PJN
ISSN 1680-5194

# PAKISTAN JOURNAL OF NUTRITION

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

Pakistan Journal of Nutrition 8 (5): 558-567, 2009
ISSN 1680-5194

# Cocoyam Starch Modification Effects on Functional, Sensory and Cookies Qualities

M.C. Ojinnaka, E.N.T. Akobundu and M.O. Iwe
Department of Food Science and Technology, Michael Okpara University of Agriculture,
Umudike, P.M.B. 7267, Umuahia, Abia State, Nigeria

**Abstract:** Starches of fine texture from cormels of cocoyam (*Xanthosoma sagittifolium*), cultivar *Ede ocha* and cultivar *Ede uhie* were subjected to acid and enzyme modification treatments. Proximate composition, functional and amylograph pasting properties of the starches were evaluated. The starch samples were also used in the production of cookies at 5, 10, 15, 20 and 25% level of substitution with wheat flour. The cookies produced were subjected to proximate analysis and sensory evaluation. The result of the sensory evaluation showed that cookies prepared at 5% level of substitution were most acceptable. After eight weeks of storage in light polythene bags, the cookies prepared at 5 and 10% levels of substitution with wheat flour were found to be more acceptable by the panelists. Observations on the functional properties showed that the modified cocoyam starches exhibited higher bulk densities than the untreated starches. Native and modified starches with the high water absorption capacity and swelling index were produced from cultivar *Ede uhie*. There was no significant difference (p>0.05) in the solubility of the starch samples.

**Key words:** Cocoyam, starch, modification, cookies, *Ede ocha*, *Ede uhie*

## INTRODUCTION

Cocoyams (*Xanthosoma sagittifolium*) contribute significant portion of the carbohydrate content of the diet in many regions in developing countries and provide edible starchy storage corms or cormels. Although, they are less important than other tropical root crops such as yam, cassava and sweet potato, they are still a major staple in some parts of the tropics and sub-tropics (Opara, 2002).

Cocoyams have nutritional advantages over root crops and other tubers crops (Lyonga and Nzietchueng, 1986). It has more crude protein than root and other tubers and its starch is highly digestible because of the small size of the starch granules, its contents of calcium, phosphorus, vitamins A and B vitamins are reasonable. All these are lost to nutrition because of low production and utilization.

Despite the economic importance of cocoyams as a food material in some parts of the tropics and sub-tropics, there is limited information on their post harvest characteristics, which perhaps contributes to the very limited application of improved post harvest technologies to maintain quality and improve marketing potential

Flours milled from other crops such as maize, millet, sorghum, cassava, potatoes and rice had been added to wheat flour to extend the use of the local crops and reduce the cost of wheat importation. This is practiced mostly in tropical countries where the soil and climate are not favourable for commercial large scale production of wheat. Satisfactory bread has been made from such composite flour through a blend of wheat flour with other cereals and root crops (Kent and Evers, 1994). Composite flour incorporating cocoyams has been used in extruded products such as noodles and macaroni (FAO, 1990). Akobundu *et al.*, (1982) reported that lack of the knowledge of the functional, chemical and nutritional properties of grain-legumes grown in developing countries is responsible for the inextensive use of these traditional crops in different food formulations.

Cocoyam consumption has been affected by the presence of acridity factors, which cause sharp irritation and burning sensation in the throat and mouth on ingestion (Akpan and Umoh, 2004). The acridity factor can also be reduced by peeling, grating, soaking and fermentation operations during processing (FAO, 1990). Removal of the thick layer of skin and long period of cooking is required to remove acridity (Sakai, 1983; Crabtress and Baldry, 1982). Other methods of removal of acridity include fermentation, baking or extraction with ethanol (Carpenter and Steinke, 1983). Traditional cooking methods also can neutralize the acridity in cocoyams (Okaka *et al.*, 1992). There is also the selection and breeding of non-or low acrid cultivars of aroids (Akpan and Umoh, 2004).

Cocoyam is a good base for food preparation for infants because of the high digestibility of its starch, reasonable content of calcium and phosphorus (for bone building), B-complex vitamins and provitamin A (Onwueme, 1987; Eleje, 1987). Infants in some developing countries are traditionally weaned solely on starch prepared from pre-cooked, wet-milled and wet-sieved corn (Akobundu and Hoskins, 1987). Recent studies also show that cocoyam starch can be incorporated in the development of weaning food which is easily digestible and accessible to low-income earners in developing countries (Oti and Akobundu, 2008).

According to Kent and Evers (1994), starch finds numerous uses in the baking industry. Wurzburg (1989) gave insight into the physical properties of native starch, which limits its usefulness in many commercial applications and defined a modified starch as a product in which the chemical and (or) the physical properties of the native starch may have been altered.

Starch modification involves the alteration of chemical and/or physical properties of native starches. This alteration has the main objective of producing more satisfactory products for specific food applications. Food consumers are primarily influenced by the sensory properties of the food while the manufacturers are interested in the technological and functional properties of which starchy foods are linked closely to their rheological behaviour. The most important of these are viscosity, stability to heat, acid and shear, heat penetration and workability (Rapaille, 1995).

The starches most commonly modified for commercial use are those from normal maize, tapioca, potato and waxy maize. Modified starches are used to improve viscosity, shelf stability, particulate integrity, processing parameters, textures, appearance and emulsification. Different starches have different properties and are used in the food industry for nutritional, sensory and even aesthetic purposes (Rapaille, 1995).

In this study, starches from two cultivars of cocoyam (cultivar *Ede ocha* and *Ede uhie*) were modified and the effects of levels of modification on the production of soft dough cookies, the functional, proximate and pasting properties of the modified and unmodified cocoyam starches were studied.

## MATERIALS AND METHODS

**Source of materials:** The two cocoyam cultivars were supplied by the Cocoyam Programme of the National Root Crops Research Institute, Umudike. The cocoyams supplied were Cultivar *Ede ocha* and Cultivar *Ede uhie* of the *Xanthosoma sagittifolium* variety. The ingredients for the cookie production were purchased from the Umuahia main market in Abia State, Nigeria.

Cocoyam cormels of cultivar *Ede ocha* and cultivar *Ede uhie* were washed and peeled after harvesting. They were wet milled using double disc attrition milling machine. The slurry was then sieved with a starch sieve (200 mm Endicott sieve).

The cocoyam starch was allowed to settle at the bottom of the container before decanting the water. The extracted starch slurries were transferred into a clean tray and sun-dried. The starch was dry milled and stored in air-tight plastic containers prior to use.

The acid and enzyme modification treatments of cocoyam starch was performed using the method of Asinobi *et al.* (1988).

**Proximate and functional determination:** The proximate analysis of the cookie samples were carried out using the method of AOAC (1990). The wettability, packed bulk density and loose bulk density of the starch samples were determined by the method of Okezie and Bello (1988). Gelation property, water absorption capacity and foaming capacity/foam stability were estimated by employing the method of Abbey and Ibeh (1988). The swelling index was determined by the method of Ukpabi and Ndumele (1996). An ANOVA one-way test was performed on all the values collected. All determinations were in triplicate. The oxalate content was determined by the method of Eheart and Hurst (1962).

**Production of cookies:** The native and modified cocoyam starches were used in the preparation of cookies at different levels of substitution (5, 10, 15, 20 and 25%) with wheat flour. The cookies were prepared using the cream-in method (Asumugha and Uwalaka, 2000). One hundred percent wheat flour was used as the standard.

**Sensory evaluation:** The sensory evaluation was performed using the method of Iwe (2002). A 20 man panel was used for the sensory evaluation of the cookies for taste, appearance, texture, flavour and general acceptability. The scoring was based on a 9-point hedonic scale ranging from 1 (extremely like) to 9 (extremely dislike) and 5 (neither like not dislike). The values obtained from the sensory evaluation was statistically analyzed using MSTAT-C program (Anonymous, 1988).

## RESULTS AND DISCUSSION

### Functional properties of modified cocoyam starches

**Bulk density:** There were significant differences ($p<0.05$) in the bulk densities of the starch samples (Table 1). The 1.5% HCl treated *Ede uhie* and 1.5 mL glucoamylase treated *Ede ocha* had the highest bulk densities of 0.75 g/mL. Native *Ede ocha* starch had the lowest bulk density of 0.62g/mL. The modified cocoyam starches had higher bulk densities than the native cocoyam starches. Bulk density of foods increases with increase in starch content (Bhattacharya and Prakash, 1994). High bulk density of protein material is important in relation to its packaging (Okezie and Bello, 1988). The results of the bulk density of the starch samples also shows that the native starch from the 2 cultivars of cocoyam will be good for developing foods that requires more protein while the modified starches will be good for energy foods. This means that modified cocoyam starch will exhibit better packaging properties that the native cocoyam starch.

**Water absorption capacity:** The results from Table 1 showed that significant differences ($p<0.05$) existed

Table 1: Functional Properties of Native and Modified Cocoyam starches

| Code | Sample | Packed bulk density (g/mL) | Loose bulk Density (g/mL) | Water absorption capacity | Swelling index | Solubility in water | Foam Capacity | Wett-ability (secs) |
|---|---|---|---|---|---|---|---|---|
| NRC | Native *Ede uhie* starch | $0.67^{c-e}$ | $0.49^{b-e}$ | $1.67^{a}$ | $3.71^{b-d}$ | 10.00 | $11.64^{a}$ | $25.77^{c-d}$ |
| NWC | Native *Ede ocha* starch | $0.62^{e}$ | $0.47^{b-e}$ | $1.23^{b-c}$ | $3.15^{e}$ | 23.33 | $3.86^{b-d}$ | $19.33^{c-d}$ |
| RCA | 0.5% HCl treated *Ede uhie* starch | $0.73^{a-b}$ | $0.50^{b-d}$ | $1.23^{b-c}$ | $3.91^{a-b}$ | 20.00 | $-2.80^{e}$ | $40.67^{b-c}$ |
| RCB | 1.0% HCl treated *Ede uhie* starch | $0.71^{a-c}$ | $0.49^{b-e}$ | $1.60^{a}$ | $4.31^{a}$ | 10.00 | $-2.80^{e}$ | $17.33^{c-d}$ |
| RCC | 1.5% HCl treated *Ede uhie* starch | $0.75^{a}$ | $0.48^{b-e}$ | $0.97^{d}$ | $3.85^{a-c}$ | 13.33 | $8.33^{a-b}$ | $63.67^{a-b}$ |
| WCA | 0.5% HCl treated *Ede ocha* starch | $0.65^{d-e}$ | $0.45^{e}$ | $0.93^{d}$ | $3.29^{d-e}$ | 10.00 | $1.07^{c-e}$ | $73.33^{a}$ |
| WCB | 1.0% HCl treated *Ede ocha* starch | $0.70^{b-d}$ | $0.47^{b-e}$ | $0.97^{d}$ | $3.52^{b-e}$ | 13.33 | $4.44^{b-c}$ | $91.00^{a}$ |
| WCC | 1.5% HCl treated *Ede ocha* starch | $0.65^{d-e}$ | $0.45^{d-e}$ | $1.30^{b}$ | $3.80^{b-c}$ | 13.33 | $8.88^{a-b}$ | $69.33^{a-b}$ |
| EWA | 0.5mL glucoamlylase treated *Ede ocha* starch | $0.69^{b-d}$ | $0.46^{c-e}$ | $1.00^{c-d}$ | $3.49^{b-e}$ | 26.67 | $1.07^{c-e}$ | $16.00^{c-d}$ |
| EWB | 1.0mL glucoamlylase treated *Ede ocha* starch | $0.72^{a-b}$ | $0.46^{c-e}$ | $0.87^{d}$ | $3.58^{b-e}$ | 16.67 | $0.53^{c-e}$ | $16.00^{c-d}$ |
| EWC | 1.5mL glucoamlylase treated *Ede ocha* starch | $0.75^{a}$ | $0.56^{a}$ | $0.97^{d}$ | $3.59^{b-e}$ | 10.00 | $1.07^{c-e}$ | $9.33^{d}$ |
| ERA | 0.5mL glucoamlylase treated *Ede uhie* starch | $0.73^{a-b}$ | $0.51^{a-b}$ | $1.03^{c-d}$ | $3.58^{b-e}$ | 16.67 | $-2.27^{d-e}$ | $6.00^{d}$ |
| ERB | 1.0mL glucoamlylase treated *Ede uhie* starch | $0.74^{a-b}$ | $0.51^{b-c}$ | $1.67^{a}$ | $3.41^{c-e}$ | 20.00 | $1.07^{c-e}$ | $10.67^{d}$ |
| ERC | 1.5ml glucoamlylase treated *Ede uhie* starch | $0.72^{a-b}$ | $0.51^{b-c}$ | $0.83^{d}$ | $3.64^{b-d}$ | 13.33 | $1.60^{c-e}$ | $15.00^{c-d}$ |
|  | LSD 0.05 | 0.05 | 0.05 | 0.26 | 0.48 |  | 6.58 | 29.82 |

*Any sample mean not followed by the same superscript in the same column is significantly different ($p<0.05$)

among the samples. The water absorption capacity of native *Ede uhie* starch and 1.0 mL glucoamylase treated *Ede uhie* were 1.67, closely followed by 1.0% HCl treated *Ede uhie* starch which has water absorption capacity of 1.60. This implies that cultivar Ede uhie produced native starch that has good water absorption characteristics. Also, modified *Ede uhie* starch using 1.0% and 1.0 mL glucoamylase also has better water absorption capacity than the other samples. Better water absorption and retention suggests better performance in texture and/or comminuted meats and baked products (Okezie and Bello, 1988).

Increase in water absorption capacity implies increase in digestibility of the starches. The difference might depend on the amount and nature of hydrophilic constituents (Ayele and Nip, 1994). The increase in water absorption capacity of the starches from cultivar *Ede uhie* suggested possible increase in the level of their incorporation into food formulation like dough in order to improve its handling characteristics and also to maintain freshness of product.

**Swelling index:** Significant differences ($p<0.05$) occurred among the starch samples. The 1.0% HCl treated *Ede uhie* starch had the highest swelling index of 4.31 followed closely by 0.5% HCL treated *Ede uhie* starch which has a swelling index of 3.91. Native starch from *Ede ocha* had the lowest swelling index. The results showed that modified starch from cultivar *Ede uhie* produced starches with better swelling index than those of cultivar *Ede ocha*. It could be attributed to the cold water used and that possibly the starch from *Ede uhie* could be more readily digestible than *Ede ocha* starch.

Generally the samples showed good swelling index when compared to other root crops like cassava. This is because of the smaller particle size of cocoyam starch and its highly digestible nature. The starch grain of cocoyam is about one tenth of potato starch grain (Akomas *et al.,* 1987). Cocoyam starch is a better quality starch than other root crops because of its high swelling volume and swelling power (Bainbridge *et al.,* 1996).

**Solubility in water:** There were no significant difference ($p>0.05$) observed in the solubility of the cocoyam starch samples. Their values ranged from 10.00-26.67%. Both acid and enzyme modified starches have approximately the same solubility in cold water with their corresponding untreated starches. Shipman (1967) reported that some acid modified starches have approximately the same solubility in cold water with their corresponding untreated starches.

Bremiller (1993) also reported that modification of starches could bring about increased solubility of the starches. Bainbridge *et al.* (1996) stated that good quality starch with a high starch content and paste viscosity will have a low solubility and high swelling volume and swelling power.

**Foam capacity/foam stability:** The starch samples showed significant differences in foaming capacities. Native *Ede uhie* starch showed a higher whipability than that from *Ede ocha*. The foams were however very unstable and so its stability could not be measured. The foaming capacity of all the starch samples can be rated as low since they do not contain considerably high amounts of proteins, a good foaming agent (Ayele and Nip, 1994). The inability of the modified starch samples to foam very well could probably be due to the processes of the modification treatment.

**Wettability:** Significant differences ($p<0.05$) existed among the samples. The results showed that HCl treated starches have higher wettability values when compared to the glucoamylase treated starches. This could be attributed to the levels of concentration of HCl used to modify the starch samples. The 1.0% HCl treated *Ede ocha* had the highest wettability value of 91.00 sec while the lowest wettability value was 6 sec by

Table 2: Least gelation concentration

| Code | Sample % Concentration | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NRC | Native *Ede uhie* starch | - | - | - | - | G | G | G | G | G | G |
| NWC | Native *Ede ocha* starch | - | - | - | - | G | G | G | G | G | G |
| RCA | 0.5% HCl treated *Ede uhie* starch | - | - | - | - | - | - | G | G | G | G |
| RCB | 1.0% HCl treated *Ede uhie* starch | - | - | - | - | - | - | G | G | G | G |
| RCC | 1.5% HCl treated *Ede uhie* starch | - | - | - | - | - | - | G | G | G | G |
| WCA | 0.5% HCl treated *Ede ocha* starch | - | - | - | - | - | - | G | G | G | G |
| WCB | 1.0% HCl treated *Ede ocha* starch | - | - | - | - | - | - | G | G | G | G |
| WCC | 1.5% HCl treated *Ede ocha* starch | - | - | - | - | - | - | G | G | G | G |
| EWA | 0.5 mL glucoamlylase treated *Ede ocha* starch | - | - | - | - | - | - | G | G | G | G |
| EWB | 1.0 mL glucoamlylase treated *Ede ocha* starch | - | - | - | - | G | G | G | G | G | G |
| EWC | 1.5 mL glucoamlylase treated *Ede ocha* starch | - | - | - | - | - | - | G | G | G | G |
| ERA | 0.5 mL glucoamlylase treated *Ede uhie* starch | - | - | - | - | - | - | G | G | G | G |
| ERB | 1.0 mL glucoamlylase treated *Ede uhie* starch | - | - | - | - | - | G | G | G | G | G |
| ERC | 1.5 mL glucoamlylase treated *Ede uhie* starch | - | - | - | - | - | G | G | G | G | G |

Table 3: Viscosity of starch samples

| Code | Sample | Gelatinization Temp. (Tg) | Peak Viscosity (Vm) | Viscosity at 92°C after peak (Vr) | Stability (Vm-Vr) |
|---|---|---|---|---|---|
| NWC | Native *Ede ocha* Starch | 73.05°C | 1150 BU | 720 BU | 555 BU |
| NRC | Native *Ede uhie* Starch | 72.00°C | 1250 BU | 638 BU | 612 BU |
| XWT | Wheat flour | 72.00°C | 1125 BU | 622 BU | 503 BU |
| EWB | 1.0 mL Glucoamlylase treated *Ede ocha* starch | 71.25°C | 1250 BU | 920BU | 330 BU |
| RCB | 1.0% HCl treated *Ede uhie* starch | 69.00°C | 1250 BU | 921 BU | 612 BU |

0.5 mL glucoamylse treated treated *Ede uhie* starch. Although the samples have high wettability values due to its low protein content, it is still a better substitute when compared to other root and tuber crops. It was also discovered that the lower the level of denatured protein in the starch, the slower it takes to get wetted or imbibe water (Oti and Akobundu, 2008).

**Least gelation property:** Table 2 shows that the gelling ability of the native and enzyme modified starches could be due to the nature of the starch and protein and also their interaction during processing. The 10% (w/v) of three starch samples (Native *Ede uhie* starch, Native *Ede ocha* starch and 1.0 mL glucoamylase treated *Ede ocha* starch) gelled (Table 2). However at 14% (w/v) all the starch samples gelled. Hence the least concentration of all the acid modified starch samples was 14% (w/v). The native starch and glucoamylase treated starch could be used in food production as gels enhance the body and texture of a product by solidifying the free water in the food. Gelatinization affects digestibility and texture of starch containing foods, leaching amylase enhances susceptibility of starch to enzyme attack (Rickard, 1991) and the textural quality when starch is incorporated in food products such as creams, soups, puddings, pie fillings and many sauces in viscosity (Osman, 1967).

It is also observed that gel forming capacity increased with increase in concentration of the starch samples (Lawal *et al.,* 2004). Although the result of this study showed that acid modification did not affect gelation. Sester (1993) reported that acid hydrolysis may make starch to loose its ability to gel.

**Viscosity:** Amylograph pasting viscosity studies on some of the cocoyam starch samples (Table 3) showed that their gelation temperature ranged between 69.00 and 73.05°C. Amani *et al.* (2005) in a study of the stability of yam starch gels during processing found that native cassava starch and *xanthosoma* starch gelled at a temperature of 64.30 and 76.50°C, respectively. This agrees with the result in Table 3.

The result also showed that the samples have high gelatinization temperature which is a desirable property. Native *Ede uhie* starch and 1.0% HCl treated *Ede uhie* starch had the highest paste stability of 612BU which is a requirement for industrial use of starch (Bainbridge *et al.,* 1996). This was closely followed by Native *Ede ocha* starch with 555BU while 1.0 mL glucoamylase treated *Ede ocha* had the lowest paste stability of 330BU. It will be observed from the results that the lower the drop in viscosity the more stable the paste.

The results showed that native *Ede uhie* starch and 1.0% HCl treated *Ede uhie* starch formed more stable paste and higher thickening on cooling. Increase in viscosity on cooling is due to retrogradation and congelation of the amylase (Schoch, 1967) and retrograded starch is not readily digestible. Low viscosity values have been reported for *Xanthosoma* starch (Rickard, 1991). Cocoyam starches produce pastes which show some breakdown on prolonged heating and stirring (Rasper, 1969). Cocoyam starch is not readily susceptible to retrogradation. This makes it suitable for use as a source of carbohydrate in complementary food production (Oti and Akobundu, 2008).

Ogazi (1985) in determining the amylograph characteristics of plantain-wheat composite flour found

Table 4: Proximate Composition of cocoyam-wheat based cookies

| Code sample | Moisture % | Ash % | Crude Protein% | Crude fiber% | Crude fat% | Total carb.% | Energy (Kcal) |
|---|---|---|---|---|---|---|---|
| A= 0.5 mL glucoamlylase treated *Ede ocha* starch | 8.48$^{f}$ | 1.45$^{a-b}$ | 6.13c | 0.85$^{b-e}$ | 2.25$^{b-d}$ | 80.84$^{f-g}$ | 368.13$^{a-c}$ |
| B= 1.5% HCl treated *Ede uhie* starch | 8.18$^{g}$ | 1.45a-b | 6.06$^{c-d}$ | 0.65$^{f}$ | 2.00$^{e-g}$ | 81.66$^{b-c}$ | 368.88$^{c-f}$ |
| C = Native *Ede uhie* starch | 8.66$^{e}$ | 1.45$^{a-b}$ | 6.48b | 0.93$^{b-c}$ | 2.01$^{e-g}$ | 80.47$^{c-f}$ | 365.89$^{e-g}$ |
| D =1.0 mL glucoamlylase treated *Ede ocha* starch | 9.16$^{a-b}$ | 1.30$^{a-d}$ | 5.86e | 0.85$^{b-e}$ | 2.35$^{a-b}$ | 80.48$^{g}$ | 366.61$^{a-b}$ |
| E= 0.5% HCl treated *Ede uhie* starch | 9.26$^{a}$ | 1.43$^{a-c}$ | 5.69$^{f}$ | 0.90$^{b-d}$ | 2.11$^{c-e}$ | 80.61$^{c-g}$ | 364.19$^{c-f}$ |
| F =0.5 mL glucoamlylase treated *Ede uhie* starch | 9.21$^{a-b}$ | 1.43$^{a-c}$ | 5.32$^{g}$ | 0.80$^{b-f}$ | 2.27$^{a-c}$ | 80.97$^{f-g}$ | 365.59$^{a-d}$ |
| G=1.5 mL glucoamlylase treated *Ede uhie* starch | 8.90$^{c-d}$ | 1.26$^{c-d}$ | 5.97$^{d-e}$ | 0.95$^{b}$ | 2.05$^{d-f}$ | 80.87$^{b-e}$ | 365.81$^{d-g}$ |
| H=1.0% HCl treated *Ede ocha* starch | 8.87$^{d}$ | 1.25$^{c-d}$ | 5.25$^{g-h}$ | 0.79$^{c-f}$ | 2.03$^{d-f}$ | 81.81$^{b-d}$ | 366.51$^{d-g}$ |
| I=100% Wheat flour | 8.90$^{c-d}$ | 1.48$^{a}$ | 10.98$^{a}$ | 1.90$^{a}$ | 2.47$^{a}$ | 74.27$^{h}$ | 363.23$^{a}$ |
| J=1.0 mL glucoamlylase treated *Ede uhie* starch | 8.82$^{d-e}$ | 1.25$^{c-d}$ | 5.60f | 0.73$^{e-f}$ | 2.22$^{b-d}$ | 81.38$^{d-g}$ | 367.90$^{a-d}$ |
| K=1.5% HCl treated *Ede ocha* starch | 8.78$^{d-e}$ | 1.13$^{d-e}$ | 5.08i | 0.73$^{d-f}$ | 1.81$^{g}$ | 82.47$^{a}$ | 366.49$^{g}$ |
| L=1.5 mL glucoamlylase treated *Ede ocha* starch | 9.05$^{b-c}$ | 1.28$^{b-d}$ | 5.12$^{h-I}$ | 0.70$^{e-f}$ | 1.89$^{f-g}$ | 81.96$^{a-b}$ | 365.33$^{f-g}$ |
| M=0.5% HCl treated *Ede ocha* starch | 9.14$^{a-b}$ | 1.05$^{e}$ | 5.58$^{e}$ | 0.72$^{e-f}$ | 2.13$^{c-e}$ | 81.38$^{c-f}$ | 367.01$^{b-e}$ |
| N=1.0% HCl treated *Ede uhie* starch | 9.07$^{c}$ | 1.20$^{d-e}$ | 4.55$^{j}$ | 0.73$^{e-f}$ | 2.33$^{a-c}$ | 82.12$^{e-g}$ | 367.65$^{a-b}$ |
| O=Native *Ede ocha* starch | 8.73$^{d-e}$ | 1.05$^{e}$ | 4.38$^{k}$ | 0.83$^{b-f}$ | 2.31$^{a-c}$ | 82.30$^{c-f}$ | 369.11$^{a-b}$ |
| LSD 0.05 | 0.18 | 0.18 | 0.15 | 0.15 | 2.15 | 2.23 | 10.57 |

*Any sample mean not followed by the same superscript in the same column is significantly different (p<0.05)

that as the proportion of plantain flour in the mixture increased, the maximum viscosity increased dramatically and he also observed that the gelling temperature was higher for the mixtures than the control (Leviathan flour, a strong Canadiean wheat flour). Iwe (1998) also found that peak viscosity of soy-sweet potato blends decreased with increase in protein content and Oti and Akobundu (2008) observed that the proportion of cocoyam flour increased as the peak viscosity increased in cocoyam-soyabean-crayfish composite flour.

**Oxalate:** The oxalate content in the modified cocoyam starch samples could not be detected and therefore could not be measured. The levels of oxalate in the native *Ede ocha* and *Ede uhie* starches were 0.021 and 0.024%, respectively. Akpan and Umoh (2004) reported that the use of heat treatment and different concentrations of tetracycline during cooking reduced the level of acridity in cocoyam. It will be observed that modification of starch using HCl and glucoamylase reduced the level of acridity in the cocoyam starch samples. Also no taste panelist reported irritation of the mouth or throat during or after the organoleptic evaluation of the cocoyam-wheat based cookies. This indicates the very low level of oxalate in the starch samples, if any.

Selection and breeding of non-or low acrid cultivars of aroids also helps in reduction of the acrid levels in cocoyam (Akpan and Umoh, 2004). Fermentation, baking or extraction with ethanol also helps in reduction of acridity levels in cocoyam (Carpenter and Steinke, 1983). Traditional cooking methods also can neutralize the acridity in cocoyams (Okaka *et al.*, 1992).

**Proximate composition of the cocoyam-wheat based cookies:** Significant differences (p<0.05) occurred among the cookies in terms of moisture, protein fat, ash, crude fibre and total carbohydrate (Table 4). All the cookie samples were low in crude fibre the control (100% wheat flour) with the value of 1.90. The ash content of all the cookies ranged from 1.05 -1.48% while the crude protein ranged from 4.38-10.98%. This is in agreement with Asumugha and Uwalaka (2000) who reported that the protein content of cookies prepared from cocoyam/wheat flour ranged from 5.95-12.25%.

The total carbohydrate lies between 74.27 and 82.47%. This agrees with the findings that cocoyam being high in starch content should be eaten together with other high protein foods (Akpan and Umoh, 2004).

The higher energy content of the cookies in kilo calories made from cocoyam starch as shown in Table 4 (363.23-368.88) is higher than those of Asumugha and Uwalaka (2000). This could be attributed to the type of cocoyam starch used in the cookie production.

**Sensory evaluation of cocoyam-wheat based cookies**

**Taste:** There was significant difference (p<0.05) in the taste of the cookie samples (Table 5). The 100% Wheat flour was the best in terms of taste of all the cookies. This was closely followed by the 15% substitution level (0.5% HCl treated *Ede ocha* starch). The least preferred of the cookies with regards to taste was the 10% level of substitution (1.5 mL glucoamylase treated *Ede ocha* starch) and the 20% level of substitution (1.5 mL glucoamylase treated *Ede uhie* starch) having 4.45, even though it translates to like slightly on the hedonic scale. There was no significant difference (p>0.05) detected at the interaction between the concentration and cookies. However the taste of cookies baked at 5% level of substitution were preferred most to those of other substitution levels.

**Appearance:** The results of the sensory evaluation showed that there were no significant difference (p>0.05) at the interaction between the substitution levels and cookies in terms of appearance (Table 6). The appearance of the cookies at 5% level of substitution was best compared to other substitution levels.

Table 5: Effect of levels of modification on the Taste of cookie samples

| Code | Sample | 5 | 10 | 15 | 20 | 25 | Cookies means |
|---|---|---|---|---|---|---|---|
| A | Native *Ede uhie* starch | $2.70^{iq}$ | $2.90^{fq}$ | $3.20^{eo}$ | $3.15^{ep}$ | $2.25^{pq}$ | 2.84 |
| B | Native *Ede ocha* starch | $2.90^{fq}$ | $2.65^{jq}$ | $3.05^{eq}$ | $3.70^{ag}$ | $3.25^{do}$ | 3.11 |
| C | 100% Wheat flour | $2.20^{q}$ | $3.50^{bk}$ | $3.05^{eq}$ | $4.35^{ab}$ | $3.45^{bl}$ | 3.31 |
| D | 0.5% HCl treated *Ede uhie* starch | $2.80^{gq}$ | $2.65^{ah}$ | $3.45^{bl}$ | $2.40^{oq}$ | $3.20^{eo}$ | 3.10 |
| E | 1.0% HCl treated *Ede uhie* starch | $3.30^{do}$ | $2.45^{nq}$ | $3.90^{ae}$ | $4.35^{ab}$ | $2.80^{gq}$ | 3.36 |
| F | 1.5% HCl treated *Ede uhie* starch | $2.70^{iq}$ | $3.06^{eq}$ | $2.80^{gq}$ | $3.60^{ai}$ | $3.20^{eo}$ | 3.06 |
| G | 0.5% HCl treated *Ede ocha* starch | $2.80^{gq}$ | $2.60^{kq}$ | $2.25^{pq}$ | $4.15^{ad}$ | $2.60^{kq}$ | 2.88 |
| H | 1.0% HCl treated *Ede ocha* starch | $2.65^{jq}$ | $2.85^{fq}$ | $3.40^{cm}$ | $4.30^{ac}$ | $3.75^{hq}$ | 3.19 |
| I | 1.5% HCl treated *Ede ocha* starch | $2.55^{lq}$ | $3.15^{ep}$ | $2.90^{fq}$ | $3.65^{ah}$ | $2.85^{fq}$ | 3.02 |
| J | 0.5 mL glucoamlylase treated *Ede ocha* starch | $2.45^{nq}$ | $3.05^{eq}$ | $3.60^{ai}$ | $3.75^{af}$ | $3.10^{eq}$ | 3.19 |
| K | 1.0 mL glucoamlylase treated *Ede ocha* starch | $2.55^{lq}$ | $2.85^{fq}$ | $2.65^{jq}$ | $3.40^{cm}$ | $2.90^{fq}$ | 2.87 |
| L | 1.5 mL glucoamlylase treated *Ede ocha* starch | $2.50^{mq}$ | $4.45^{a}$ | $3.50^{bk}$ | $3.60^{ai}$ | $3.05^{eq}$ | 3.42 |
| M | 0.5 mL glucoamlylase treated *Ede uhie* starch | $3.10^{eq}$ | $3.35^{dn}$ | $2.90^{fq}$ | $2.80^{gq}$ | $3.55^{aj}$ | 3.14 |
| N | 1.0 mL glucoamlylase treated *Ede uhie* starch | $2.50^{mq}$ | $2.90^{fq}$ | $3.10^{eq}$ | $4.30^{ac}$ | $2.90^{fq}$ | 3.14 |
| O | 1.5 mL glucoamlylase treated *Ede uhie* starch | $2.50^{mq}$ | $3.65^{ah}$ | $3.35^{dn}$ | $4.45^{a}$ | $3.55^{aj}$ | 3.50 |
| Concentration Means (Different levels of substitution) | | $2.68^{c}$ | $3.13^{b}$ | $3.14^{b}$ | $3.73^{a}$ | $3.03^{b}$ | |

*Cookie means with different superscript down the row are significantly different ($p<0.05$), *concentration means with different superscript in the same column are significantly different ($p<0.05$), *any cookie x concentration means with different superscript are significantly different ($p<0.05$), $LSD_{0.05}$ for any two cookie means =ns, $LSD_{0.05}$ for any two concentration means =0.24, $LSD_{0.05}$ for any two cookie x concentration = 0.94

Table 6: Effect of levels of modification on the Appearance of cookie samples

| Code | Sample | 5 | 10 | 15 | 20 | 25 | Cookies means |
|---|---|---|---|---|---|---|---|
| A | Native *Ede uhie* starch | $2.45^{lm}$ | $2.90^{en}$ | $2.65^{in}$ | $3.20^{cn}$ | $2.50^{kn}$ | 2.74 |
| B | Native *Ede ocha* starch | $2.90^{en}$ | $2.85^{fn}$ | $3.05^{dn}$ | $3.50^{bi}$ | $2.90^{en}$ | 3.04 |
| C | 100% Wheat flour | $2.60^{in}$ | $3.15^{cn}$ | 2.75hn | $4.05^{ac}$ | $2.70^{hn}$ | 3.05 |
| D | 0.5% HCl treated *Ede uhie* starch | $2.65^{in}$ | $3.70^{ag}$ | $3.20^{cn}$ | $3.05^{dn}$ | $3.25^{cm}$ | 3.17 |
| E | 1.0% HCl treated *Ede uhie* starch | $2.90^{en}$ | $2.30^{n}$ | $3.30^{bl}$ | $3.10^{dn}$ | $3.30^{bl}$ | 2.98 |
| F | 1.5% HCl treated *Ede uhie* starch | $2.65^{in}$ | $3.25^{cm}$ | $3.75^{af}$ | $3.95^{ad}$ | $2.70^{hn}$ | 3.26 |
| G | 0.5% HCl treated *Ede ocha* starch | $2.70^{hn}$ | $2.45^{ln}$ | $2.70^{hn}$ | $3.60^{bh}$ | $2.80^{gn}$ | 2.85 |
| H | 1.0% HCl treated *Ede ocha* starch | $2.80^{gn}$ | $3.15^{cn}$ | $3.35^{bl}$ | $3.90^{ad}$ | $2.55^{jn}$ | 3.15 |
| I | 1.5% HCl treated *Ede ocha* starch | $3.10^{dn}$ | $2.85^{fn}$ | $2.75^{hn}$ | $3.50^{bi}$ | $2.80^{gn}$ | 3.00 |
| J | 0.5 mL glucoamlylase treated *Ede ocha* starch | $2.50^{kn}$ | $2.45^{ln}$ | $3.10^{dn}$ | $4.60^{a}$ | $2.90^{en}$ | 3.11 |
| K | 1.0 mL glucoamlylase treated *Ede ocha* starch | $2.35^{mn}$ | $3.45^{bj}$ | $3.15^{cn}$ | $3.80^{ae}$ | $3.20^{cn}$ | 3.19 |
| L | 1.5 mL glucoamlylase treated *Ede ocha* starch | $2.45^{ln}$ | $4.55^{a}$ | $3.40^{bk}$ | $2.95^{en}$ | $3.25^{cm}$ | 3.32 |
| M | 0.5 mL glucoamlylase treated *Ede uhie* starch | $2.55^{jn}$ | $3.10^{dn}$ | $2.95^{en}$ | $2.45^{ln}$ | $3.05^{dn}$ | 2.82 |
| N | 1.0 mL glucoamlylase treated *Ede uhie* starch | $2.80^{gn}$ | $2.90^{en}$ | $2.90^{en}$ | $4.20^{ab}$ | $2.80^{gn}$ | 3.12 |
| O | 1.5 mL glucoamlylase treated *Ede uhie* starch | $2.65^{in}$ | $3.25^{cm}$ | $3.95^{ad}$ | $3.30^{bl}$ | $3.15^{cn}$ | 3.26 |
| Concentration means (Different levels of substitution) | | $2.67^{c}$ | $3.09^{b}$ | $3.13^{b}$ | $3.54^{a}$ | $2.92^{b}$ | |

*Cookie means with different superscript down the row are significantly different ($p<0.05$), *concentration means with different superscript in the same column are significantly different ($p<0.05$), *any cookie x concentration means with different superscript are significantly different ($p<0.05$), $LSD_{0.05}$ for any two cookie means = ns, $LSD_{0.05}$ for any two concentration means =0.23, $LSD_{0.05}$ for any two cookie x concentration =0.91

The best sample in terms of the appearance of the cookie was the 10% substitution level (1.0%HCl treated *Ede uhie* starch), while the least preferred of the cookies were the 10% level (1.5 mL glucoamylase treated *Ede ocha*) and the 20% level (0.5 mL glucoamylase treated *Ede ocha* starch). This could be attributed to the cultivar type used. Modification treatments of the cocoyam starches did not alter their appearance but the pinkish colour of the starch from Cultivar *Ede uhie* starch was prefered.

**Texture:** There was no significant difference ($p>0.05$) detected in the texture of the all the cookie samples (Table 7). But significant difference ($p<0.05$) existed at the interaction between cookies and their different substitution levels. The 0.5% HCl treated *Ede uhie* starch and 0.5 mL glucoamylase treated *Ede uhie* starch were most preferred to other cookies of different substitution levels.

There were significant differences in cookies prepared at different substitution levels. Cookies baked at 5, 10 and 15% levels were preferred in terms of their texture to the other substitution range. This significant difference in texture could be due to the effect of the modified starches incorporated into the wheat flours which improved the plastic-elastic properties of the cookie dough.

Table 7: Effect of levels of modification on the Texture of cookie samples

| Code | Sample | 5 | 10 | 15 | 20 | 25 | Cookies means |
|---|---|---|---|---|---|---|---|
| A | Native *Ede uhie* starch | 3.20 | 3.35 | 3.05 | 2.45 | 3.50 | $3.11^{cf}$ |
| B | Native *Ede ocha* starch | 2.85 | 2.45 | 3.20 | 2.95 | 3.45 | $2.98^{ef}$ |
| C | 100% Wheat flour | 3.05 | 3.40 | 3.90 | 3.25 | 4.55 | $3.63^{a}$ |
| D | 0.5% HCl treated *Ede uhie* starch | 2.75 | 3.05 | 3.05 | 3.20 | 2.60 | $2.93^{f}$ |
| E | 1.0% HCl treated *Ede uhie* starch | 3.60 | 2.50 | 3.15 | 3.45 | 3.30 | $3.20^{bf}$ |
| F | 1.5% HCl treated *Ede uhie* starch | 3.50 | 3.30 | 3.10 | 3.00 | 4.35 | $3.45^{ac}$ |
| G | 0.5% HCl treated *Ede ocha* starch | 3.10 | 2.55 | 2.95 | 3.20 | 3.45 | $3.05^{df}$ |
| H | 1.0% HCl treated *Ede ocha* starch | 3.25 | 2.95 | 3.40 | 2.90 | 4.40 | $3.38^{ad}$ |
| I | 1.5% HCl treated *Ede ocha* starch | 2.70 | 3.10 | 3.15 | 2.95 | 3.35 | $3.05^{df}$ |
| J | 0.5 mL glucoamlylase treated *Ede ocha* starch | 2.60 | 2.55 | 3.40 | 2.95 | 3.85 | $3.07^{cf}$ |
| K | 1.0 mL glucoamlylase treated *Ede ocha* starch | 2.95 | 3.65 | 2.60 | 3.15 | 4.45 | $3.36^{ae}$ |
| L | 1.5 mL glucoamlylase treated *Ede ocha* starch | 2.65 | 3.55 | 3.10 | 3.00 | 3.60 | $3.18^{bf}$ |
| M | 0.5 mL glucoamlylase treated *Ede uhie* starch | 2.95 | 3.15 | 2.95 | 2.85 | 2.80 | $2.94^{f}$ |
| N | 1.0 mL glucoamlylase treated *Ede uhie* starch | 3.50 | 3.20 | 3.30 | 2.35 | 4.30 | $3.53^{ab}$ |
| O | 1.5 mL glucoamlylase treated *Ede uhie* starch | 2.90 | 3.50 | 3.50 | 3.40 | 4.55 | $3.57^{ab}$ |
| Concentration menas (Different levels of substitution) | | $3.04^{b}$ | $3.08^{b}$ | $3.19^{b}$ | $3.07^{b}$ | $3.77^{a}$ | |

*Cookie means with different superscript down the row are significantly different ($p<0.05$), *concentration means with different superscript in the same column are significantly different ($p<0.05$), * any cookie x concentration means with different superscript are significantly different ($p<0.05$), $LSD_{0.05}$ for any two cookie means = 0.39, $LSD_{0.05}$ for any two concentration means = 0.23, $LSD_{0.05}$ for any two cookie x concentration = ns

Table 8: Effect of levels of modification on the flavour of cookie samples

| Code | Sample | 5 | 10 | 15 | 20 | 25 | Cookies mean |
|---|---|---|---|---|---|---|---|
| A | Native *Ede uhie* starch | 2.60 | 3.20 | 2.95 | 3.15 | 2.70 | 2.92 |
| B | Native *Ede ocha* starch | 2.80 | 3.05 | 3.30 | 3.85 | 3.30 | 3.26 |
| C | 100% Wheat flour | 2.60 | 3.55 | 3.45 | 4.40 | 3.35 | 3.47 |
| D | 0.5% HCl treated *Ede uhie* starch | 2.60 | 3.25 | 3.25 | 3.80 | 3.65 | 3.31 |
| E | 1.0% HCl treated *Ede uhie* starch | 2.95 | 2.40 | 3.60 | 4.35 | 3.40 | 3.34 |
| F | 1.5% HCl treated *Ede uhie* starch | 2.60 | 3.20 | 3.25 | 4.10 | 3.30 | 3.29 |
| G | 0.5% HCl treated *Ede ocha* starch | 2.45 | 3.20 | 2.85 | 3.90 | 3.05 | 3.09 |
| H | 1.0% HCl treated *Ede ocha* starch | 2.25 | 3.50 | 3.20 | 4.95 | 3.30 | 3.44 |
| I | 1.5% HCl treated *Ede ocha* starch | 2.85 | 3.30 | 3.25 | 3.70 | 2.95 | 3.21 |
| J | 0.5 mL glucoamlylase treated *Ede ocha* starch | 2.65 | 3.30 | 3.65 | 4.30 | 2.95 | 3.37 |
| K | 1.0 mL glucoamlylase treated *Ede ocha* starch | 2.80 | 3.25 | 3.05 | 4.05 | 2.75 | 3.18 |
| L | 1.5 mL glucoamlylase treated *Ede ocha* starch | 3.10 | 4.20 | 3.30 | 3.90 | 3.10 | 3.52 |
| M | 0.5 mL glucoamlylase treated *Ede uhie* starch | 3.15 | 3.40 | 2.85 | 3.10 | 3.05 | 3.11 |
| N | 1.0 mL glucoamlylase treated *Ede uhie* starch | 2.50 | 3.30 | 3.70 | 5.10 | 3.50 | 3.62 |
| O | 1.5 mL glucoamlylase treated *Ede uhie* starch | 2.45 | 3.55 | 3.80 | 4.25 | 3.80 | 3.57 |
| Concentration means (Different levels of substitution) | | $2.69^{c}$ | $3.31^{b}$ | $3.29^{b}$ | $4.06^{a}$ | $3.21^{b}$ | |

*Cookie means with different superscript down the row are significantly different ($p<0.05$), *concentration means with different superscript in the same column are significantly different ($p<0.05$), *any cookie x concentration means with different superscript are significantly different ($p<0.05$), $LSD_{0.05}$ for cookie means = ns

**Flavour:** The results of the sensory evaluation for flavour showed that there were no significant difference ($p>0.05$) in the flavour of the cookies and the interaction between the cookie and their different substitution levels (Table 8).

However, significant difference ($p<0.05$) existed among the levels of concentration. The flavour of the cookies baked at the 5% level of the substitution were better and more liked by the members of the panel than those of other substitution levels.

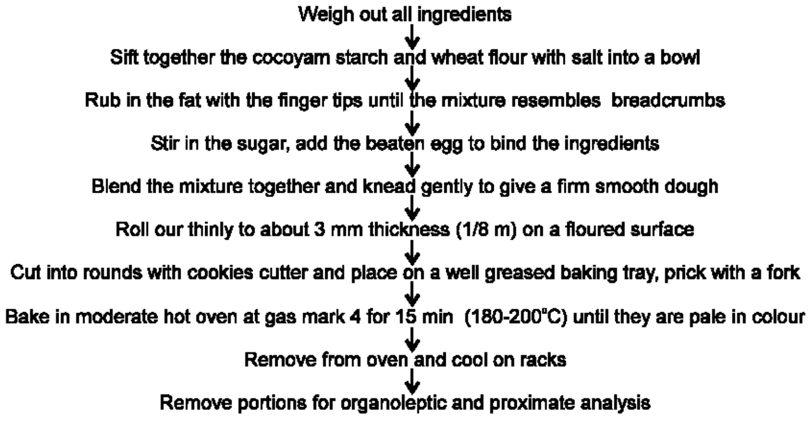
**Acceptability:** There were significant difference ($p<0.05$) in the general acceptability if the cookies. Table 9 shows that the most acceptable cookie was sample with 5% level of substitution (1.0% HCl treated *Ede ocha* starch) while the least accepted was the 25% substitution level (1.0 mL glucoamylase treated *Ede uhie*).

At the interaction between cookies and substitution levels, samples with native *Ede uhie* starch, 0.5% HCl treated *Ede ocha* starch and 0.5 mL glucoamylase treated *Ede* uhie starch were the most accepted..Also significant difference ($p<0.05$) also occurred at the different substitution levels. Cookies baked at 5% substitution level was most preferred to other substitution levels. This was closely followed by cookies prepared at 10 and 15% substitution levels. Roberta and Jovita (1986) observed that cassava and sweet potato flour used at 50% level of substitution for cookie

Table 9: Effect of levels of modification on the General Acceptability of cookie samples

| Code | Sample | 5 | 10 | 15 | 20 | 25 | Cookies mean |
|---|---|---|---|---|---|---|---|
| A | Native *Ede uhie* starch | $3.00^{io}$ | $3.40^{eo}$ | $3.15^{fo}$ | $2.55^{no}$ | $3.60^{dn}$ | $3.14^{c}$ |
| B | Native *Ede ocha* starch | $2.95^{jo}$ | $3.30^{eo}$ | $3.35^{eo}$ | $3.40^{eo}$ | $4.05^{ch}$ | $3.41^{ac}$ |
| C | 100% Wheat flour | $2.85^{lo}$ | $3.70^{dl}$ | $3.55^{dn}$ | $3.80^{dl}$ | $4.90^{ac}$ | $3.76^{a}$ |
| D | 0.5% HCl treated *Ede uhie* starch | $2.65^{mo}$ | $3.75^{dl}$ | $3.55^{dn}$ | $3.70^{dl}$ | $2.80^{lo}$ | $3.29^{bc}$ |
| E | 1.0% HCl treated *Ede uhie* starch | $3.30^{eo}$ | $2.55^{no}$ | $3.90^{ck}$ | $4.05^{ch}$ | $3.75^{dl}$ | $3.51^{ac}$ |
| F | 1.5% HCl treated *Ede uhie* starch | $3.20^{fo}$ | $3.45^{eo}$ | $3.15^{fo}$ | $3.45^{eo}$ | $4.25^{be}$ | $3.50^{ac}$ |
| G | 0.5% HCl treated *Ede ocha* starch | $2.80^{lo}$ | $3.05^{ho}$ | $2.95^{jo}$ | $3.00^{io}$ | $3.90^{ck}$ | $3.14^{c}$ |
| H | 1.0% HCl treated *Ede ocha* starch | $2.45^{o}$ | $3.00^{io}$ | $3.55^{dn}$ | $2.95^{jo}$ | $5.25^{ab}$ | $3.44^{ac}$ |
| I | 1.5% HCl treated *Ede ocha* starch | $3.15^{fo}$ | $3.10^{go}$ | $3.10^{go}$ | $3.00^{io}$ | $3.95^{cj}$ | $3.26b^{c}$ |
| J | 0.5 mL glucoamlylase treated *Ede ocha* starch | $3.00^{io}$ | $2.90^{ko}$ | $4.00^{ci}$ | $3.30^{eo}$ | $4.10^{cg}$ | $3.46^{ac}$ |
| K | 1.0 mL glucoamlylase treated *Ede ocha* starch | $3.15^{fo}$ | $3.50^{dn}$ | $3.15^{fo}$ | $3.80^{dl}$ | $3.65^{dm}$ | $3.45^{ac}$ |
| L | 1.5 mL glucoamlylase treated *Ede ocha* starch | $3.05^{ho}$ | $4.50^{ad}$ | $3.45^{eo}$ | $4.00^{ci}$ | $3.50^{dn}$ | $3.70^{ab}$ |
| M | 0.5 mL glucoamlylase treated *Ede uhie* starch | $3.20^{fo}$ | $3.40^{eo}$ | $3.05^{ho}$ | $3.55^{dn}$ | $3.00^{io}$ | $3.24^{c}$ |
| N | 1.0 mL glucoamlylase treated *Ede uhie* starch | $2.90^{ko}$ | $3.35^{eo}$ | $3.45^{eo}$ | $4.05^{ch}$ | $5.30^{a}$ | $3.81^{a}$ |
| O | 1.5 mL glucoamlylase treated *Ede uhie* starch | $3.30^{eo}$ | $3.75^{dl}$ | $3.75^{dl}$ | $4.15^{cf}$ | $3.95^{cj}$ | $3.78^{a}$ |
| Concentration means (Different levels of substitution) | | $2.99^{c}$ | $3.38^{b}$ | $3.41^{b}$ | $3.52^{b}$ | $3.99^{a}$ | |

*cookie means with different superscript down the row are significantly different ($p<0.05$), *concentration means with different superscript in the same column are significantly different ($p<0.05$), *any cookie x concentration means with different superscript are significantly different ($p<0.05$), $LSD_{0.05}$ for any two cookie means = 0.45, $LSD_{0.05}$ for any two concentration means = 0.26, $LSD_{0.05}$ for any two cookie x concentration = 1.02



**(Source: Asumugha and Uwalaka, 2000)**

Fig. 1: Flow diagram for the preparation of cookies

production were more acceptable to cookies baked with 100% wheat flour. Our result shows that cookies produced with cocoyam starch will be highly marketable.

**Conclusion:** Modified starch of *Xanthosoma sagittifolium* can be utilized as major raw materials for cookie production. Studies show that modified starch from cultivar *Ede uhie* produced starch with high water absorption capacity and swelling index. Most of the cookies preferred had native and modified starch from cultivar *Ede uhie* which also performed well in the functional and pasting properties.

Modification of cocoyam starch for use in the food industry especially in cookies production should be encouraged by the government as this will add variety and also reduce level of oxalate in cocoyam. The use of cocoyam starch in cookie production at 5 and 10% level of substitution with wheat flour should also be encouraged since its starch is readily digestible, it will be a very good substitute for children, diabetics and the aged.

Government should encourage the substitution of some part of wheat flour with cocoyam starch in the production of snack products, this will help minimize the rate of post harvest losses and encourage cocoyam cultivation. Cocoyam has proved to be a good source of carbohydrates for meeting the energy requirement in human diets, including those of the aged, diabetics, invalids. Efforts should be made to exploit its usage in the bakery industry.

Research on cocoyam starch modification should also be intensified in order to find new food applications and to determine the potential of cocoyam starch as substitute to other starches needed in food processing.

## REFERENCES

Abbey, B.W. and G.O. Ibeh, 1988. Functional properties of raw and heat processed cowpea (*Vigna unguiculata*, walp) flour. J. Food Sci., 53:1775-1791.

Akobundu, E.N.T., J.P. Cherry and S.G. Simmons, 1982. Chemical, functional and nutritional properties of egusi (*Citrullus vulgaricus*) seed protein products. J. Food Sci., 47: 829-835.

Akobundu, E.N.T. and F.H. Hoskins, 1987. Potential of corn-cowpea mixtures as infant food. J. Food Sci. Agric., 2: 111-114.

Akomas, E.C.A., E.N.A. Mbanaso and O.E.U. Akoma, 1987. Food Forms of Cocoyam for Home and Commercial Use. In: Arene, O.B., L.S.O. Ene, S.O. Odurukwe and N.O.A. Ezeh (Eds.). Proc.1st National Worskshop on Cocoyam. NRCRI, Umudike, Nigeria, pp: 187-195.

Akpan, E.J. and I.B. Umoh, 2004. Effect of heat and tetracycline treatments on the food quality and acridity factors in cocoyam (*Xanthosoma sagittifolium* (L.) Schott). Pak. J. Nutr., 3: 240-243.

Amani, N.G., A. Kamenan, A. Rolland-Sabate and P. Colonna, 2005. Stability of yam starch gels during processing. Afr. J. Biotechn., 4: 94-101.

Anonymous, 1988. A Microcomputer program for the Design, Management and Analysis of Agronomic Research Experiments. MSTAT Development Team, Michigan State University, United States of America.

AOAC, 1990. Official Methods of Analysis. Assn. Official Anal. Chemists, Washington,D.C.

Asinobi, C., P.C. Ojimelukwe, M.C. Uzo and J.C. Onwuluzo, 1988. Comparative effects of various viscosity reducing treatments on the quality characteristics of cowpea-sorghum infant food. J. Food Biochem.,22: 441-453.

Asumugha, V.U. and B.C. Uwalaka, 2000. Chemical and organoleptic evaluation of snacks developed from cocoyam (*Colocasia esculenta, Xanthosoma mafafa*) and wheat (*Triticum spp)* composite flours. Nig. Agric. J., 31: 78-88.

Ayele, T. and W.K. Nip, 1994. Functional properties of raw and precooked taro (*Colocasia esculenta*) flours. Int. J.Food Sci. Techno. (IFST), 29: 457-462.

Bainbridge, Z., K. Tomlins, K. Wellings and A. Westby, 1996. Methods of assessing quality characteristics of non-grain starch staples. Part 4: Advanced Methods. Natural Resources Institute, Chartham, UK.

Bhattacharya, S. M. and Prakash, 1994. Extrusion blends of rice and chicken pea flours: A response surface analysis. J. Food Eng., 21: 315-330.

Bremiller, J.N., 1993. Modified Starches. In Encyclopedia of Food Science. Food Technol. Nutr., 7: 4384-4387.

Carpenter, J.R. and W.E. Steinke, 1983. Animal feed. In: Wang, J. Ed. Taro a review of *Colocasis esculenta* and its potentials. University of Hawaii Press, Honolulu, pp: 200-269.

Crabtress, J. and J. Baldry, 1982. Technical note: The use of taro products in bread making. J. Food Technol., 17: 771-777.

Eheart, J.F. and D.C. Hurst, 1962. Oxalates in plants. J. Assoc. Official Agric. Chemistsm, 48: 98-101.

Eleje, I., 1987. Cocoyam, a Major National Carbohydrate Staple for the Future in Nigeria. In: Arene, O.B, L.S.O. Ene, S.O. Odurukwe and N.O.A. Ezeh (Eds.). Proc. 1st National Workshop on cocoyams. NRCRI, Umudike, Nigeira, pp: 11-16.

FAO, 1990. Roots, tubers, plantains and bananas in human nutrition. Food and Agricultural organization of the United Nations, Rome.

Iwe, M.O., 1998. Effects of extrusion cooking on functional properties of mixtures of full-fat soy and sweet potato. Plant foods for Human Nutrition., 53: 37-46.

Iwe, M.O., 2002. Handbook of Sensory methods and analysis. Rojoint Com. Services Ltd. Enugu, Nigeria.

Kent, N.L. and A.D. Evers, 1994. Kent's Technology of cereals. 4th Edn. Introduction for students of food sciences and Agriculture. Pergamon Press, New York.

Lawal, O.S., Ago-Iwoye, K.O. Adebowale and R.A. Oderinde, 2004. Functional Properties of amylopectin and amylose fractions isolated from Bambarra groundnut (*Voandxeia subterranean*) starch. Afr. J. Biotechnol., 3: 399-404.

Lyonga, S.N. and S. Nzietchueng, 1986. Cocoyam and African food crisis. In "Proc. of the 3rd Triennial Symp., Int. Soc. Trop. Root Crops. African Branch, Owerri- Imo State, Nigeria.

Ogazi, P.O., 1985. The rheological properties of plaintain flour as composite with wheat flour. Nig. Food J., 2: 190-193.

Okaka, J.C., E.N.T. Akobundu and A.N.C. Okaka, 1992. Human Nutrition-An Integrated Approach. ESUT publications. Enugu, Nigeria, pp: 108.

Okezie, B.O. and A.B. Bello, 1988. Physicochemical and functional properties of winged bean flour and isolate compared with soy isolate. J. Food Sci., 53: 450-454.

Onwueme, I.C., 1987. Strategies for Increasing Cocoyam (*Colocasia* and *Xanthosoma* sp.) in Nigerian Food Basket. In: O.B. Arene, L.S.O. Ene, S.O. Odurukwe and N.O.A. Ezeh (Eds.). Proc. 1st National Workshop on Cocoyam NRCRI Umudike Nigeria, pp: 35-42.

Opara, L.U., 2002. Edible Aroids: Postharvest Operation. In: AGST/FAO: Danilo, M. (Ed.). Massey University, New Zealand.

Osman, E.M., 1967. Starch in the food industry. Academic Press. New York, pp: 163-193.

Oti, E. and E.N.T. Akobundu, 2008. Potentials of cocoyam-soybean-crayfish mixtures in complementary feeding. Nig. Agric. J., 39: 137-145.

Rapaille, A., 1995. Use of Starch in heat processed food. Food Tech. International Europe, pp: 73-76.

Rasper, V., 1969. Investigations on starches from major starch crops grown in China 1-Hot paste viscosity and gel forming power. J. Sci. Food Agric., 20: 165-171.

Rickard, J.E., 1991. Quality aspects of tropical root crop starches. In: 9th Symposium. Int. Soc. Trop. Root Crops, Ghana.

Roberta, D.L. and A.P. Jovita, 1986. Root crop flour: potential substitute for wheat flour in some selected baked products. The RADIX-semi-annual Research Publication of the Philippine Root Crop Research Training Center, Visca, Leyte, 8: 17-18.

Sakai, W.S., 1983. Aroid Root Crops. In: Chan, H.T. (Ed.) Handbook of Trop. Foods.New York, Marcel Dekke, pp: 29-83.

Schoch, T.J., 1967. Properties and uses of rice starch. In: Whistler, R.L. and Paschall, E.F. (eds) Starch Chemistry and Technology. Academic Press, London.

Sester, C., 1993. Viscosity of Flour Paste. In Encyclopaedia of Food Sciene, Food Technology and Nutrition. Macrae, R., R.K. Robinson and M.J. Sadler (Eds). Vol. 4, Academic Press, UK.

Shipman, L., 1967. Manufacture of Tapioca, Arrowroot and Sago Starches. In: Starch Chemistry and Technology. Hamilton, R.M. and E.F. Paschal, (Eds.). Vol. 2. Academic Press. New York.

Ukpabi, U.J. and C. Ndumele, 1996. Evaluation of the quality of garri produced in Imo State. Nig. Food J., 8: 103-110.

Wurzburg, O.B., 1989. Modified Starches: Properties and Uses. CKC Press Inc. Boca Raton, Florida, pp: 200-220.