temperature resulted to decrease in mucilage yield. In another development, the mucilage yield was highest (12%) at the temperature of 30ºC for Okra (conventional method) and increased from 10.858 to 14.171% as the temperature increased from 30 to 80ºC for Okra seed (microwave method). The above results are in accordance with the result of Lamina, et al., (2015) and Manzar, et al.,(2023) which both revealed that an increase in temperature up 70ºC increased the mucilage yield of Opuntia Ficus-Indica Cladode and Quince respectively. This is because the high temperature might disturb the cell structure and steer to increased cell membrane permeability, complementing the target component solubility and mass transfer. Furthermore, high

3.2b: Effect of temperature on mucilage yield of Ogbono seed

S/N	Temperature (^{0}C)	Conventional Method	Microwave Method
1	30	4.98	36.309
2	50	5.44	51.310
3	70	7.22	24.790
4	90	9.03	7.156

Table 3.2c: Effect of temperature on the mucilage yield of Okra se

S/N	Temperature (^{0}C)	Conventional Method	Microwave Method
1	30	12	10.858
2	40	5.3	11.400
3	60	5	13.940
4	80	4.7	14.171
5	100	2.5	10.836

temperatures could result in the decomposition of some compounds such as the de-polymerization of some polysaccharides (Syed, et al.,2022, Manzar, et al.,2023). There is also a significant increase in mucilage yield of microwave method compared to conventional method for Achi and Ogbono seed at different temperatures

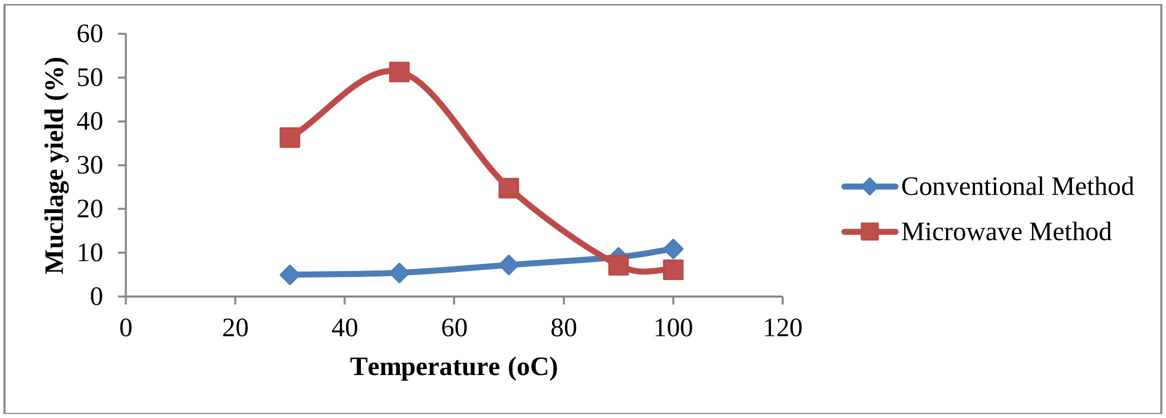


Figure 3.2(a); Effect of temperature on the yield of Achi seed mucilage.

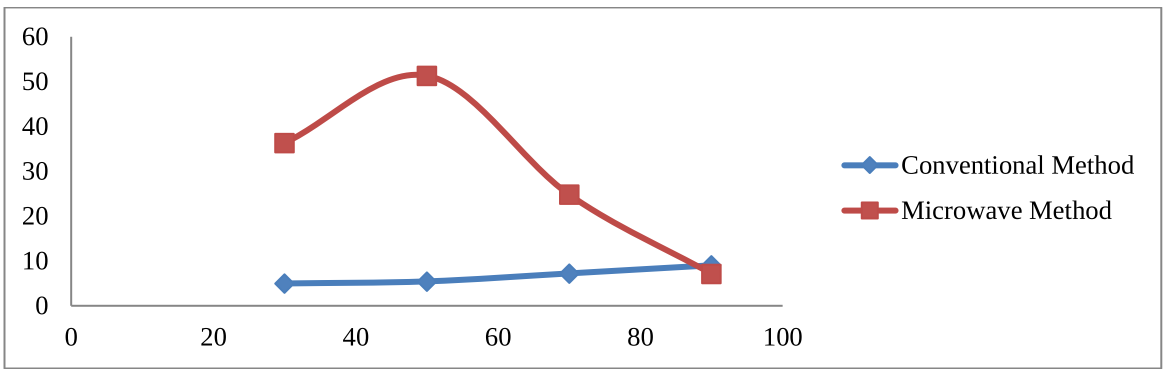


Figure 3.2(b): Effect of temperature on mucilage yield of Ogbono seed

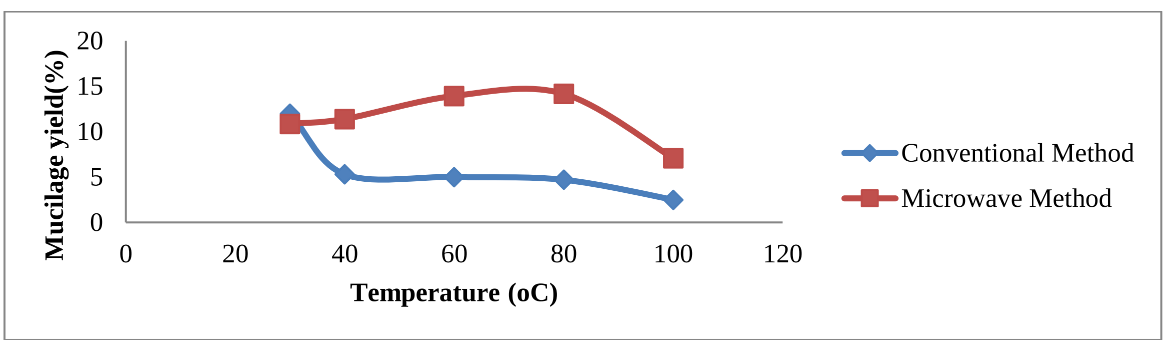


Figure 3.2(c); Effect of temperature on the mucilage yield of Okra seed

Table 3.3a: Effect of Ph on mucilage yield of Achi seed

S/N	Ph	Conventional Method (Yield %)	Microwave Method. (yield %)
1	3	17.660	24.790
2	5	20.104	41.869
3	7	16.940	32.573
4	9	15.640	30.272
5	11	13.451	21.602

3.1.3. Effect of pH on the mucilage yield

Figure 3.3a, 3.3b, and 3.3c depict the Effect of Ph on the yield of mucilage of Achi, Ogbono, and Okra seeds respectively. The effect of the pH of the three seeds under investigation was evaluated by varying the pH of the extraction medium from 1 to 11 keeping other extraction parameters such as seed-to-water ratio (1:40w/w), heating time (60min.), extraction temperature (50°C) constant. The results obtained show that Ph significantly affects the mucilage yield of all the seeds for both conventional and microwave extraction methods. It was also observed that the mucilage yield increased as pH increased from 3 to 7 for the three seeds when the conventional method was used.

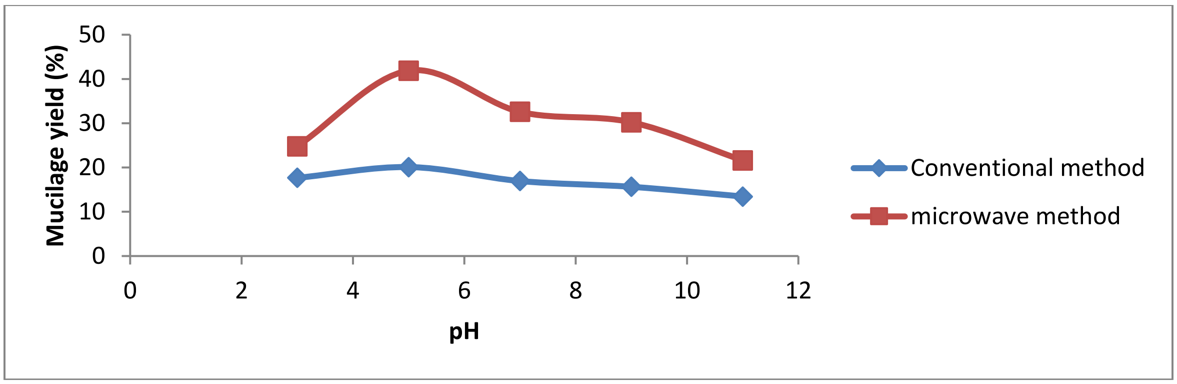


Figure 3.3(a); ; Effect of pH on the mucilage yield of Achi seed.

Table 3.3b:Effect of pH on mucilage yield of Ogbono seed.

S/N	pH	Conventional Method	Microwave Method
1	3	7.55	24.790
2	5	7.64	41.869
3	7	9.69	32.573
4	9	9.89	30.222
5	11	7.294	24.827

Table 3.3c: Effect of pH on the mucilage yield of Okra seed.

S/N	pH	Conventional Method	Microwave Method
1	3	0.8	10.858
2	5	2	9.868
3	7	15	22.686
4	8	1.4	37.385
5	11	3.7	24.827

A similar trend was reported by Syed, et al., (2022) and Mariana, et al.,(2021). Further increase in pH decreased the mucilage yield. The highest yield was recorded at a pH of 7 (20.101% for Achi, 9.99% for Ogbono, and 15% for Okra). This could be linked to the fact that insoluble polysaccharide fractions get converted into soluble ones (Syed, et al., 2022). With microwave extraction, the highest yield was obtained at a pH of 7 for Achi (26.913%), pH of 5 for Ogbono (41.869%), and PH of 8 for Okra (37.386%). Here the pH effect depends on the plant and other conditions of the microwave. Overall, a significant increase in the yield of mucilage was recorded with an increase in pH due to the separation of the acidic groups such as uranic acids and due to attraction between negatively charged ions, which lead to an increase in the solubility of the mucilage (Mariana, et al.,2021). The results also show that microwave extraction recorded more yield with increased pH compared to the conventional method.

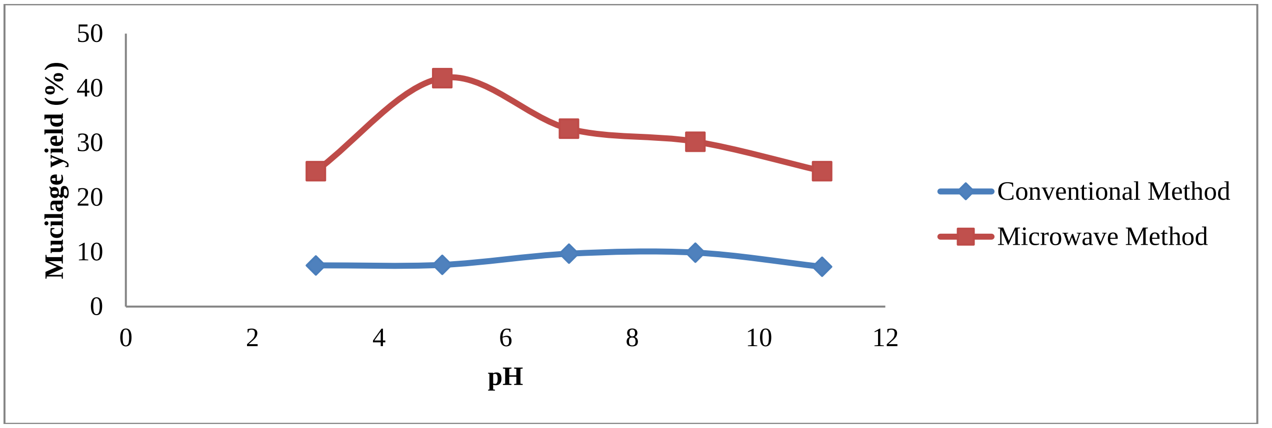


Figure 3.3(b): Effect of pH on mucilage yield of Ogbono seed

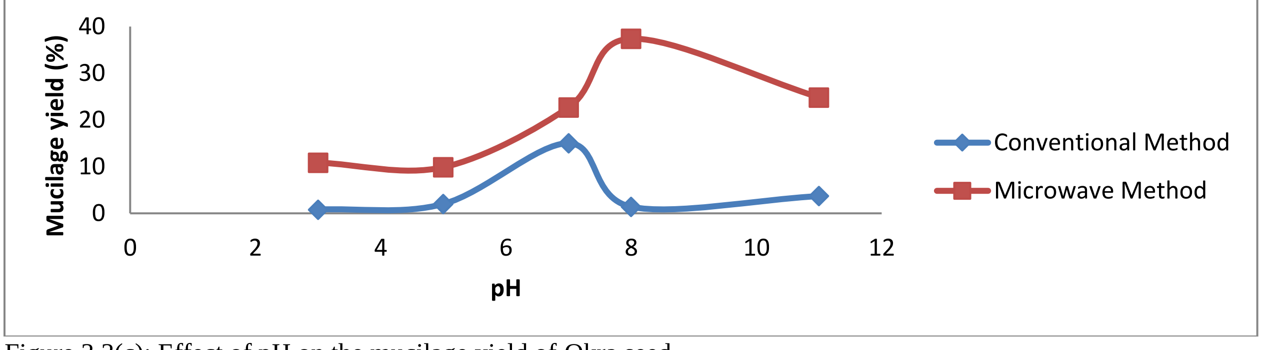


Figure 3.3(c); Effect of pH on the mucilage yield of Okra seed .

3.1.4. Effect of extraction time.

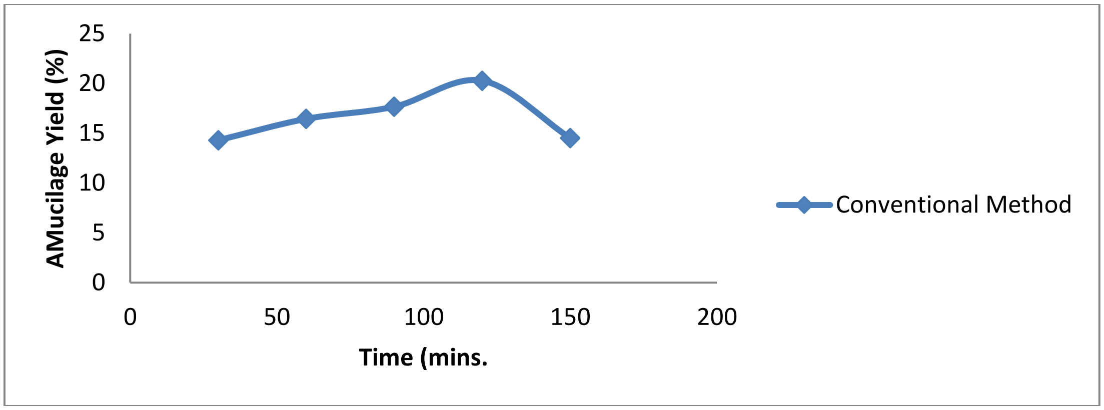
The effect of extraction time on the mucilage yield of Achi, Ogbono, and Okra for both conventional and microwave methods was studied within the time ranging from 30 to 120 minutes (conventional method and 5 to 30 minutes (microwave method) with other process parameters such as temperature 50ºC, seed-to-water ratio 1:40w/w, and pH 3 kept constant. The results are shown in Figures 3.4a, 3.4b, and 3.4c for Achi, Ogbono, and Okra respectively. In the study, it was discovered that a significant yield of mucilage was recorded between the ranges of 5 to

Table 3.4a: Effect of time on the yield mucilage of Achi seed.

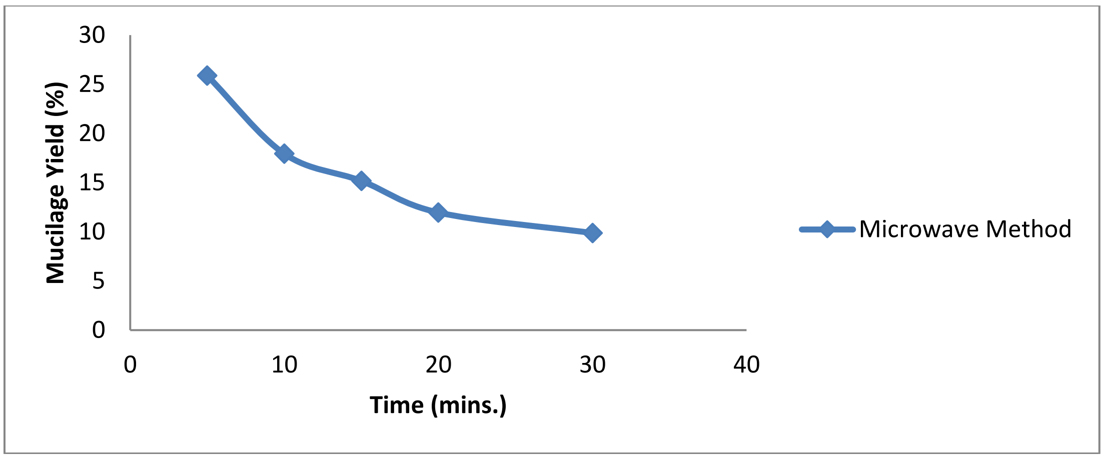
S/N	Time (min.)	Microwave Method	Time (mins.)	Conventional Method
1	5.00	25.807	30	14..294
2	10.00	18.612	60	16.440
3	15.00	16.013	90	17.660
4	20.00	11.958	120	20.272
5	30.00	8.964	150	13.903

Table 3.4b: Effect of time on mucilage yield of Ogbono seed

S/N	Time (min.)	Microwave Method	Time (mins.)	Conventional Method
1	5.00	20.679	30	6.77
2	10.00	24.790	60	7.93
3	15.00	25.125	90	8.51
4	20.00	30.024	120	9.57

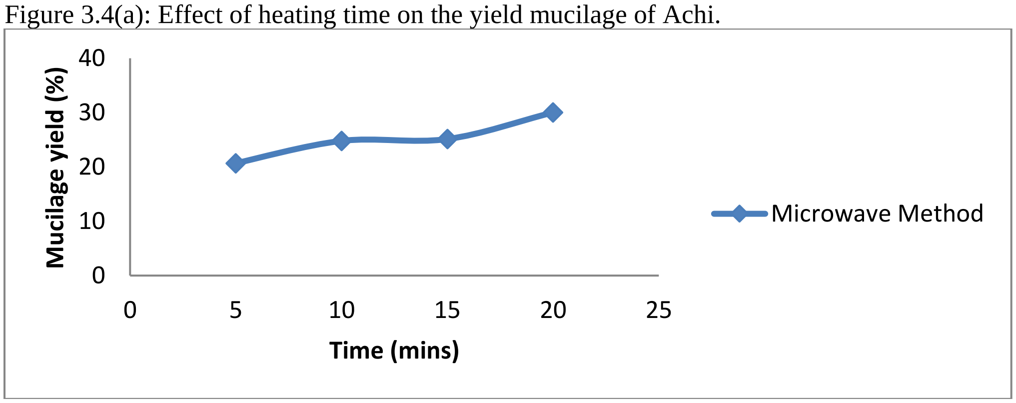


a(i); Conventional method

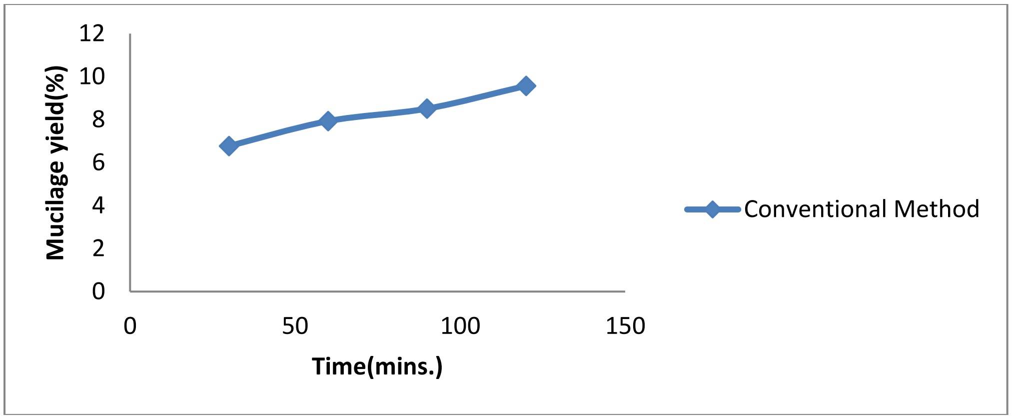


a(ii); Microwave method

Figure 3.4(a): Effect of heating time on the yield mucilage of Achi.



b(i) Microwave method

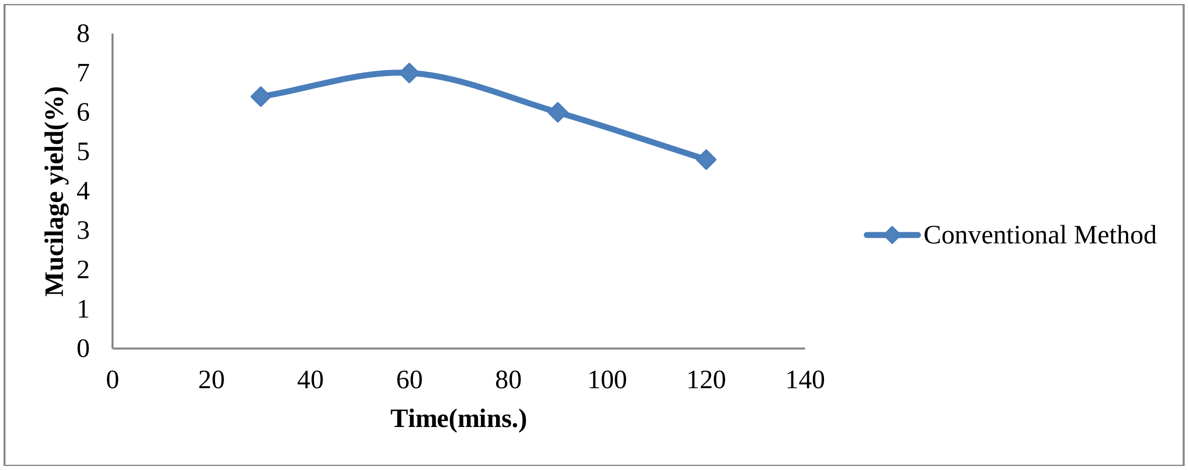


b(ii) Conventional method
Figure 3.4b:Effect of time on mucilage yield of Ogbono seed.

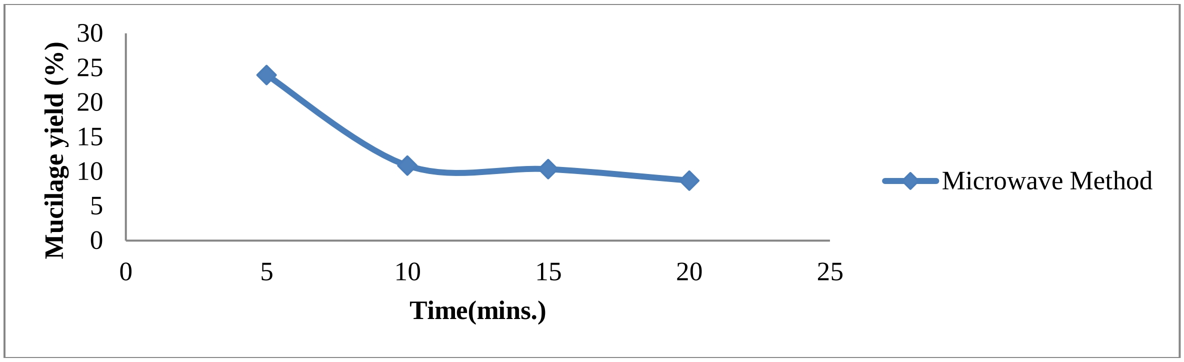
Table 3.4c: Effect of time on the yield mucilage of Okra seed.

S/N	Time (min.)	Microwave Method	Time (mins.)	Conventional Method
1	5.00	23.975	30	6.4
2	10.00	10.858	60	7
3	15.00	10.346	90	6
4	20.00	8.695	120	4.8

20 minutes for the microwave extraction method and 30 to 120 minutes for the conventional method. This is due to the fact that the speed of breaking up of plant cells and plant tissues is much higher under microwave conditions and this reduced process time is an economic advantage that will reduce the risk of decomposition or disintegration and oxidation of the important plant constituents (Antionos and Spridon2013). A report by Lamina et al.,(2015) also observed the reduced extraction time under the microwave method. From the results of the conventional



c(i) Conventional method



C(ii) Microwave method
Figure3.4b: Effect of time on the mucilage yield of Okra seed.

method, it was observed that the mucilage yield of Ach i (14.294 to 20.272%) and Ogbono (6.77 to 9.57%) increased with an increase in time from 30 to 120 minutes, while that of Okra increased from 6.6 to 7 % with an increase in time from 30 to 60 minutes. Further increase in time resulted in a decrease in mucilage yield. Different results were obtained with the microwave extracted method where the highest mucilage yield of Achi (15.807%) and Okra (23.975%) was recorded at 5mins, and that of Ogbono increased from 20.679 to 30.024% as time increased from 5 to 30mins with highest recorded at 30mins. This can be explained due to the fact that the cell wall integrity is destroyed by detaching the parenchymal cells with the effect of microwave radiation and better the interaction between the solvent and the soluble mucilaginous material (Hulya et al.,2023). Presently, there are no comparative studies for the microwave extraction method from the three seeds under study. Sameera et al., (2020) reported the highest yield of Chia seeds at 4.5mins It can be concluded here that the selected plant seeds produced a higher yield of mucilage in a shorter duration by the microwave method relative to the conventional method.

4.0. Conclusion

It has been established that microwave heating is very effective in the extraction of mucilage from Achi, Ogbon, and Okra seeds using ethanol as precipitating solvent.. The results showed that low solid to water (1:30 to 1:50w/w) gives higher mucilage yield in both microwave and conventional methods for the three seeds studied. With this, it is concluded that a low solid-to-water ratio is required to obtain a high yield of mucilage from any of the seeds under study. This agrees with the report by Lamia,et al.,(2015), Sameera and Subba,(2020), Mahdiye,et al.,(2023) and Hulya,et al.,(2023). Heating temperatures ranging from 30-70 ºC are more effective in the extraction of mucilage from the seeds of Achi, Ogbono, and Okra for both methods adopted. Similarly, pH and time also affected the mucilage yield in conventional and microwave methods. The results revealed that higher yields were obtained at different pH in each of the seeds which can lead to conclude that different seeds required different pH mediums for a better yield of mucilage. The microwave method recorded higher yields at lower time (less than 10 minutes), while better yields were obtained in the conventional method at very high time. This is in conformation with the literature (Sarahi et al.,2014, Lamia et al.,2016, and Mahdiye et al.,2023) which reported that the microwave extraction method gives a better yield at a very reduced time. The four process parameters such as seed-to-water ratio, temperature, pH and time studied showed positive effects on the mucilage yield of the seed investigated for both conventional and microwave methods. With the results achieved, it can be concluded that microwave extraction of mucilage from Achi, Ogbono, and Okra produced better yield and reduced process heating time relative to the conventional method. Above all, it can also be concluded that microwave heating is very effective for the extraction of mucilage from plant seeds. With microwave –assisted method, Okra plant seed produced a higher yield of the mucilage relative to Ogbono and Achi seeds. Further studies are required to optimize and evaluate the significance of these process parameters in the microwave extraction of these common seeds found in Igbo land in Nigeria so that their economic value can be raised.

5.0 Recommendation

It is recommended to adopt microwave-Assisted extraction method in mucilage isolation from plant seed due its high yield and short time.

Further studies are required to optimize and evaluate the significance of these process parameters in the microwave extraction of these common seeds found in Igbo land in Nigeria so that their economic value can be raised

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Nomenclature

HCL = Hydrochloric acid

Hr = hour

g = gramme

KOH = potassium hydroxide

ml = milliliter

mins = minutes

^{o}C = degree Celsius

S/N = serial number

W = watts

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