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Drying and quality characteristics of selected fruit in Zambia: The case of mumosomoso (*Vangueriopsis lanciflora* Hiern)

BACHELOR'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled Drying and quality characteristics of selected fruit in Zambia: The case of mumosomoso (*Vangueriopsis lanciflora* Hiern) independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 16.4. 2021

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Kateřina Mullerová

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Abstract

The drying and sensory properties of mumosomoso (*Vangueriopsis lanciflora* Hiern) was investigated in this study. Fruit of mumosomoso was dried in a climate chamber at 50° C. Three pre-treatments were chosen: no treatment, cooking and blanching. The Cooked sample was drying faster than the other ones. Organoleptic properties of dried fruit was assessed by the 8 member degustation panel. Traditionally open to sun dried fruit was used for sensory analysis alongside the other samples. The Blanched sample retained it's colour the best, but all samples showed a great change in colour. The pre-treatments had an effect on the texture and taste of the fruit.

Key words: mumosomoso, fruit drying, Zambia, sensory analysis, preservation

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1. Introduction

1.1. Food in Zambia

Out of 17.8 million people in Zambia, 48% are not getting the minimum calorie intake that is required and 35% of children under five years of age are stunted and many children and women are facing an iron deficiency due to malnutrition (WFP 2021).

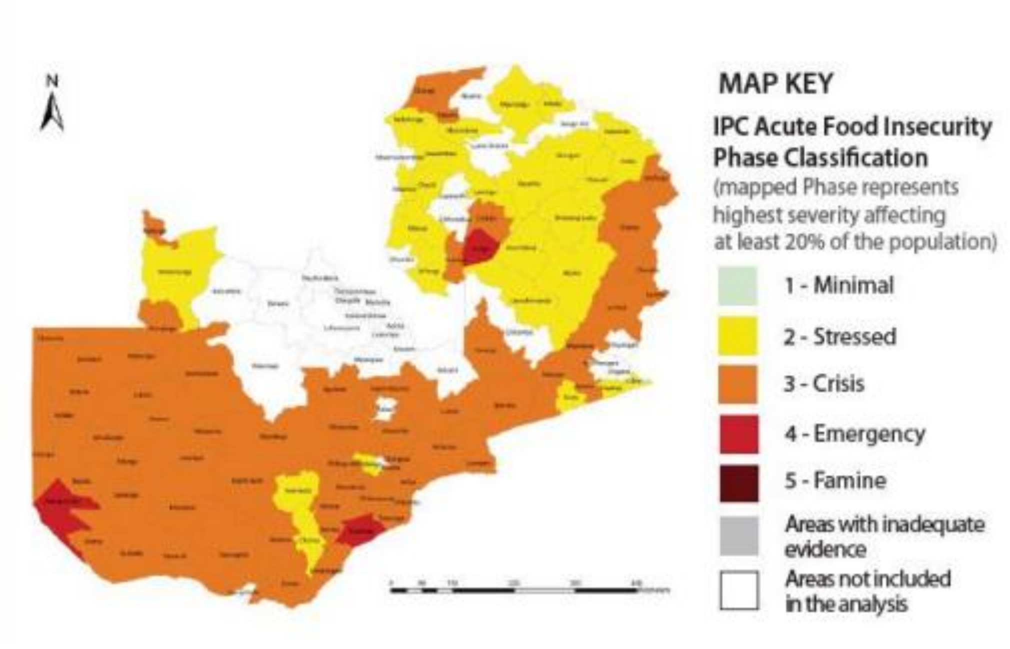

Figure 1 Hunger map – Zambia (WFP 2021)

Families in Zambia usually eat three meals a day, breakfast, lunch, and dinner. It is most common to eat bread or other wheat product with a hot drink for breakfast, poor households are known to skip breakfast from time to time. The most commonly consumed food for lunch and dinner is nshima (Harris et al. 2019), which is a white paste made out of ground-up maize (McCammon 2014). Maize is the staple food for Zambian cuisine followed by sorghum and cassava. Which is eaten with locally grown vegetables such as Kalembula, Chibwabwa, Katapa, and more (CUTS & WFP 2018).

In recent years there have been some changes to how food is consumed in Zambia and the overall nutritional intake.

In 2019 the International Federation of Red Cross and Red Crescent Societies has published an information bulletin drawing attention to food insecurity in Zambia caused by droughts and a late rain season. This has affected all households relying on rain for irrigation and limited sources of safe drinking water available. At least 1.7 million people were affected by this crisis (IRCR 2019). This number skyrocketed in 2020 as the number of people affected reached 2.4 million (Act!onAid 2020).

At the same time, Zambia has experienced a rise in supermarket chains both in urban and rural areas. This has made a shift in the habits of obtaining food for many people as supermarket chains and smaller stores called “kantenba” started growing in the country alongside many cheap fast-food chains. Most people still get fresh produce from markets, but saving time and energy has begun buying highly processed food from the stores. These occasions have dramatically changed the nutrition intake from homemade meals made from fresh ingredients available at food markets to fast-food meals and highly processed food such as pre-made frozen meals, canned meat, and cookies. But even with the rise of consumption of processed food, more than half of the food consumed by people are cereals, mostly maize. Even though the fruit and vegetable availability is not enough, the availability of various animal products and cereals has risen in recent years. Unfortunately, the overall food availability has been on a decline since the 1960s (Harris et al. 2019) this includes various types of fruits.

Fruits contain necessary components of a healthy diet – potassium, fibre, and vitamin C. Dried fruit is one of the major potassium sources for people all around the world, especially apricots and peaches (Aksoy et. al. 2011). Unfortunately, the fruit consumption in Zambia is low, with around 23 % of poor households reporting they do not eat fruit at all (CUTS & WFP 2018). This issue is further deepened by the constantly changing prices of food, especially in rural areas. Prices of fruits, eggs, milk, beef, and fish are constantly fluctuating and getting higher, which means most households cannot afford them (Harris et al. 2019). Implementing dried fruit into the diet of Zambians could fix the nutritional deficit as dried fruit can be stored for a long time and therefore could be more available and eventually have a relatively low stable price (Manaker 2020).

1.2. Fruit Conservation

1.2.1. Drying

Fruit drying is one of the oldest fruit conservation methods and works by removing moisture from the fruit. The benefits of removing moisture from fruit are that bacteria and fungi cannot grow in a dry environment. Methods for drying fruit are sun drying, solar drying, oven drying, and food dehydrators. Pre-treatments might be used to preserve the colour of the fruit or change taste and texture (Andress & Harrison 2000).

The nutritional value of dried foods might happen, especially a loss of the C and A vitamins (Brennan 2011).

The University of Georgia deems these fruits the best for drying: apples, apricots, bananas, cherries, citrus peel, coconuts, currants, dates, figs, grapes, nectarines, papayas, peaches, pears, pineapples, and plums (Garden-Robinson 2017).

1.2.1.1. Drying untreated fruit

Drying of untreated fruit consists of using a method of removing moisture from the selected fruit but skipping any possible pre-treatments. This can be done by various traditional and modern methods, for example, sun drying, drying using solar dryers, or dryers using fuels. Before drying the fruits are examined for signs of decay and moulds, afterwards they are washed and, depending on if it is necessary or desired, peeled and cut (Mercer 2012).

1.2.1.2. Traditional drying of fruit

We define traditionally dried fruit as fruit that is dried without modern technology, usually by people practising the technique for multiple generations. Traditionally dried fruit does not have added sugar or juice, and is not candied, fruits with low water content also do not fit into this category. This protects the fruits nutritional value as it’s not altered with additives (Aksoy et. al. 2011).

1.2.1.3. Blanching and drying fruit

Blanching is a form of pre-treatment of fruit that is done before drying them. The fruit is cooked at a high temperature in water or syrup, there is also a possibility of steam blanching. After cooking for a time appropriate for the type of fruit, the cooking process is stopped by putting the cooked fruit in cold water, ice water, or under running water (Fifield 2016). Blanching is used to block enzymatic reactions, it changes the flavour and texture of the fruit and helps to preserve the natural colour (Andress & Harrison 2014). But water and syrup blanching will result in a nutrient loss (Brennand 1994).

Fruits that need to be blanched as a part of a drying procedure, usually have thicker skin, for example cranberries, plums, and most commonly grapes (Gardner-Robinson 2017).

1.2.1.4. Cooking and drying fruit

It is possible to dry cooked fruit, this provides a double layer of protection as the cooking process kills bacteria and microbes, but it also causes a nutrient loss. Cooking is used as a pre-treatment for making fruit leathers. Fruit leathers are thin sheets of dried fruit juice or purée. It is common to mix fruit juices and purées to created interesting flavours (Raab & Oehler 1999).

1.2.1.5. Lyophilisation

Lyophilisation works by eliminating ice from frozen produce by sublimation, that is the water changes directly into vapour. This means the fruit is protected from bacteria and moulds but does not need to stay in the freezer (Barley 2012). Freeze-drying fruit also helps preserve vitamins and overall appearance better than conservation methods using heat (Marques et al. 2006). This method of food conservation is relatively new, being first used in the 1950s (Brennan 2011).

1.2.2. Canning

Canning fruit is the act of boiling fruit in a liquid or covering raw fruit in a boiling liquid and then canning it in sterilized jars. This way of fruit conservation focuses on destroying microbes by heat treatment. Products of canning are compotes, marmalades, and canned juices. Sugar and/or syrups might be used to change the final flavour. Most commonly canned fruits are apples, apricots, peaches, pears, pineapple, plums, oranges, and berries (Kendle & Shumaker 2015).

1.2.3. Freezing

Freezing is the process of lowering the temperature of the fruit, usually -18°C. This slows down any chemical processes happening as well as stops the growth of bacteria and microorganisms (Barbosa-Cánovas 2005).

1.2.4. Fermenting

Fermentation is a chemical reaction that happens if certain conditions are achieved. Lactic-acid fermentation can occur spontaneously alongside alcohol fermentation. Even at the beginnings of the fermentation process, bacteria causing food-borne illnesses are inhibited. Fruits are mainly fermented to produce alcoholic products, for example, wine and fruit liquors (Di Cagno et al. 2016).

1.3. Quality of food

1.3.1. Methods of quality control

Food quality is a complex measurement of different qualities of certain foods, different food groups have different quality requirements for each measurement. Any measurements of fresh food quality are valid for only a short period of time as the quality will quickly deteriorate. Preserved foods and foods with long shelf-life can maintain their quality for more extended periods, even decades, for example, alcoholic beverages.

One of the ways to measure food quality is sensory analysis, which is discussed below. There are also many instruments used to measure food quality, for example penetrometers which measure the hardness of foods, different models are used for measuring canned, cooked, or fresh food (Molnár 2009).

1.3.2. Moisture and quality control

Moisture content is very important for food quality as water in food is a potential home for microorganisms. This potential is measured with a water activity (aw) which is residual water in food. Water activity is measured by the difference between vapour pressure in the food and vapour pressure of distilled water that is under the same conditions (FDA 2014). The results are on a scale from 0 to 1.0. In which 0 is no water and 1.0 is pure water. The more the result reaches 1.0 the bigger is the probability of microbial activity in the food (Levi 2016).

Table 1 Microorganism activity at different aw levels

Range of aw	Microorganisms generally inhibited by lowest aw in the range
1.00-0.95	*Pseudomonas*, *Escherichia*, *Proteus*, *Shigella*, *Klebsiella*, *Bacillus*, *Clostridium perfringens*, some yeasts
0.95-0.91	*Salmonella*, *Vibrio parahaemolyticus*, *C. botulinum*, *Serratia*, *Lactobacillus*, *Pediococcus*, some moulds, yeasts
0.91-0.87	Many yeasts (*Candida*, *Torulopsis*, *Hansenula*), *Micrococcus*
0.87-0.80	Most moulds (mycotoxigenic *Penicillia*), *Staphyloccocus aureus*, most *Saccharomyces* (bailii) spp., *Debaryomyces*
0.80-0.75	Most halophilic bacteria, mycotoxigenic *Aspergilli*
0.75-0.65	Xerophilic moulds (*Aspergillus chevalieri*, *A. candidus*, *Wallemia sebi*), *Saccharomyces bisporus*
0.65-0.60	Osmophilic yeasts (*Saccharomyces rouxii*), few moulds (*Aspergillus echinulatus*, *Monascus bisporus*)
0.60-0.00	No bacterial proliferation

1.3.3. Sensory analysis

Sensory evaluation measures human responses to food that are not affected by subjective matters, such as branding. The sensory analysis measures these responses by evaluating sight, smell, touch, taste, and hearing. (Lawless & Heymann 2010)

Sensory analysis is the easiest way to measure the quality of food. Specific parameters are divided into appearance, texture, taste, and odour. All these measurements are subjective as different people have different preferences and tolerance levels.

Results that arise from the sensory analysis are vital to see the subjective quality of food. Usually, the first thing we look at in sensory analysis is the appearance that focuses on the shape, visual texture, and food colour. This is the most important measurement for determining whether a new food product should be brought to the market. By appearance, we can decide if the food is mouldy, not ripe, or otherwise undesirable. These qualities can also be noticed by the texture of the food either by sight or touch, soft fruits are most likely going to be deemed undesirable and overripe. The most important factor when it comes to the texture of food is how easy or hard it is to chew, both overly mushy and overly hard foods are undesirable. Taste and odour combined give us flavour and overall experience of the food, this also includes heat from spices or astringency (Molnár 2009).

1.3.3.1. Methods of sensory analysis

There are two classifications of sensory analysis methods. The first is a discriminant method. All discriminatory tests are based on comparison. The easiest test to conduct as a discriminatory test is the Paired Comparison test which compares two samples to each other, for example - which one is softer/sweeter/chewier. The Duo-Trio test compares two samples to a third one and wants to determine which of the two samples is more similar to the third sample. The Triangle test is trying to determine which two samples are the most similar or which sample is the most different from all the samples. The second classification of sensory analysis methods is the descriptive method. This method focuses more on the descriptive element of the analysis and is generally more subjective and focused on describing a single sample individually. Some of the descriptive methods are the Flavour Profile Method – which focuses on the flavour of the sample like sweetness, sourness, bitterness, and in some cases, odd, unexpected flavours present in the chosen sample. Another example is the Texture Profile Method – which focuses on texture and the Quantitative Descriptive Analysis and the Spectrum Method. Another possible variant to a sensory analysis method is a Time-intensity measurement which mainly measures the duration of certain tastes and how does the intensity of the taste change over time (Piggott et al. 1998).

1.3.4. Colour

Colour is an indicator of many things when it comes to food quality. We can determine the ripeness of fruits and vegetables or inconsistencies in the quality of cheese, meat, and beer. People tend to pick food that looks familiar and appealing, that’s why many foods are artificially coloured to resemble the flavours they have. Mint ice cream is artificially coloured mint green since that is the colour associated with mint flavour and odour. One of the options how to measure the colour of food is the spectrophotometric and the Munsell systems, both measure three values and from those values compose the final measurement (Molnár 2009). Other colour systems used in measuring the colour of food are the CIE system and the Hunter L, a, b, system. The Hunter L, a, b system measures L – lightness, a – redness or greenness, b – yellowness or blueness. The Munsell system measure hue, value, and chroma (Giese 2000). It was established by Albert H. Munsell, who felt the need for seeing colour values as three-dimensional (Munsell Color 2011). Spectrophotometry measures how much light is absorbed or transmitted, by measuring these properties it is determined what colour it is. If a sample absorbs red light it means it is green (Vo 2013). Spectrophotometry is used in the food industry to measure the quality and origins of oil, wine, and other beverages and foods (Leder & Porcu 2018).

2. Objective

The main objective of this work was to investigate the drying and sensory properties of selected fruit in Zambia, concretely mumosomoso (*Vangueriopsis lanciflora* Hiern).

The specific objectives were to evaluate the influence of three different pre-treatments on the drying behaviour, final colour, and sensory attributes of the dried product.

3. Materials and Methods

3.1. Fruit Samples

Research was carried on fruit called "mumosomoso" (*Vangueriopsis lanciflora* Hiern) available in Zambia. A wild fruit growing on small branchy trees in Central and South Africa, the fruits are yellow to brown in colour, 20 - 40 mm in size with one or two long oval pits (Bridson 1998). The plant belongs to the Rubiaceae family. It commonly grows 1.5 – 6 metres tall, but trees up to 13 metres have been sighted. There is not much information available about mumosomoso, but it is known the plant that is usually found at medium to higher altitudes, in deciduous woodlands and grasslands but has been sighted growing in sand and in rocky terrain. Apart from the plant being harvested for fruit, the wood is used for fuel or made into small utensils such as spoons. (Fern 2021).

Figure 2 Fresh mumosomoso samples

Both the fresh and the traditionally dried samples of fruit were collected at the same location, near Mongu in the Western Province of Zambia on 2nd December 2019 and given to the members of the Agribusiness for LIFE – Livelihoods, Innovation, Food

& Empowerment project from CULS by a local guide. The fruit was stored in plastic containers lined with newspapers and paper towels to help remove additional moisture. The container with fresh fruit was kept in the fridge until the start of the drying experiment on the 10th December 2019.

The traditionally dried Mumosomoso was prior to drying boiled, then open to sun-dried at least for 24 to 48 hours. However, the length of drying largely depends on the weather conditions. After the fruit was dried it was stored in plastic containers or baskets lined with newspapers at room temperature. Under this condition, it is usual to store it for several months.

3.2. Drying experiment and Drying pre-treatments

The drying of fresh fruit samples was carried out in the Laboratory of Food Processing at the Faculty of Tropical AgriSciences (FTA), CZU Prague, Czech Republic. Samples were divided into three experimental groups, each by four fruit pieces, according to three different pre-treatments prior to drying. The three groups were labelled as follows: Cooked, Blanched and No Treatment. The individual fruits inside each group were marked by letters: a. b, c, d. The total amount of fresh fruit samples used for cooked, blanched, and no treatment were: 120.53 g, 128.56 g, and 115.85 g, respectively, weighted before any pre-treatments. No Treatment sample group wasn't treated before drying at all. The Cooked sample group was prior to drying cooked at a temperature of 100° C for 20 minutes. The Blanched sample group was immersed for 20 s in water at 70° C and then immediately submerged in ice water for 40 seconds.

After the pre-treatment procedure, samples were dried in the climate chamber KK115 (POL-EKO-APARATURA sp.j., PL) at 50° C for 45 hours. Fruits labelled "c" from each sample group were used as reference samples and the process of drying was monitored by continuous weight measurement every 5 minutes.

3.3. Dry matter content

After drying in a climate chamber, all reference samples were places in a drier Memmert UFP 400 (Memmert, DE) for 24 hours at a temperature of 105° C to determine dry matter content. The pit/s were not removed from the fruit before the experiment.

Moisture content on wet basis (MC_{wb}) was calculated according to the formula:

$$MC_{wb} = \frac{water\ (kg)}{water\ (kg) + dry\ meat\ (kg)} \quad (1)$$

(Belessiotis & Delyannis 2011)

3.4. Colour measurement

The spectrophotometer Konica Minolta CM 600-d (Konica Minolta, JP) was used for surface colour measurements. This spectrophotometer uses the CIE L, a, b colour system. In which L is lightness/darkness, a is redness/greenness and b is yellowness/blueness.

The colour of all 4 fruits from the 3 sample groups was measured before pre-treatments, after pre-treatments, and after drying. Each individual fruit was measured twice each time, which means each pre-treatment was measured 8 times.

Index ΔE was used to evaluate the effect of different pre-treatments on the colour of dried fruit samples. Using the fresh No Treatment sample as a standard. The following formula was used for calculation (Mokrzycki & Tatol 2011):

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \quad (2)$$

Where:

$\Delta L = L - L_{NT}$

$\Delta a = a - a_{NT}$

$\Delta b = b - b_{NT}$

L, a, and b= colours coordinates of the sample

L_{NT}, a_{NT} and b_{NT} = colour coordinates of the No Treatment sample before drying

3.5. Sensory analysis

The sensory analysis was conducted on 5.12.2020 in the Sensory Analysis Laboratory at the Faculty of Agrobiology, Food and Natural Resources (FAFNR), CZU Prague, Czech Republic. One independent panel was organized, where eight assessors participated. All expert assessors were trained. The descriptive method with a 100 mm unstructured graphic scale was chosen and thirteen parameters were evaluated (see Table 2) Each type of dried fruit, namely cooked, blanched, no treatment, and traditional, was assigned a three-digit number sample code. Each fruit was cut into pieces and had its stone removed before being plated on a glass dish which had the sample number written on the bottom from the outer side of the dish. Each participant received four glass dishes with a single piece of dried fruit, a piece of bread, a glass of water, and the sensory analysis form, presented in Figure 3. See the original sensory analysis form in Annex A.

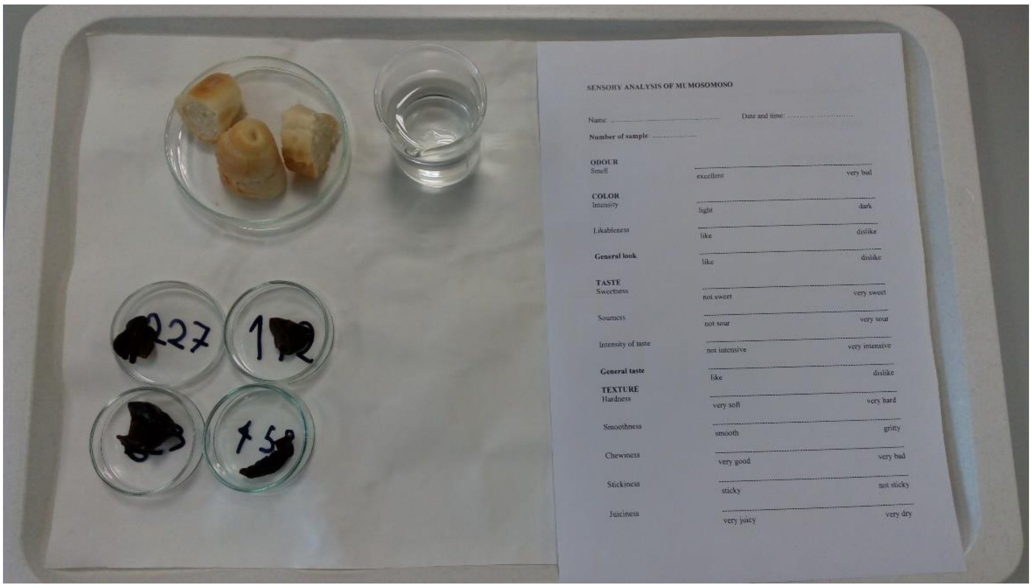

Figure 3 Samples of dried fruit prepared for assessor

Table 2 Parameters used for sensory analysis

	0	100
Smell	Excellent	Very bad
Intensity of colour	Light	Dark
Likableness (colour)	Like	Dislike
General Look	Like	Dislike
Sweetness	Not sweet	Very sweet
Sourness	Not sour	Very sour
Intensity of taste	Not intense	Intense
General taste	Like	Dislike
Hardness	Very soft	Very hard
Smoothness	Smooth	Not smooth
Chewiness	Chewy	Not chewy
Stickiness	Sticky	Not sticky
Juiciness	Very juicy	Very dry

3.6. Statistical analysis

The sensory analysis data were analysed using SPSS Statistics software, version 27.0 (IBM, US). First, the descriptive statistic was used, see in Annex B. Afterwards the data were tested for normal distribution of data using P-P plots, see in Annex C. The data were deemed as normally distributed for the functionality of other tests. Then a Oneway ANOVA and Post Hoc Tukey tests were conducted. For the statistical analysis of the drying measurements an independent samples T-test was used, first comparing the No Treatment pre-treatment with the Cooked pre-treatment and then with the Blanched pre-treatment.

4. Results and Discussion

4.1. Results of drying

4.1.1. Drying and dry matter content

In Figure 4 are presented data on drying of three different pre-treatments used prior to drying and the change of the weight during the drying. The biggest difference in weight before and after drying is visible in the Cooked pre-treatment sample, which was drying at a faster rate than the Blanched and No Treatment samples. The Blanched and No Treatment samples are very similar in their drying rate.

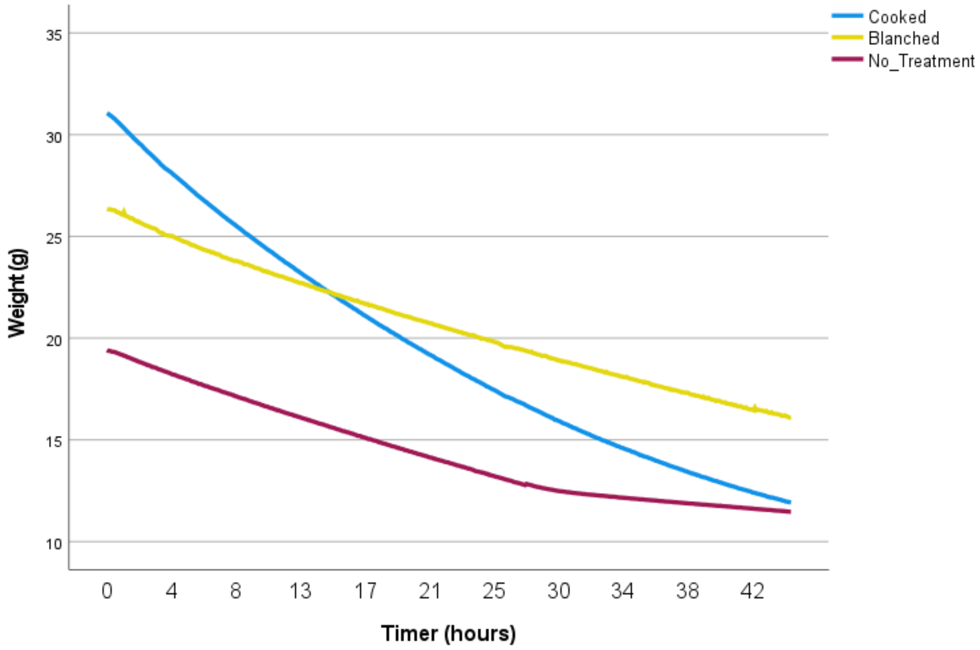

Figure 4 Weight measurements line graph

In table 3 are presented the T test results, where there has been found a significant statistical difference in both pairings.

Table 3 T-test results

Independent Samples Test - No treatment and Blanched

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Weight	Equal variances assumed	21.798	.000	-37.896	1060	.000	-6.25967985	.1651823415	-6.58380138	-5.93555832
	Equal variances not assumed			-37.896	1025.977	.000	-6.25967985	.1651823415	-6.58381367	-5.93554603

Independent Samples Test - No Treatment and Cooked

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Weight	Equal variances assumed	396.982	.000	-19.633	1060	.000	-5.14903955	.2622610167	-5.66364929	-4.63442980
	Equal variances not assumed			-19.633	727.844	.000	-5.14903955	.2622610167	-5.66391789	-4.63416121

The moisture content after pre-treatments of No Treatment, Cooked, and Blanched samples was 61.3 %, 81.8 % and 82.0%, respectively. The higher moisture content for the Blanched and Cooked samples could be attributed to the fruits soaking up water during pre-treatments. The final moisture content of No Treatment, Cooked, and Blanched samples was 34.5%, 52.6 % and 61.9% respectively. These results might be severely affected by the pit of the fruit as its weight is included in the measurements.

4.2. Results of colour

The measured colour for all three pre-treatments can be seen in table 4.

Table 4 Colour measurements

Before treatment

	L		a		b	
Pre-treatment	Mean	SD	Mean	SD	Mean	SD
No Treatment	35.89	2.57	10.9	0.65	21.5	1.08
Cooked	39.13	2.59	11	1.24	23.23	1.39
Blanched	44.63	3.76	12.24	2.07	26.45	3.9

After treatment

	L		a		b		
Pre-treatment	Mean	SD	Mean	SD	Mean	SD	ΔE
Cooked	34.64	1.65	10.71	0.59	13.53	1.68	11.48
Blanched	44.99	4.23	12.66	2.51	26.94	4.56	6.16

After drying

	L		a		b		
Pre-treatment	Mean	SD	Mean	SD	Mean	SD	ΔE
No Treatment	22.71	3.38	7.62	2.52	8.46	2.94	23.28
Cooked	17.67	2.09	3.53	1.02	2.9	0.9	31.45
Blanched	26.4	5.4	10.55	4.38	12.62	5.46	17.49

The colour difference ΔE is not noticeable (0-0.5), slightly noticeable (0.5-1.5), noticeable (1.5-3.0), well visible (3.0-6.0), and great (>6.0) according to the work of Cserhalmi et al. (2006). All after treatment results of colour difference, cooked and blanched, and all after drying results of colour difference, No Treatment, Cooked, Blanched are in the great (>6.0) category of the classification. The colour difference for after-treatment samples, Cooked and Blanched is 11.48 and 6.16 respectively. The colour difference for after drying samples, No Treatment, Cooked and Blanched is 23.28, 31.45, and 17.49, respectively. The biggest colour difference was measured for the After drying Cooked sample. The smallest colour difference was measured for the After treatment Blanched sample being in the great difference category only by 0.16. These results correspond with Krokidas MK et. Al (2000) findings that pre-treatments have a significant impact on the colour of fruit after drying.

4.3. Results of sensory analysis

Results of sensory analysis are presented in Figure 5. All samples were very dark in colour and generally on the same level when it comes to sweetness and smell. The most likable and with the best general taste and general look score is the Traditional sample, but it was found to be very hard and hard to chew, quite sour and the least sweet. On the other hand, the No Treatment sample was the least likable with the lowest general look but was found to be much softer than the other samples, the least sticky, and very sour.

The Cooked and Traditional samples have very similar results as the traditionally dried fruit is also cooked before drying. The Cooked scored much less on the general taste and likableness scale and was not as sour as the Traditional sample.

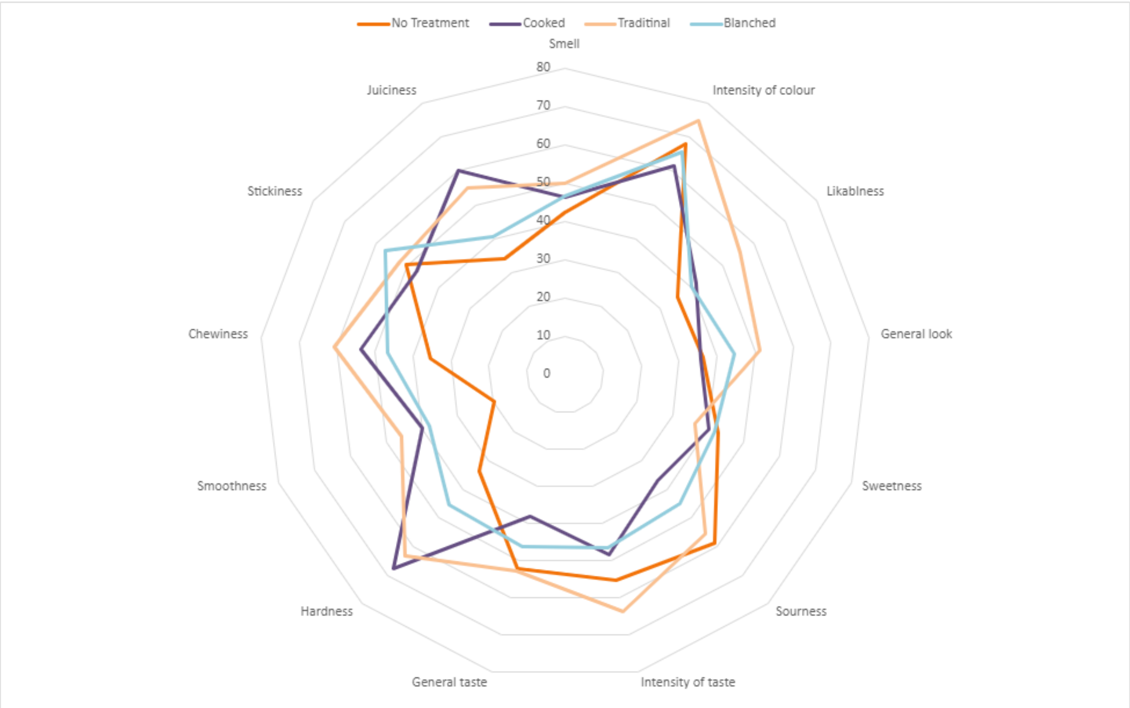

Figure 5 Sensory analysis spider graph

From the verbal descriptions in the sensory analysis forms, it is apparent that the Blanched and No Treatment samples were the best ones. Some people found the No

Treatment sample too sour or the Cooked sample too hard to chew. The Traditional sample was too sour and very hard to chew and overall was not enjoyable.

As seen in table 5 there is a statistically significant difference in the parameters Hardness and Juiciness, which correlate with each other. In both cases between the No Treatment and Cooked pre-treatments.

Table 5 Tukey test results

	Pre-treatments							
	No treatment		Cooked		Blanched		Traditional	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Smell	42.38^{a}	22.61	46.13^{a}	19.20	46.63^{a}	26.39	50.00^{a}	23.26
Intensity of colour	67.88^{a}	20.26	61.38^{a}	15.84	65.63^{a}	17.47	74.88^{a}	9.14
Likableness (colour)	35.63^{a}	19.53	41.75^{a}	25.01	40.25^{a}	17.52	55.75^{a}	20.11
General Look	36.25^{a}	18.21	35.63^{a}	23.46	44.63^{a}	26.55	51.25^{a}	27.55
Sweetness	42.63^{a}	24.45	40.13^{a}	25.23	41.88^{a}	21.44	36.13^{a}	29.32
Sourness	58.88^{a}	17.83	36.75^{a}	20.67	45.00^{a}	19.53	55.13^{a}	28.93
Intensity of taste	55.25^{a}	27.24	48.38^{a}	28.06	46.63^{a}	23.63	63.50^{a}	24.41
General taste	52.25^{a}	14.06	38.13^{a}	25.49	46.38^{a}	25.16	52.50^{a}	34.56
Hardness	**33.88^{a}**	16.61	**67.63^{b}**	24.04	45.50^{ab}	26.45	63.13^{ab}	23.74
Smoothness	19.88^{a}	12.67	39.75^{a}	27.34	38.00^{a}	23.68	45.63^{a}	24.58
Chewiness	35.50^{a}	20.28	53.63^{a}	31.28	46.75^{a}	15.99	60.63^{a}	27.52
Stickiness	50.50^{a}	26.76	47.13^{a}	18.43	57.13^{a}	26.95	52.13^{a}	19.31
Juiciness	**34.13^{a}**	14.27	**60.00^{b}**	22.55	40.50^{ab}	15.56	55.00^{ab}	20.85

$^{a-b}$ Mean values with different superscripts within the same row are significantly different ($p < 0.05$)

5. Conclusions

The mumosomoso fruit was dried using a climate chamber at 50° C. Three pre-treatments were chosen: No Treatment, Cooked and Blanched. The difference in drying between the No Treatment sample and the Cooked sample, and the difference between the No Treatment sample and the Cooked sample was statistically significant. The drying rate of the Cooked sample was faster than the other samples, this corresponds with the fact that the pre-treatment used to traditionally dry the fruit is cooking. The colour was measured before pre-treatment, after pre-treatment and after drying. It has been found that pre-treatments greatly ($\Delta E > 6$) affect the colour change. The Blanched sample had the best colour retention out of all the pre-treatments. The dried fruit was then used for sensory analysis alongside traditionally dried fruit, which determined that the most liked sample was the Traditional one. A statistically significant difference has been found in the parameters Hardness and Juiciness, which is understandable as they correspond with each other.

Mumosomoso is an underutilized crop that could potentially help with food consumption problems in Zambia. There is very little data available and further research should focus on nutritional values and other possible utilizations of the plant not just for consumption but also for fuel or animal feed.

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7. Annex A

Table 4 Sensory analysis form

SENSORY ANALYSIS OF MUMOSOMOSO

Name: .... Date and time: ……………………

Number of sample: ....

ODOUR

Smell	--	
	excellent	very bad

COLOR

Intensity	--	
	light	dark
Likableness	--	
	like	dislike
General look	--	
	like	dislike

TASTE

Sweetness	--	
	not sweet	very sweet
Sourness	--	
	not sour	very sour
Intensity of taste	--	
	not intensive	very intensive
General taste	--	
	like	dislike

TEXTURE

Hardness	--	
	very soft	very hard
Smoothness	--	
	smooth	not smooth
Chewiness	--	
	very good	very bad
Stickiness	--	
	sticky	not sticky
Juiciness	--	
	very juicy	very dry

OFF TASTE (If any, describe)

……..…………………………………………………………..

AFTER TASTE (If any, describe)

...………………………………………………………………

VERBAL DESCRIPTION:…………………………………………………………

8. Annex B

Table 5 Descriptive statistics

Descriptive Statistics - No Treatment

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Smell	8	14.00	77.00	42.3750	22.60807	.236	.752	-1.422	1.481
Intensity of colour	8	40.00	88.00	67.8750	20.25860	-.549	.752	-1.865	1.481
likableness	8	11.00	72.00	35.6250	19.52974	.827	.752	.426	1.481
general_look	8	17.00	61.00	36.2500	18.21106	.243	.752	-2.181	1.481
sweetness	8	17.00	82.00	42.6250	24.45367	.561	.752	-1.003	1.481
sourness	8	31.00	78.00	58.8750	17.82805	-.748	.752	-.619	1.481
intensity_of_taste	8	.00	92.00	55.2500	27.23837	-1.053	.752	2.150	1.481
genereral_taste	8	35.00	73.00	52.2500	14.05855	.125	.752	-1.529	1.481
hardness	8	14.00	67.00	33.8750	16.60841	1.110	.752	1.426	1.481
smoothness	8	.00	35.00	19.8750	12.66534	-.257	.752	-1.082	1.481
chewiness	8	9.00	67.00	35.5000	20.28370	.798	.752	-.297	1.481
stickiness	8	18.00	91.00	50.5000	26.76351	.343	.752	-1.356	1.481
juiciness	8	19.00	65.00	34.1250	14.26722	1.587	.752	3.223	1.481

Descriptive Statistics - Cooked

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Smell	8	18.00	81.00	46.1250	19.20147	.360	.752	.861	1.481
Intensity of colour	8	28.00	81.00	61.3750	15.83791	-1.271	.752	2.922	1.481
likableness	8	9.00	72.00	41.7500	25.01285	-.229	.752	-1.764	1.481
general_look	8	7.00	64.00	35.6250	23.45779	.114	.752	-2.094	1.481
sweetness	8	4.00	80.00	40.1250	25.22718	.379	.752	-.734	1.481
sourness	8	.00	66.00	36.7500	20.67262	-.467	.752	.245	1.481
intensity_of_taste	8	.00	85.00	48.3750	28.06084	-.414	.752	-.327	1.481
genereral_taste	8	8.00	83.00	38.1250	25.48634	.677	.752	-.116	1.481
hardness	8	19.00	100.00	67.6250	24.03532	-1.076	.752	2.066	1.481
smoothness	8	.00	71.00	39.7500	27.34306	-.220	.752	-1.987	1.481
chewiness	8	14.00	97.00	53.6250	31.28184	.125	.752	-1.802	1.481
stickiness	8	20.00	69.00	47.1250	18.43473	-.417	.752	-1.369	1.481
juiciness	8	28.00	86.00	60.0000	22.54519	-.601	.752	-1.179	1.481

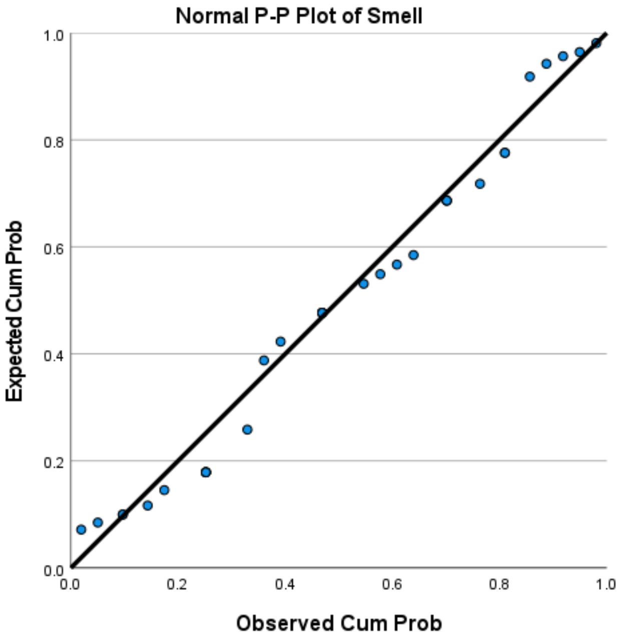
Descriptive Statistics - Traditional

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Smell	8	18.00	92.00	50.0000	23.26248	.448	.752	.416	1.481
Intensity of colour	8	57.00	86.00	74.8750	9.14076	-1.045	.752	1.122	1.481
likableness	8	25.00	85.00	55.7500	20.10508	-.137	.752	-.826	1.481
general_look	8	17.00	85.00	51.2500	27.55125	-.072	.752	-1.765	1.481
sweetness	8	.00	92.00	36.1250	29.32302	.730	.752	.961	1.481
sourness	8	29.00	100.00	55.1250	28.93064	.591	.752	-1.452	1.481
intensity_of_taste	8	37.00	100.00	63.5000	24.41311	.385	.752	-1.599	1.481
genereral_taste	8	6.00	100.00	52.5000	34.56257	.332	.752	-1.143	1.481
hardness	8	25.00	100.00	63.1250	23.73928	.140	.752	.011	1.481
smoothness	8	.00	79.00	45.6250	24.58186	-.751	.752	.554	1.481
chewiness	8	20.00	98.00	60.6250	27.51590	.233	.752	-.899	1.481
stickiness	8	21.00	83.00	52.1250	19.31275	-.121	.752	.084	1.481
juiciness	8	35.00	100.00	55.0000	20.84638	1.764	.752	3.012	1.481

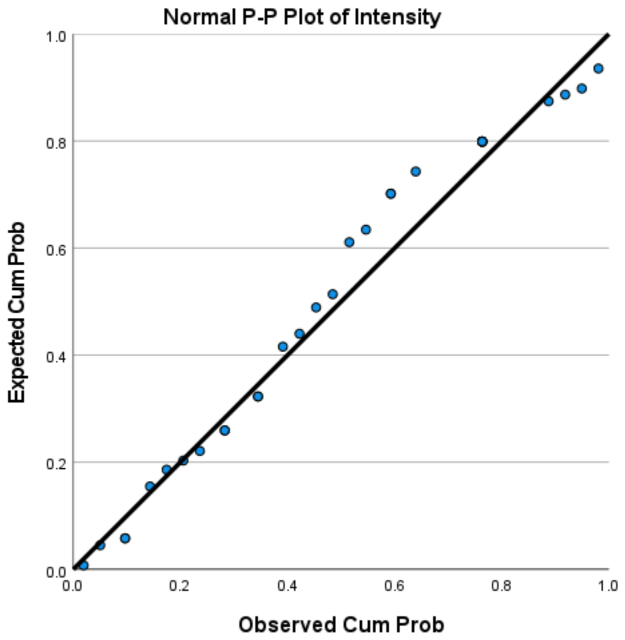
Descriptive Statistics - Blanched

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Smell	8	16.00	86.00	46.6250	26.39230	.648	.752	-.853	1.481
Intensity of colour	8	42.00	92.00	65.6250	17.46783	.273	.752	-1.351	1.481
likableness	8	21.00	72.00	40.2500	17.51530	.771	.752	-.146	1.481
general_look	8	17.00	84.00	44.6250	26.54881	.417	.752	-1.700	1.481
sweetness	8	11.00	67.00	41.8750	21.43720	-.208	.752	-1.777	1.481
sourness	8	7.00	72.00	45.0000	19.53020	-.914	.752	1.413	1.481
intensity_of_taste	8	.00	73.00	46.6250	23.63374	-1.065	.752	1.100	1.481
genereral_taste	8	18.00	94.00	46.3750	25.15630	.801	.752	.673	1.481
hardness	8	12.00	83.00	45.5000	26.45211	.351	.752	-1.470	1.481
smoothness	8	.00	71.00	38.0000	23.68242	.197	.752	-.001	1.481
chewiness	8	23.00	65.00	46.7500	15.98884	-.231	.752	-1.870	1.481
stickiness	8	16.00	98.00	57.1250	26.95201	-.028	.752	-.849	1.481
juiciness	8	20.00	62.00	40.5000	15.55635	.350	.752	-1.641	1.481

9. Annex C



Normal P-P Plot of Smell
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0



Normal P-P Plot of Intensity
Expected Cum Prob
Observed Cum Prob
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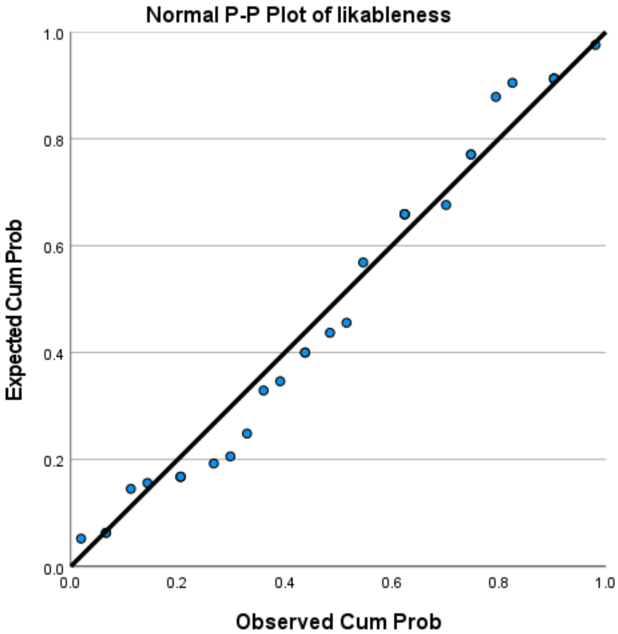
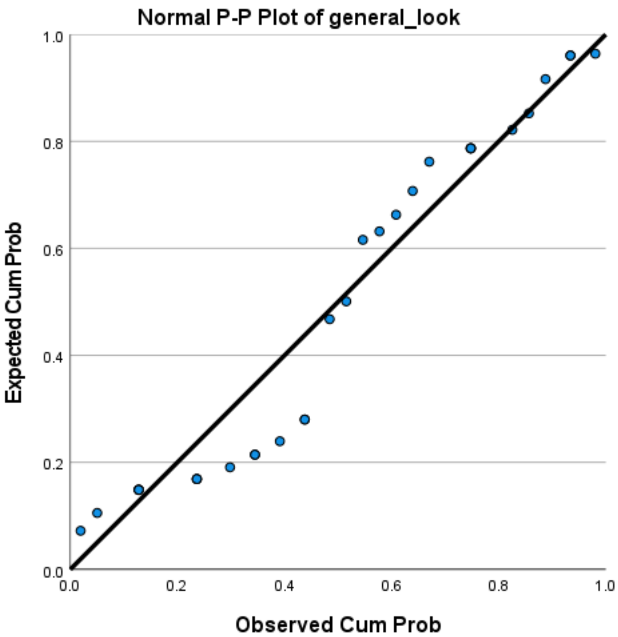
0.2
0.4
0.6
0.8
1.0


Normal P-P Plot of likableness
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0


Normal P-P Plot of general_look
Expected Cum Prob
Observed Cum Prob
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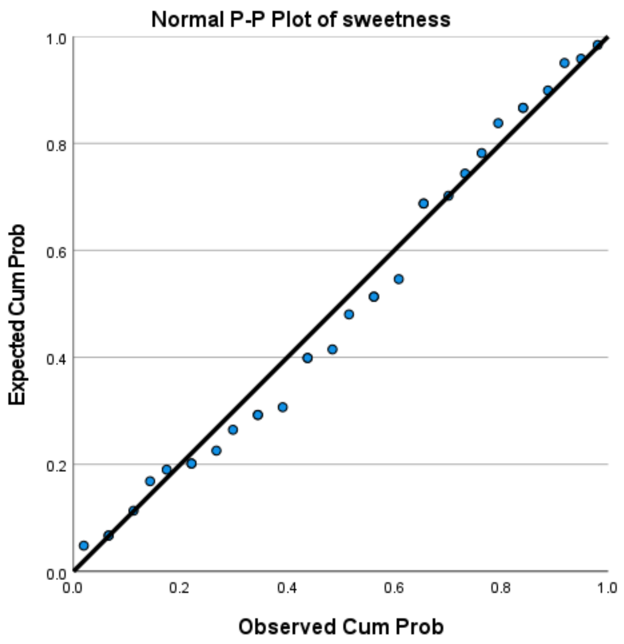
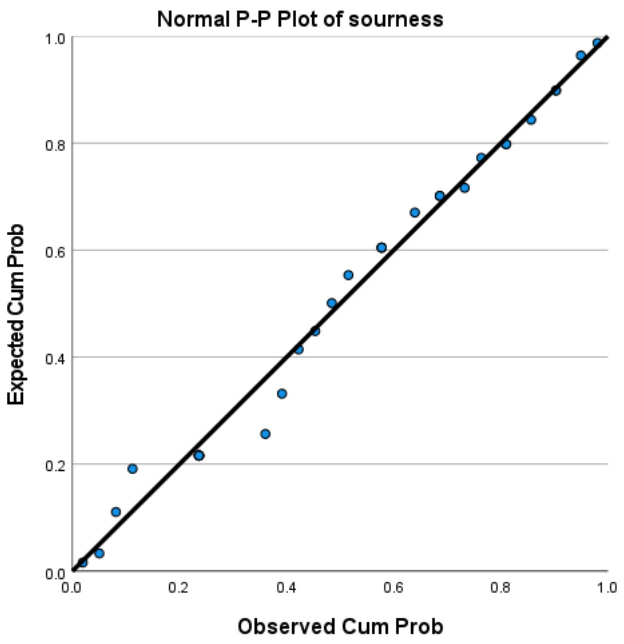
0.2
0.4
0.6
0.8
1.0


Normal P-P Plot of sweetness
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0


Normal P-P Plot of sourness
Expected Cum Prob
Observed Cum Prob
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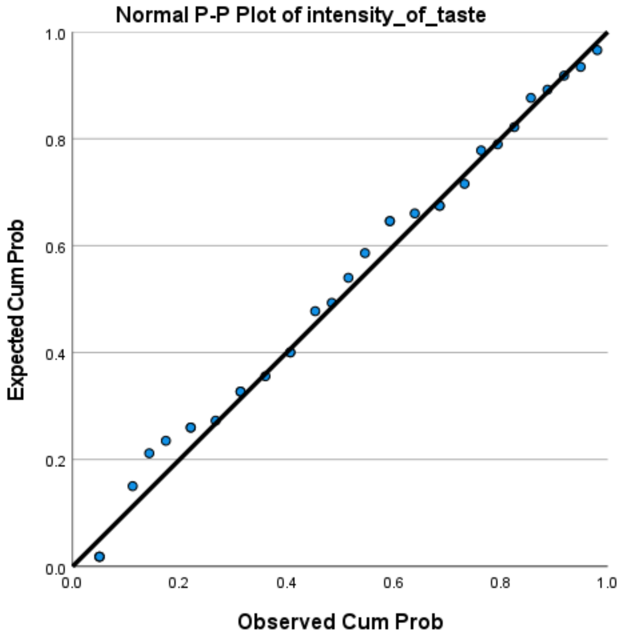
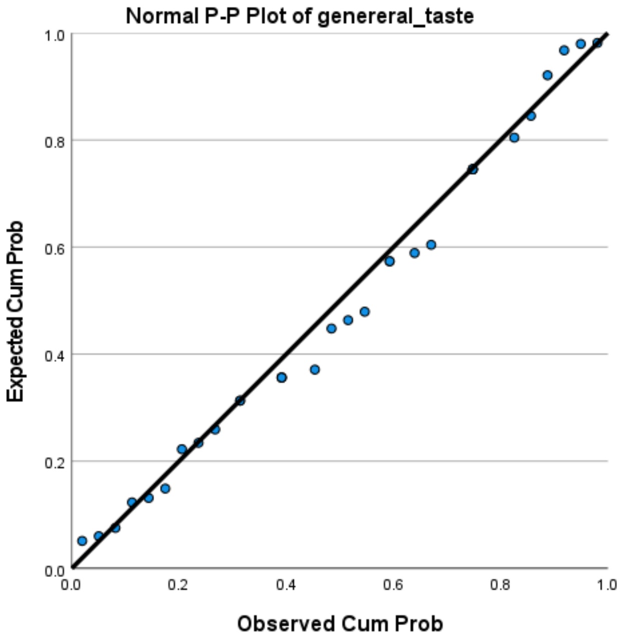
0.2
0.4
0.6
0.8
1.0


Normal P-P Plot of intensity_of_taste
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0


Normal P-P Plot of genereral_taste
Expected Cum Prob
Observed Cum Prob
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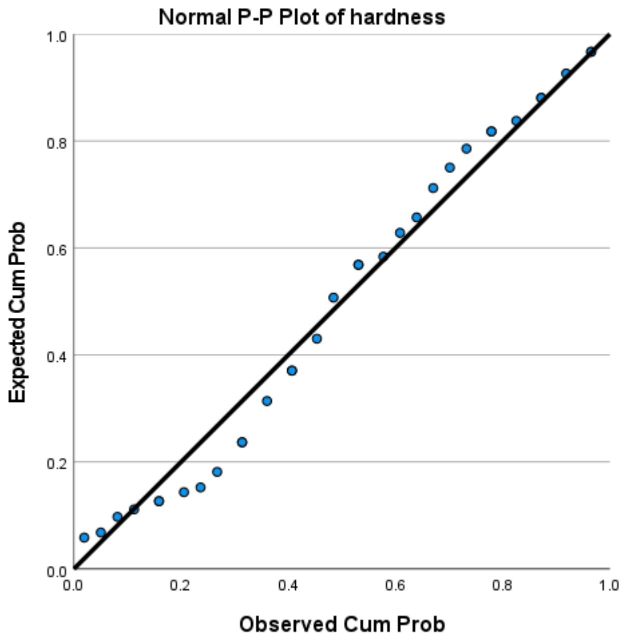
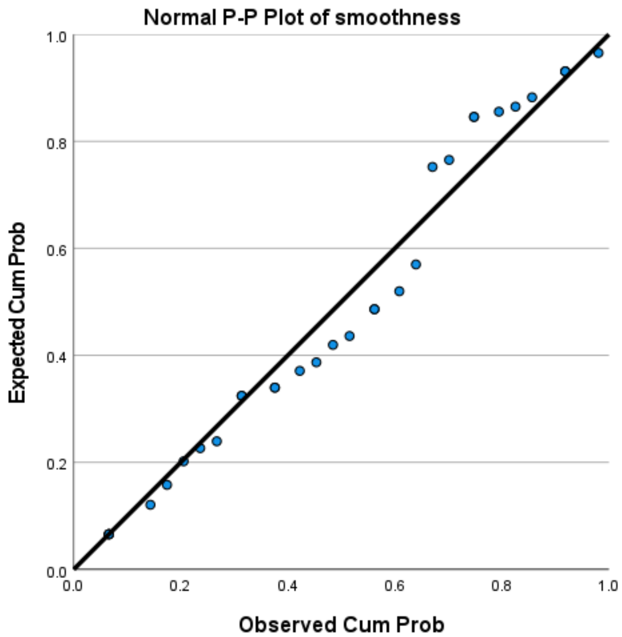
0.2
0.4
0.6
0.8
1.0


Normal P-P Plot of hardness
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0


Normal P-P Plot of smoothness
Expected Cum Prob
Observed Cum Prob
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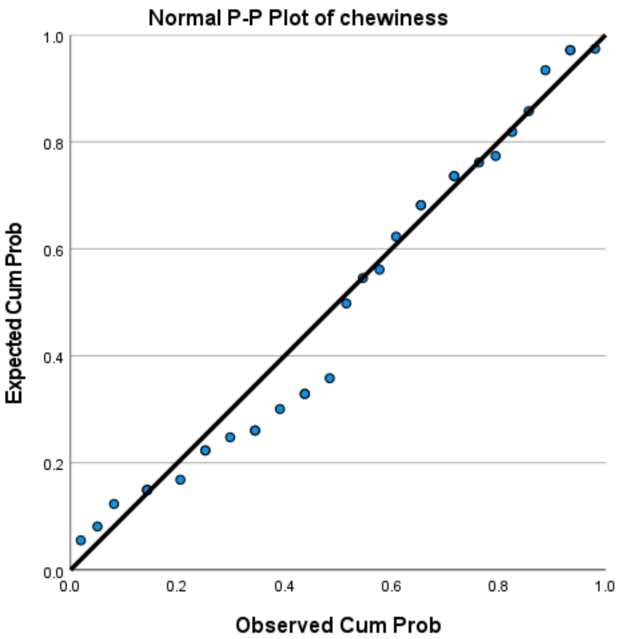
0.4
0.6
0.8
1.0


Normal P-P Plot of chewiness
Expected Cum Prob
Observed Cum Prob
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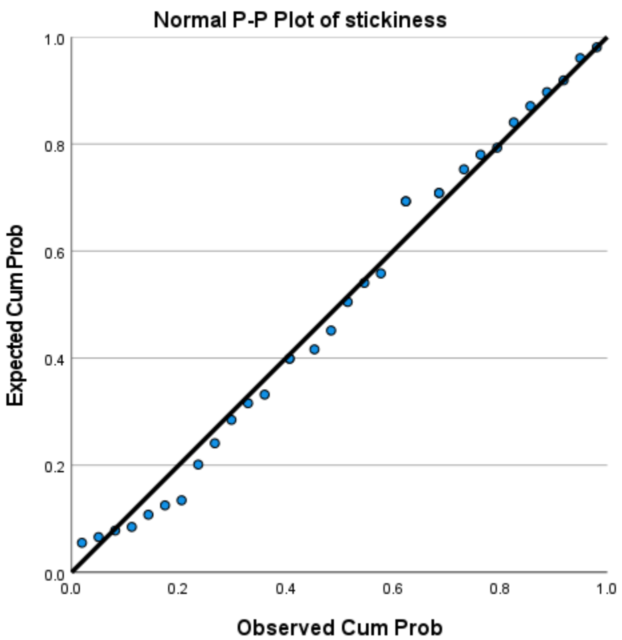
0.2
0.4
0.6
0.8
1.0


Normal P-P Plot of stickiness
Expected Cum Prob
Observed Cum Prob
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0.2
0.4
0.6
0.8
1.0

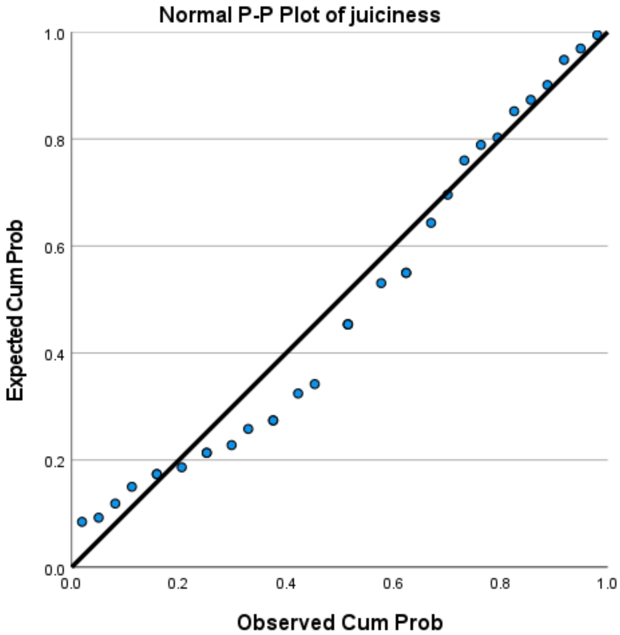

Figure 6 P-P Plots for sensory analysis