



*Full Length Research Paper*

# The technology of producing banana wine vinegar from starch of banana peels

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## ABSTRACT

**Bananas (*Matooke*) are a common food crop in Uganda, generating vast agricultural waste during preparation. In this study, banana peels, which had adequate starch remaining in them, were used to process the vinegar. A sharp stainless steel knife was used to cut the banana peels into smaller pieces and these were boiled to gelatinize the starch. The extract was separated from the boiled mass via a muslin-cheese cloth, and fermented by adding wine yeast (VIN13) in a 10 liter jerry-can, fitted with an air lock. A muslin-cheese cloth was then used to separate the extract from the boiled mass. A laboratory-scale 20 liter fermenter was used to produce the wine vinegar by surface culture acetification. This resulted in banana wine vinegar whose properties comply with the Food and Drug Administration (FDA) requirements for vinegar.**

**Keywords:** Banana (*Matooke*) peels, acetification, fermenter

## INTRODUCTION

There are several types of banana grown in Uganda for food consumption. These have been classified as cooking bananas, roasting bananas, sweet bananas and brewing bananas (Spilsbury et al., 2002). Of all these bananas, the cooking bananas, commonly known as *matooke* (*Musa spp*) are the most widely grown and consumed in Uganda (See Table 1). According to recent studies, Uganda is the leading producer of *matooke* worldwide (Edmeades and Smale, 2006; Bagamba et al., 2010). In Uganda, *matooke* is mostly used for food, and the waste may be used as feed for live stock or organic manure on farm yards.

Currently, there are several efforts to study and explore the potential of these bananas in Uganda. For example, the Presidential Initiative for Banana Utilization which aims to improve and maximize banana utilization in Uganda (Beed and Markham, 2008; Tumutegyereize et

al., 2011). Much of this research has focused mostly on increasing the variety of products obtained from the banana. Such projects are recording significant success, and show great potential. Examples of such research includes; powdered *matooke*, with increased shelf life and nutritional value (Muranga et al., 2009), improving the taste of dried bananas by adding other food stuffs to improve taste (Pekke et al., 2004), and Banana Products Ltd (2012), under Banana Value Chain.

Aside from food, *matooke* generate vast amounts of waste in form of the banana peels (Khan et al., 2009), because the peels need to be removed first before the food is consumed. At the moment, some propositions on how to utilize the wastes are underway including conversion of the waste to biogas and live stock feed (Tumutegyereize et al., 2011; Tumwesigye et al., 2013).

This paper reports an attempt to utilize *matooke* peels

**Table 1.** Production of bananas in Uganda (tonnes)

Banana type	Year	Year	% production
	1995/1996	1999/2000	1999/2000
Cooking bananas ( <i>matooke</i> )	7,908,984	5,545,134	90
Brewing bananas	1,164,887	538,304	9
Sweet (dessert) bananas	383,949	46,286	1
<b>Total</b>	<b>9,457,820</b>	<b>6,129,724</b>	<b>100</b>

Source: Spilsbury et al., 2002

for the production of vinegar. Vinegar is produced by fermentation of alcohols to acetic acid by bacteria (Anchanarach et al., 2010). Generally, the acetic acid bacteria break down the sugars or starch in the food (substrate) converting it to alcohol and then further to acetic acid by membrane bound enzymes (Anchanarach et al., 2010). The vinegar can then be used in dressing salads, manufacture of useful medicines, preservation of food stuffs, provision of antioxidants or as an anti-bacterial agent (Johnston et al., 2004; Shizuma et al., 2011; Soltan and Shehata, 2012).

Vinegar is commonly obtained from good wine, cider, fruits and starchy foods (Silva and Swarnakar, 2007; Krusong and Assanee, 2010). These undergo fermentation by acetic acid bacteria during the process of secondary fermentation.

Since the *matooke* peel has about 2% starch adhering to it after peeling, it was hypothesized that this can be further processed by fermentation into a valuable product such as vinegar. The production of vinegar from the *matooke* waste can be of great value to the country both economically (by increasing the economic value of *matooke*, providing locally made vinegar on the market, creating jobs and reducing seasonal losses of the fruits) and will also provide an avenue to utilize the vast waste produced in form of peels.

## MATERIALS AND METHODS

### Materials

Fresh bananas (*matooke*) from Nakasero market, Kampala Uganda, stainless steel knife (Impala, made in Uganda), muslin-cheese cloth (from Nytil, Uganda), 10 liter Jerry-can (Mukwano, Uganda), Wine yeast (VIN13) from Anchor yeast, South Africa were used. Laboratory-scale 20 liter fermenter (Prince-ware, Tanzania) was used to produce wine vinegar by surface culture

acetification. It consisted of a flat bottomed, double walled plastic cylindrical container of 20 liter capacity; with a small aspirator at its bottom end and height to diameter ratio of 2:1 built in 100% virgin plastic material were used.

### Methodology

#### Preparation of the banana peel must

Fresh healthy *matooke* were peeled with a sharp stainless steel knife. The *matooke* peels were manually sorted and a mass 1.5 Kg was weighed (Globe Carry-China), washed thoroughly in rain water and drained for 30 minutes. The peels were then sliced into pieces of about 3cm thick, and heated at 98°C in 1 L of water for 20 minutes. The boiled mixture was cooled to room temperature filtered using a muslin-cheese cloth and the residue was further extracted at 98°C in 1.5 L of water for 5 minutes. The first and second filtrates were then blended and 2 L of water added. The physiochemical properties of the extract were measured and recorded in Table 1. The filtrate was ameliorated using sucrose to raise the sugar level to 21°Brix and ammonium sulphate (111ppm) added to stabilize the must and to provide a nitrogen source for yeast. The pH of the must was adjusted to pH4 by adding 120 mls of vinegar. The treated must was pasteurized at 63°C for 30 minutes and then allowed to cool to room temperature of 25°C.

#### Preparation of the yeast starter culture

A small amount of must (20 ml) was inoculated with viable wine yeast (VIN13) at a rate of 0.3g/L. This solution was sweetened to 12°Brix with sucrose to provide yeast with required nutrients, and left to incubate in a water bath for approximately 20 minutes.

**Table 2.** The physiochemical properties of the banana peel extract, wine and must

Parameter	Extract	Must	Banana peel wine
Total soluble solids (° Brix)	6.9±1.00	21.0±0.00	0.6±0.00
Titrateable Acidity (%)	0.023±0.00	0.016±0.00	0.42±0.01
pH	5.93±0.1	6.30±0.00	3.6±0.00
Specific Gravity	1.0063±0.001	1.089±0.00	0.92±0.00
Alcohol (%v/v)	0.00	0.00	13.02
Colour	Light brown	Deep brown	Light brown

Values are means ±SD of triplicate determinations.

### Must inoculation for alcoholic fermentation

Approximately 3.8 Litres of standardized must was poured into a 10 Litre sterile plastic jerry-can and inoculated with 20 ml of the yeast starter culture. The jerry-can was tight fitted with an air lock filled with distilled water. The inoculated must was subjected to primary fermentation at ambient temperature for 7 days to produce banana peel wine, which was then filtered using a sterile folded muslin-cheese cloth after complete primary fermentation. The physiochemical properties of the must and wine were then determined, and the results of this primary fermentation are presented in Table 1.

### Must preparation and Acetic acid fermentation

The wine obtained after the alcoholic fermentation contained 13.02% (v/v) alcohol. It was filtered and alcohol wort added for vinegar production. The addition of alcohol wort for vinegar production was conducted by taking out 4 L of unpasteurized vinegar with about 6% (w/v) acidity and adding 2.8 L of alcohol wort with 13.02% (v/v) alcohol content.

### Acetic acid fermentation

The acetic fermentation was conducted by seeding the wine obtained at alcoholic fermentation with acetic acid bacteria from a non-pasteurized alcohol vinegar/strong vinegar (obtained from the fresh vacuum sealed *matooke* (FREVASEMA) plant in Mbarara Industrial Park, Uganda). This was a mixture of acetic microorganisms obtained previous successive fermentations rather than isolated specific *Acetobacter spp.*

### Routine analyses

A sample of the mash was analyzed every two days for the ethanol content, pH, total acidity. Monitoring of the percent alcohol production (%v/v) was done by gravimetric Analysis, Percent acetic acid production (w/w)

was done by neutralizing samples at pH 7.2 with 0.1N NaOH; it was assumed that all medium acidities were due to acetic acid, pH was estimated using pH meter; (Hanna) and total soluble solids as degrees Brix using RHB-32 (ATC) refractometer; ERMA) acquired over a period of 30 days at room temperature.

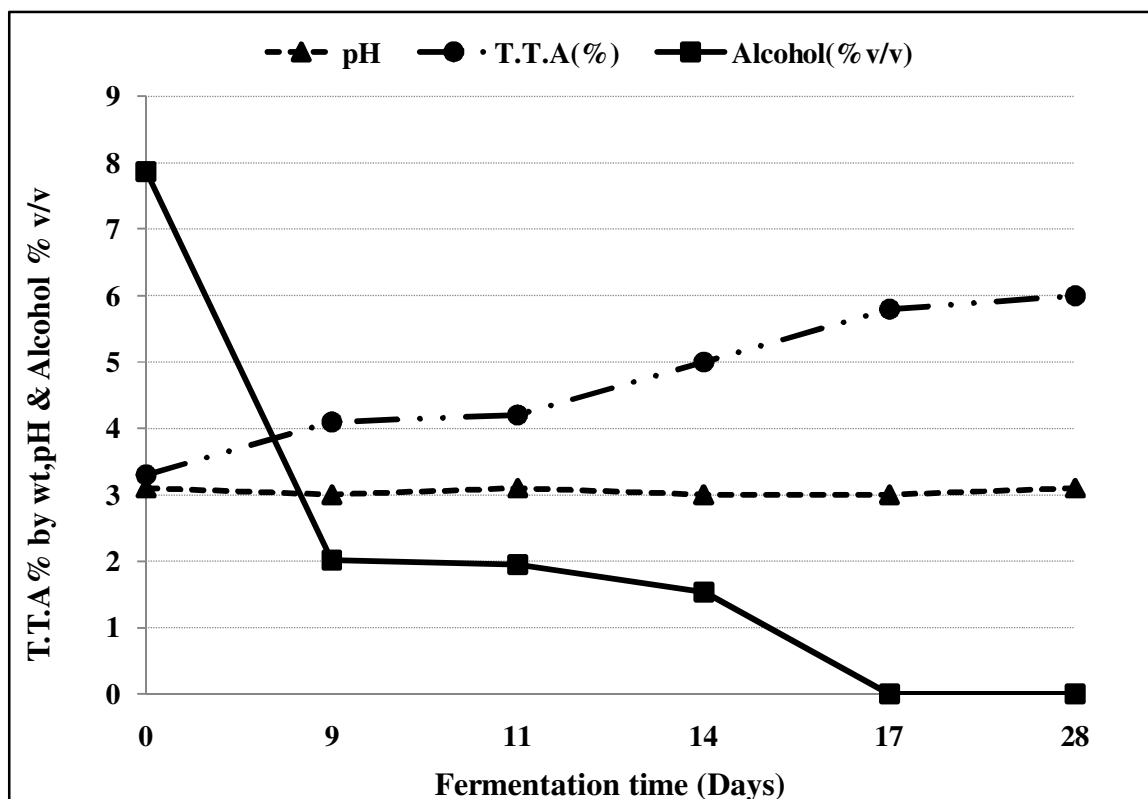
## RESULTS AND DISCUSSION

Table 2 shows the physiochemical properties of the banana peel extract, must and wine after primary fermentation.

The banana peel extract had slightly low amount of sugars (TSS,6.9°Brix). This necessitated amelioration in order to raise the levels sugar to provide for adequate nutrients for yeast fermentation. The titrateable acidity and pH did not change appreciably upon amelioration. However, the pH value decreased to pH 3.6 after primary fermentation of the wine. The banana extract color changed from light brown to deep brown after amelioration. This was possibly due to the brown color of the sugar that was used. Primary fermentation was carried out at room temperature (25°C). This resulted in a light brown colored banana peel wine with an alcohol content of 13.02% (v/v).

The banana peel wine obtained in Table 2 was then subjected to a two step fermentation system using a batch process. This involved enzymatic oxidation where the ethanol substrate was first oxidized to acetaldehyde and subsequently oxidized to the final product, acetic acid. This process was carried out over a period of 28 days. Figure 1 shows the trends in pH, total acid accumulation and alcohol content.

Before the initial mixing of the inoculum and fresh wine (zero days) a very short lag phase with no significant acid production is observed. This may be due to the sudden change in the medium conditions at the initial mixing that affected fermentative microorganisms. According to Brock and Madigan (1991), the observed microorganisms response can be explained as an adaptation phase in which the required enzymes for substrate degradation are synthesized. During the lag phase, acetic acid



**Figure 1.** The accumulation of acetic acid (T.T.A), change in pH and alcohol content over fermentation time.

bacteria use the main proportion of their energy resources in this synthesis. It is therefore not surprising that no net production of acetic acid was produced.

The decrease in alcohol concentration was corresponding to the gradual rise in acetic acid concentration (T.T.A) which accumulated from 3.3 to 6.0% (v/v) over a fermentation progress period of 28 days. Alcohol induces stress in yeast cells causing their death and flocculation, but the stress of yeast is more related to acetaldehyde which is the first intermediate product of ethanol biological oxidation by *Acetobacter aerobes*. This acetaldehyde disrupts the enzymatic activity of yeast. The beginning of acetic acid formation is related to maximum cellular growth and sufficient biomass density to start the acetification process (Seyram et al 2009).

The pH of the vinegar during the secondary fermentation was observed to decrease slightly from pH 3.1 to pH 2.9. This slight initial increase in acidity provided optimal growth conditions to initiate acetification. This fall in pH can be attributed to accumulation of acetic acid and other volatile short chain organic acids such as propionic, tartaric and butyric acids, which are important in development of the flavor and aroma of vinegar Seyram et al., (2009).

The alcohol content continued to decrease with time from 7.87% to about 0% by the 28<sup>th</sup> day. This interprets that the alcohol conversion to acetic acid reaches zero when acetic acid reaches to the maximum in the medium. The vinegar produced from the banana peel extract contained 6.0% (v/v) acetic acid and was comparable with 6.33% (v/v) and 6.11% (v/v) vinegar obtained by Torija et al (2010) in their study of two vinegar plants; Laguinelle (B,Banyuls,France) and Viticultors Masd'en gil (P,bellmunt del priorat, Tarragona,Spain).

There was also a significant amount of sugar recorded (5.0 °Brix) in the banana wine vinegar by the end of the fermentation. This implies that there is better utilization of sugar in the production of banana wine vinegar than banana peel wine (see Table 2). Therefore, the presence of fermentable sugars adhering to banana fruit processing residues (peels) can make them ideal substrates for alcoholic fermentation of fruit juice and subsequent secondary fermentation into vinegar.

## CONCLUSION

The banana wine vinegar production process took 28 days and had physiochemical characteristics of 6.0%

(v/v) acetic acid, 5.0°Brix, and pH of 2.9 which complied with the standard ranges of brewed vinegar after complete fermentation. The aroma of the vinegar produced was appreciated by the consumers who were acquainted with vinegar. This study therefore, showed that *matooke* peels can be used as an ideal substrate for production good quality vinegar. This not only increases the economical and food value of *matooke* but also provides a way of utilizing banana waste in Uganda.

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