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# PRODUCTION AND OPTIMISATION OF MANGO JUICE CLARIFICATION USING A MANUALLY PRESSURISED FILTER AT MEDIUM SCALE LEVEL IN RUSITU VALLEY, ZIMBABWE

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## ABSTRACT

Ripe Alphonso mango (*Mangifera Indica Linn*) fruits were bought from Rusitu Valley, Zimbabwe. The study aimed at producing and optimising mango juice clarification process using a manually pressurised filter at medium scale level. Mangos were cleaned in a water bath with sodium hypochlorite. Blanching was done at 100°C. Mangoes were peeled, sliced, and pressed. Mango pulp was stored 25 °C. A two stage manual pressurized filter was designed to aid in the clarification process. Pulp particle size, turbidity, pH, brix, and rheological properties were determined. Sedimentation tests were carried out. The cleaning process and pulp extraction took 96.7and 28 minutes respectively. Cleaning, slicing, peeling and pulp extraction process had a 0.2%, 27.6%, 36.6, and 35.6% fruit loss respectively. The designed cylinder and piston pump had the least time in mango juice filtration. Mango juice had a particle size of < 10µm and turbidity between 1500 and 3000. Clarified mango pulp had a fluid behaviour index and consistency index of 0.60 and 0.63 respectively. The clarified pulp had a pH, brix, viscosity and titratable acidity of 3.8, 17, 1.7, and 0.5% respectively. The pulp had a pseudoplastic behavior. Suspended solids affected consistency index. No sedimentation was observed.

**Keywords:** Optimising, Mango, Clarification, Manual Filter, Medium Scale, Rusitu Valley

## INTRODUCTION

Fresh mangos are being exported together with other fruits from Zimbabwe to overseas markets (Moran, 1992). Mango (*Mangifera Indica Linn*) is known as an appreciable fruit due to its pleasant aroma and flavour, whose nutritional value presents high calories and vitamin contents, among others Moraes et.al., 2010 and Sharma et.al., 2006). The fruit is an emerging tropical export crop produced in about 90 countries in the world with a production of over 25.1 million tonnes (Durrani et.al., 2012). The mango world market earns about 700 million dollars per year, and world production in 2007 and 2008 was superior to 30 x 106 tonnes whose world export was approximately 11 million tons (FAO, 1997-2009). Asia is the main producer with 76.9% of the total world production, followed by America with 13.38%, Africa with 9% and less than 1% each for Europe and Oceania (Rathore et.al., 2007). In Zimbabwe mango fruit production is done on homestead by rural people. There is also large production on plantations by commercial farmers around the country. The lack of mechanized equipment for the peeling of mangoes is a serious bottleneck for the increasing production of these products (Jagtiani et.al., 1988). The lack of simple and reliable methods of determining the stages of fruit maturity for processing affects the quality of the finished product (FAO, 1995). Only a small number of developing countries have surplus of mango juice for export (FAO, 1997-2009). In order for farmers to avoid losses during market glut, they may produce juice with a longer shelf life (Fellows, 2000). Currently there is no mango juice production at medium scale level. Zimbabwe is currently going through a critical economic recession. International development assistance to the country has declined in real terms. Given this scenario, it is necessary for Zimbabwe to develop innovative strategies to complement dwindling donor participation in fostering industrial development.

Agro-processing opportunities in Zimbabwe currently tend to favour growth and development of medium-scale processing industries that match the current production levels and the distortions in marketing of produce (Moran, 1992). Market forces and the prevailing economic environment favour more down-sizing of large-scale processing systems and upgrading small-scale processing industries. Despite high level fruit production in many districts of Zimbabwe there is food insecurity at household level. There is little processing of fruits at medium scale level and farmers are losing out as they often sell fresh fruits within weeks of harvesting at low prices. Sedimentation has been found to be the major limiting factor in juice processing at medium scale level (Nagy et.al.,1993). Insoluble components tend to precipitate leading to easy sedimentation thus lowering product acceptance. Pectin has been found to form a cloud. In order to prevent sedimentation, most processors have been found to use non cloudy, transparent fruit juice, that is, clarified juice. Major methods to remove pulp include centrifugal separation, homogenisation, filtration and clarification using enzymes (Vine et.al., 1997). Shortages of electricity have caused a major decrease in processing fruit juice by large scale in terms of volume outputs. Small scale processors have resorted to use filters. However this process was seen to be inefficient as the mesh of the funnel were failing to filter out the pulp (Hoover, 1997). It was therefore important to develop a two stage manual pressurised filters that will promote better clarification of the juice among small scale fruit juice processors.

## MATERIALS AND METHODS

### STUDY AREA

The study was conducted in Rusitu Valley area in Chimanimani. Chimanimani is a district located in the south eastern part of Zimbabwe in Manicaland Province. The district covers a geographical area of 3 353 km$^2$. It borders Mutare, Chipinge, and Buhera (Chimanimani Business Trust Report, 2007). Rusitu Valley is a growing area for a variety of fruits that include mangoes, pine apples, lemons bananas, avocado pears and oranges (ZOIC, 2008-2010)

### PRODUCTION OF CLARIFIED MANGO PULP

Ripe (Alphonso) mango fruits were bought from community men and women in Rusitu Valley. They were weighed. Cleaning was done using a water bath with sodium hypochlorite (15ppm). The mangoes were placed in a wire basket and immersed into boiling water at 100$^o$C for 2.5 minutes. After blanching, the mango peels were removed using knives and the peels were stripped off by hand. The mangos were sliced manually using knives. Flesh of sliced mangoes were pressed using a bucket blender to extract the pulp. The pulp was clarified in a two-stage manual pressurised pump clarifier. Time taken to perform each process was determined. The clarified pulp was stored at room temperature of 25 $^o$C to 30$^o$C in 100 litre plastic containers with air-tight plastic lids.

### OPTIMISING A TWO STAGE MANUAL PRESSURIZED PUMP FILTER

Optimising the clarification process was done. A manually pressured cylindrical piston pump was designed. Three thick circular wooden blocks of 30mm in height were designed. The three blocks were placed on a bar to make a piston. Two depressions were designed 8mm from the top. Bottom surfaces were mounted to the first block. Two nitrile cords were used to seal the depressions and prevent backflow in clarification. The other wooden blocks were placed at equal distances along the piston. The piston was directed to the cylinder. The cylinder was 750mm in length and 100mm inside diameter. The cylinder was sealed underneath by a threaded end cap. A hole with 16mm diameter was drilled onto the end cap. The first filter was disposed around and extended from the end of the cylinder. The steel filter was mounted onto the threaded end cap. Two sieves were threading onto the end cap. The second filter was mounted onto the end cap to enhance the effectiveness of clarification.

### TIME TAKEN TO CLARIFY THE PULP

A gravity and pressure filtration test of the mango juice was conducted. Mango pulps were was clarified using three methods. These were clarification using pressure pump, cylindrical and piston pump and gravity filters. The time taken to filter the pulp was determined. Four replicates were carried out to determine mean time taken to clarify the juice using each method.

### QUALITY ATTRIBUTES OF PREFERRED PRODUCT

The viscosity of the juice samples were evaluated on a five level scale using trained panelist. A viscometer was used to validate the results.

### RHEOLOGICAL PARAMETERS OF PULP CONTENT

Rheological properties of mango pulp were measured using a rotational type viscometer (Model LVDV-II). A sample of 500 ml of mango juice was loaded into a cylindrical shape glass beaker of 600 ml size for all the experiments. The mango juice samples were allowed to equilibrate at the desired temperature using a water bath.

Particle size and turbidity of the mango juice was determined. A centrifugal separator (Gerber Nova MSE Minor 35) was used. A dilution ration for mango juice and water (1:5 v/v) was used. The juice was centrifuged at specified revolutions.

### SEDIMENTATION TESTS

Sample beverages (mango-flavored fruit wine) were prepared using clarified and un-clarified mango juice. A 750ml sweet grape wine was used as a base in all samples. Commercial clarified mango juice was bought from the local supermarkets. It was used as control product. Sweet grape wine was mixed with manually clarified mango to produce sample product A. Un-clarified mango pulp was mixed with wine to produce sample product B. The samples were evaluated for sedimentation soon after mixing and after 24 hours. An evaluation was represented on three levels as present (++), slightly present (+), and not present (-).

### DETERMINATION OF PH AND %LACTIC ACID

The pH of the fruit pulp samples were determined using a pH meter (model WTW pH 340i 82362 Weilheim) at a temperature of 20 to 25°C. The pH meter was calibrated using pH 4.00 and 7.00 standard buffers. Acid in the sample was determined by an indicator titration method (Anon, 1994). Five milliliters of the juice was diluted with 5ml of distilled water in a conical flask and titrated with 0.1 M NaOH using phenolphthalein as an indicator. The acidity was expressed as %lactic acid (w/v) as shown below:

$$\frac{\text{Normality of NaOH} \times \text{Volume of NaOH} \times M_r \text{ of Lactic Acid}}{\text{Volume of Sample} \times 10} \qquad (1)$$

Brix content was determined using a refractometer (model SKU: CBX032) at room temperature (22-26°C). Three drops of juice were squeezed out of the prism and brix was noted on a scale.

## RESULTS AND DISCUSSION

The amount of mango flesh that is required to produce the target output of 100kg pulp was 14kg/h. Therefore in order to produce this amount a single person operating the bucket blender should be supplied with mango flesh at a rate of 14kg/h.

The maximum capacity attained by the piston pump was 10liters.There was no sedimentation and clogging in the piston pump and the foot-pump. This may have been caused by the application of two filters to filters the juice. The first filter could have filtered most of the insoluble solids. The mesh was large enough to reduce sedimentation. There was no sedimentation before and after production. This may have been caused by the second filter. The second filter may have filtered some insoluble solids that may have not been filtered by the first filter. The appropriate sizing of the two meshes allowed maximum filtration without requiring immediate rinsing. The aided flow of juice through the filter may have caused the reduction in clogging of the filters. The capacity of a disc centrifuge was found to be 119 litres per hour. This decreased with prolonged processing on a particular day. The capacity of the manual pump was 25 litres per hour. This had an advantage of maintaining a constant level in separation efficiency of the manual pump. Five pumps can be used to attain the same processing obtained by a centrifuge each hour. The cost was slightly higher for the piston pump than the pressure pump. The piston pump was used instead and this may be attributed to the reproducible flow rates that the piston pump managed to attain. The piston pump was used because it is generally a simple method that does not need human labour in filtration .The foot-pump filtration rates may have been lowered by a reduced application of pressure on the pump. A constant rate of filtration was obtained using the piston pump. The pump was classified as a reciprocating pump. Reciprocating pumps have been found to be constant flow pumps and can be used at a small to medium scale plant (FAO, 1997-2009). Therefore using manual pressurized pumps at medium scale level will help to maintain product consistency (FAO, 1997-2009). The constant flow could have been produced by reciprocating pumps that maintain the speed constant. The flow can however be increased with a change in cylinder and piston diameter.

There was no priming in the piston pump. This could have been resulted from the use of reciprocating pumps. A centrifugal pump usually operates at higher speeds of up to 1750 to 3540 rpm and therefore can lose prim when there is a leak in the pump casing. Reciprocating pumps are constant flow while the centrifugal pumps are variable flow and head pumps. This suggests that specific amounts of mango pulp can be processed using a piston pump at specific time, whereas centrifugal separation and discharge head can be improved by increasing the speen. Reciprocating pumps usually operates at lower speeds of 1150 rpm. Some suspended particles were seen at lower centrifugal effects. This suggests that centrifugation can help to remove many of the clouding components in juices (Nagy and Chen, 1993). It does not allow complete removal of all suspended particles for a clear juice. This could be due to centrifuges operating in a continuous way. There might be remixing of pulp before separation.

Most juice particles were subjected to centrifugal separation and clarification were less than 10 μm (Table 2). This suggests that large sized particles (greater than10 μm) can be sufficiently removed from processed mango juice obtained with clarification (Hoover, 1997). The distinction in particle size was more evident with the centrifugal separation apparatus than with clarification. This could have been attributed to the fact that a pressure of between 1-2bars (15-20psig) was necessary for microfiltration whereas a pressure of 1-7 bars was necessary for ultra-filtration. This was attained by centrifuges which rotate a high speeds. Centrifugal separation therefore remains the simplest industrial process available although it's expensive to implement in small to medium processes (Hoover, 1997). The pressure supplied by the piston pump was necessary to produce the required sized particles of 10 μm. In order to obtain consistent pulp size, different filters with the desired mesh sizes have to be used. This explains the use of the two stage manual filter at a small scale level to reduce sedimentation.

**Table 1. Behaviour index (n) and consistency index (k) of mango pulp**

| | Pulps | |
|---|---|---|
| **Whole mango** | **Clarified mango** | |
| K | 3.63 | 0.63 |
| n | 0.44 | 0.60 |
| $R^2$ | 0.99 | 0.99 |

Clarified mango pulp had a fluid behaviour index (n) and consistency index (k) of 0.60 and 0.63 respectively.

**Table 2. Particle size and turbidity of juice**

| Centrifugal separation | Particle size (μm) | Turbidity (NTU) |
|---|---|---|
| No effect applied | 21 | 500 |
| 300 | 9 | 1500 |
| 500 | 8 | 4000 |

| | | |
|---|---|---|
| 1000 | 6 | 3360 |
| 1500 | 5 | 3280 |
| 2000 | 4 | 3000 |

Juice samples had a particle size of less than 10µm. The turbidity ranges from 1500 to 3000

**Table 3. Occurrence of sedimentation in wine-fruit samples**

| Variable | Control | Sample A | Sample B |
|---|---|---|---|
| Sedimentation before | - | - | ++ |
| Sedimentation after | - | - | ++ |
| Viscosity | 1.3 | 1.7 | 4.5 |

Sample A had the no sedimentation before and after the clarification processing. Sample B had the highest viscosity of 4.5.

**Table 4. Physical and Chemical characteristic of preferred mango based product**

| Variables | Composition |
|---|---|
| Viscosity | 1.7 |
| Flavor | 3.4 |
| pH | 3.8 |
| Titratable acidity | 0.5 |
| Brix | 17 |

The juice had a pH, brix, viscosity and titratable acidity of 3.8, 17, 1.7, and 0.5% respectively

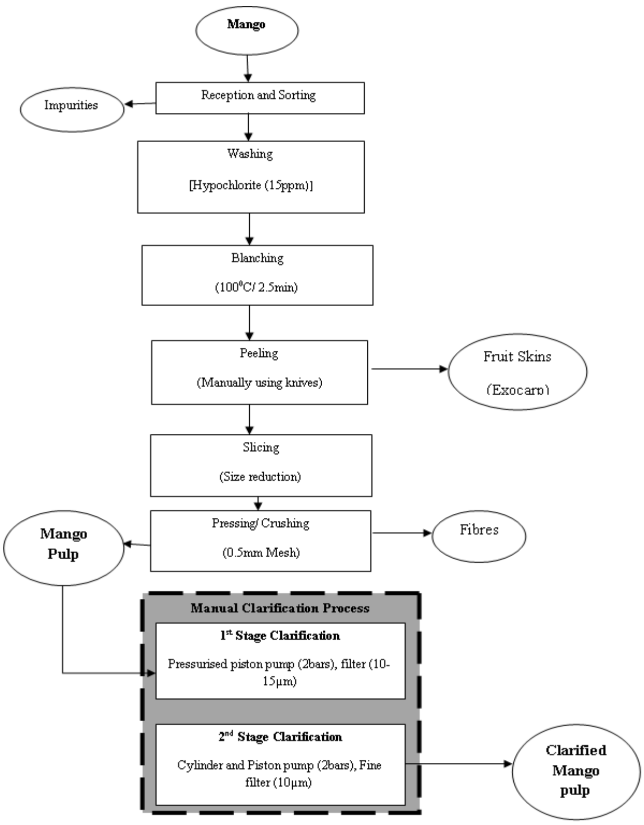


**Figure 1. Production of mango pulp using two stage manual a pressurised filter**

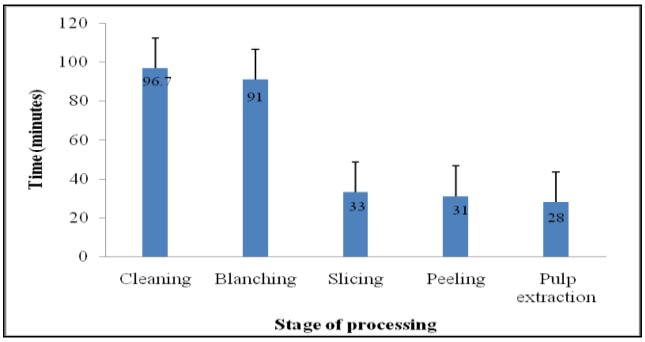


**Figure 2. Duration at each stage of processing**

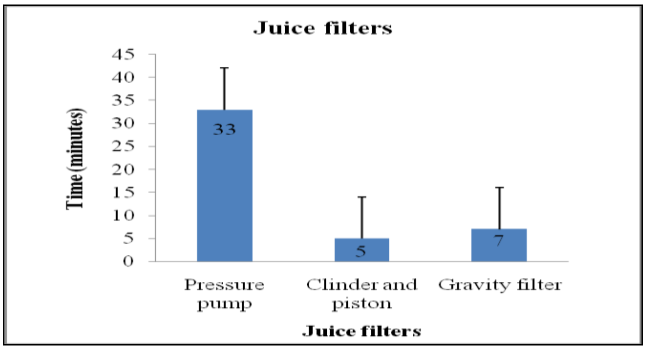


**Figure 3. Time taken to filter the mango juice at different methods**

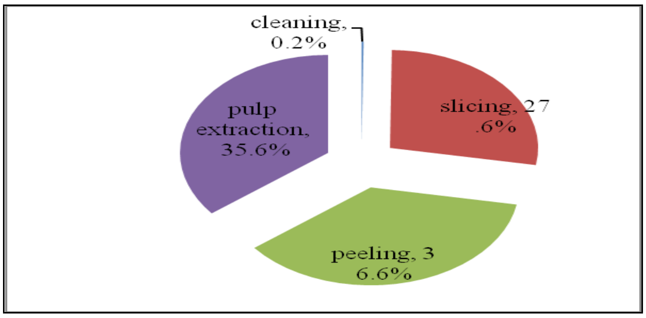


**Figure 4. Percentage losses at each stage of processing**

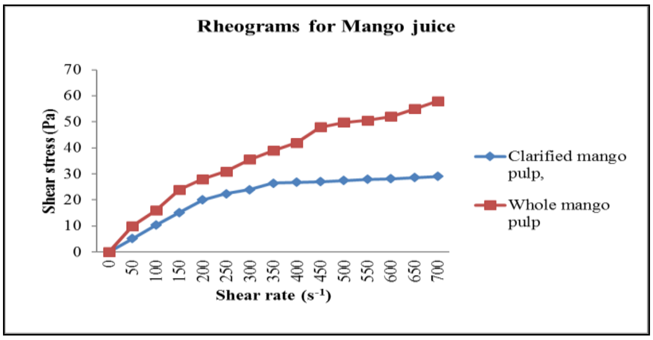


**Figure 5. Rheogram for mango juice**

The wine-mango juice had a more pronounced flavour. All batches of beverages provided the fruity flavor required to produce a beverage with the fruity flavor. This suggests the adding of fruit pulp during beverage production. The beverage that had containing a higher proportion of fruit had the highest value for the fruit derived flavor (Tables 4).The possible explanation may be because most of the flavour components were contained in processed mango juice even after removal of pulp. It was noted that clarified mango juice was useful as raw material for production of beverages with little sedimentation, with fruit flavor, low viscosity, and of good colour. To improve the colour there is need for the addition of colourings such as carmoisine and sunset red. According to Fellows (2000) these additives need to be used enhance the flavor and colour. Most of the fruit derived components may be lost during centrifugation (Shimlar, 2005). This could suggest the low values obtained on flavor.

Turbidity was lower with a stronger centrifugal effect (table 3). This could have been caused by large portions of cloudy components. The turbidity/fruit derived flavor was maintained after centrifugation. Industrial applications can therefore be matched at a medium scale level using locally available raw materials. This could have been caused by no sedimentation after clarification and the results of the piston pump could be correlated to an effect of between 500-1000g since the same particle size was obtained using both operations. The same pulp size was obtained with the two methods though fruit clarity was different. This may be because filtration is done before or after centrifugation to complement centrifugation which falls short when it comes to removal of pulp particles without prior dilution or filtration.

The fluid behaviour index (n) and consistency index results suggested that the pulp had a pseudoplastic behavior and suspended solids were found to influence the consistency index (k) of the pulp (Moraes et.al., 2010).

The clarified juice had a relative low brix value. The brix is a measurement of the fraction of sugar per hundred parts aqueous solution. It is the ratio of Total Soluble Solids (TSS) to water solution. The noted low brix value suggests that the juice had low contents in sucrose, vitamins, minerals, hormones and proteins FAO, (1995). There was a low pH value of the juice. According to Aurand *et.al.*, (1997) pH decline in passion fruit juice was a result of fermentation process by the presence of *L.bacillus* and *S.cerevisae*. Their presence might be attributed from the air and production equipment. Fermentation begins after glucose enters the cell and is broken down into Pyruvic acid. The Pyruvic acid is converted into carbon dioxide, ethanol and energy (Shimlar, 2005).

## CONCLUSIONS

Beverages having low viscosity and excellent flavour can be produced at a medium scale level using pressure filters. Minimal clogging of the filters can be archived by using pressure as a means of obtaining reproducible flow rates. Manual pressurized filters using steel filters represent the best possible alternative to reducing sedimentation in fruit juices that are produced at medium scale level. It is possible to combine two filters in a single process with the intent to reduce sedimentation of fruit juices. Initial quantity of pulp used has an effect on filtration rates. The effect is to cause clogging in most cases which results in lower pulp obtained .Fruit flavour is greatly enhanced when using mango pulp than when using other fruits. Filtration and centrifugation do not lower the fruit flavour of mango juice. Filtration can therefore be used to match the uses of centrifuges at industrial level and with great success. Processing of mango beverages is possible at small to medium scale level.

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