KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF SCIENCE

FORMULATION OF PAWPAW AND PINEAPPLE JAMS AND ASSESSMENT OF SENSORY QUALITY BY FUZZY MODELING

BY

UGETT NAA KORKOI OKINE

NOVEMBER, 2016

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A THESIS SUBMITTED TO THE DEPARTMENT OF FOOD SCIENCE AND

TECHNOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE

AWARD OF THE DEGREE OF

MASTER OF SCIENCE IN FOOD QUALITY MANAGEMENT

BY

UGETT NAA KORKOI OKINE

NOVEMBER, 2016

DECLARATION

I declare that I have wholly undertaken the study reported herein under the supervision of Mr. Isaac W. Ofosu and that except portions where references have been duly cited, this dissertation is the outcome of my research.

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Supervisor

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ABSTRACT

Fruit extract, sugar, pectin and organic acid are the four (4) ingredients needed for jam production. However, the quality of the jam is highly dependent on the choice of concentrations of each ingredient. This study investigated the highly accepted pawpaw and pineapple (*pawpine*) jam formulation using fuzzy logic modeling. Out of 13 pawpaw and pineapple blends that were formulated with Mixture design, the one with 60% pawpaw and 40% pineapple (without citric acid, sugar and pectin) proportions was highly accepted for the jam preparation. Afterwards Fuzzy logic model was used to formulate 27 *pawpine* jam products with varying concentrations (low, medium, high) of pectin, sugar, and citric acid. On the basis of 4 sensory characteristics (taste, colour, texture and odour), a 5-point hedonic scale was used by 18 panelists to assess the 27 *pawpine* jams. The responses given by the 18 panelists were analyzed by Fuzzy logic model to determine the best desired formulation. The Best desired products were that formulated with low citric acid (0 g), low sugar (100 g) and low pectin (9 g), as well as medium citric acid (3 g), medium sugar (120 g) and medium pectin (10.5 g), with each having a desirability as high as 93.5 %. Additive effects of pectin, sugar and citric acid played a significant role in the jam production. To produce the best quality *pawpine* jam, formulations of choice are either 0 g citric acid, 100 g sugar and 9 g pectin, or 3 g citric acid, 120 g sugar and10.5 g pectin.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Fruits are the fleshy seed-associated composition of a plant which has either sweet or sour taste and are edible in the raw state. The most cultivated ones include; pineapple, pawpaw, apple, cashew, orange, grape, strawberry, banana, mango and lemon. Vitamins, minerals and fibre (Duffrin and Pomper, 2006) are common beneficial uses when fruits are consumed. Pineapple fruit is a great source of fibre and is mostly consumed in countries including India, Philippines and Taiwan (Mwaikambo, 2006). The fruit has an internal juicy flesh with a mix of sweet and tart taste. The area closer to the base of the fruit has more sugar content and therefore a sweeter taste and more tender texture. The pineapple fruit contains some amount of sugar, pectin and acid.

However, the amount and proportion present is not sufficient for a successful gel formation (Afoakwa *et al*., 2006). *Carica papaya* plant bears the fruit papaya with other known names as papaw or pawpaw in other countries. It is indigenous to the tropics of the Americas, possibly from southern Mexico and bordering Central America. Pawpaw plant grows in three sexes; male (does not bear fruit), female (bears inedible fruits) and hermaphrodite/ dioecious (bears edible fruits). The hermaphrodites are widely grown for commercial purposes. Pawpaw fruit may be classified as ripe when it is soft when felt and the skin colour changes to amber and it has best qualities when it ripens on the tree. There are numerous kinds of fruits which all have their unique benefits and uses including being used in preparation of or as food products.

On the market, there are various food products ranging from drinks, candies, cakes, jellies, toppings, fillings, marmalade and jam which are prepared using fruits. Jams are crushed fruits formulated from a minimum fruit content of 40% and a final soluble solid content of 45º brix (Oyeyinka *et al*., 2009). Fruit extract, sugar, pectin and acid are the four ingredients that are needed in their right proportions for a successful fruit jam. They ensure a good gel formation, which is an important quality characteristic of a good jam (Afoakwa *et al*., 2006). Sugar imparts sweetness and has the ability to prolong the shelf life of the jam while pectin is used as a thickening agent and citric acid used to balance the sweetness of the sugar as well as bring the pH to optimum level to ensure jell formation. Each ingredient imparts different types of sensory attributes including taste, texture, odour and appearance (Pomper and Layne, 2005).

The difference in the sensory quality affects the level of demand and the market value. Sensory evaluation deals with the use of the five senses of sight, smell, taste, touch and hearing to bring to mind, assess, evaluate and infer responses to the characteristics of foods and materials as they are perceived. It is used in food industries to aid in understanding consumers' behavior and exploiting new markets (Martínez, 2007). It has three main testing or techniques for assessment namely descriptive, discriminative and affective testing (Carpenter *et al.*, 2012). Descriptive testing deals with perceiving the characteristics of the product, discriminative testing also deals with determining if there are differences among the products and affective testing deals with knowing how well a product is accepted or preferred. Sensory evaluation has been based on statistics and factorial analysis but these methods are not efficient because they are related to imprecision and vagueness of meanings.

Fuzzy logic first proposed by UC Berkeley Professor Lotfi Zadeh in 1965. It is the logic which is imprecise and occurs in our daily activities or lives and cannot be determined by mathematical sets. When input information is not exact or it is ambiguous, fuzzy logic tool is used and it represents the data and knowledge closer to human-like thinking. Fuzzy logic has in recent years demonstrated high levels of accuracy (Tang and Chi, 2005).

1.2 PROBLEM STATEMENT AND JUSTIFICATION

Fruits are widely grown and consumed, especially freshly, in the raw state by most people. The challenge with fruit is its easy perishable nature and it being a seasonal crop or plant. Due to this reason fruits are not available throughout the year and for one to consume fruit, one must wait for another seasonal time. With this challenge in the mind of food processors, there is an increase in the development of food products to serve as preserves for these fruits in order to have them available throughout the year. Some of these fruit products are jams, jellies, marmalades, juices, fruit powders and others alike.

But considering jam preparation especially for this study, processors have different methods which they use to prepare their jam as well as having different ingredients composition. In view of this, there are various options in terms of methods and ingredient composition to choose from in preparing jam. As food processors, this could give different kinds of jam with different properties but considering the acceptability of jam by consumers, a standard ingredient composition must be obtained to give consistency in the making of jam.

Formulation is a very important issue of concern when it comes to product development in the food industry. Poorly formulated fruit products particularly jams, jellies and marmalades could easily be rejected by consumers. This could lead to great loss. By way of offering solution, a number of strategies are adopted over time. Such strategies may include business process reengineering, postharvest management and the use of fuzzy logic system. Others in the academic and horticulture fields are researching to see if perishable fruits, especially pawpaw, may have a growing and marketing strategy to entice its use in food processing.

Due to the fast rate of product formulation to curtail post harvest losses, scarcity of fruits throughout the year and cost in industries, consistency of product developed has become a challenging factor in the food industries. Adaptation of the use of fuzzy logic model has seen a rise in terms of its use in the food industry. In food processing, fuzzy logic has been applied in extrusion cooking, cheese-making, mayonnaise formulation, and for controlling brewing process.

Ghoush *et al.*(2007) worked on mayonnaise by formulating a gum protein emulsifier with the aid of neuro-fuzzy modeling technique. After their study it showed that the use of the neuro-fuzzy modeling technique gave a very satisfactory prediction accuracy of about 96%. Other works performed, not only in the food processing industry, with the use of fuzzy modeling has seen positive outcome. Another work was done on optimizing the flow rate of a plastic extruder process with the use of neuro-fuzzy linguistic approach by Oke *et al.*(2006) also showed an improvement in the process compared to previous work done.

Again, Schneider *et al.*(2005) worked on assessing the sensitivity in the diagnosis of gastrointestinal tumors using fuzzy logic-based tumor marker profiles and they came out to say that fuzzy logic analysis has proven to be more powerful than the other methods that were solely used.
This conclusion was drawn by them when there was a significant difference of 63 %, 81 % and

74 % in the sensitivities of colorectical cancer, gastric cancer and also esophageal cancer, respectively. With these stated, there is no doubt that use of the fuzzy modeling can aid in the formulation of the jam and also assessment of the jam through sensory analysis.

1.3 GOAL AND OBJECTIVES

The general goal of this study was to develop a fuzzy based approach for the formulation of jam products that can be adopted by the industry.

The specific objectives were;

1. To determine the most preferred pawpaw and pineapple blend (*pawpine*) for jam preparation
2. To formulate *pawpine* jam from citric acid, sugar and pectin based on fuzzy modeling
3. To assess the response of the panelists in relation to the jam products formulated by the use of fuzzy modeling

CHAPTER TWO

LITERATURE REVIEW

2.1 FRUITS AND FRUIT PRODUCTS

Fruits have been in existence since creation. In the history of creation, it was known in the Bible that there were many different kinds of fruits and plants. In the early times of Adam and Eve in the Garden of Eden, fruits were their source of food as well as green plants as written in Genesis 1:29. Fruits have since been consumed unto these recent times but now not as a main source of food but as a dessert while food products have been developed or produced from these fruits and other green plants to serve as the source of food. Fruits are seasonal foods, easily susceptible to microbial growth as well as having a short shelf life in its natural or fresh state. Due to these it has been processed and preserved into many forms in order to have it available all year.

Fruits are the fleshy seed-associated structures of a plant with sweet or sour taste and are edible in the raw state. Fruits are numerous with different species and uses. The most cultivated ones include; pineapple, pawpaw, apple, cashew, orange, grape, strawberry, banana, mango and lemon. Fruits are consumed mostly due to their beneficial uses of serving vitamins, minerals and fibre (Duffrin and Pomper, 2006).

Crushed fruits are used in yoghurt, jam, sweets, and ice cream (Pátkai, 2006). Fruits are preserved by converting them into jam. Jams are products formulated from a minimum fruit content of 40% and a final soluble solid content of 45ºbrix (Oyeyinka *et al*., 2009).

2.1.1 PINEAPPLE FRUIT (*Ananas comosus*)

Pineapple ranks 12th among fruit crops worldwide amid the world manufacture of more than 18 million tons in 2009 (FAO, 2011). The pineapple plant is largely used as a source of fibre in most countries including India, Philippines and Taiwan (Mwaikambo, 2006). Loeillet (1997) stated that about 70 % of the pineapple grown in the world is consumed as a fresh fruit in the country of origin. The residual 30% is exported or processed into canned slices, chunks and crush (solid pack). The processing of pineapple fruits yield skins (outer peels), crowns, bud ends, cores, waste from fresh trimmings and the pomace of the fruit from which the juice has been extracted. Leaves and other non-fruit parts can be added to the wastes (Sruamsiri *et al.*, 2007; Devendra, 1985). These by-products accounting for approximately 30- 35 % of the fresh fruit weight can be used as soil alterations or as feedstuffs for all curriculums of livestock (Sruamsiri *et al.*, 2007).

Plate 2.1: Pineapple fruit

Plate 2.2: Sliced Pineapple fruit

Pineapple fruit's internally juicy flesh has a mix of sweet and tart taste with rich flavor. The area closer to the base of the fruit has more sugar content and therefore a sweeter taste and more tender texture. The pineapple fruit contains some amount of sugar, pectin and acid. However, the amount and proportion present is not sufficient for a successful gel formation (Afoakwa *et al.*, 2006).

Pineapple can be processed into frozen juice concentrate which can be used in producing juices, drinks, fruit cheese, fruit cream, puddings, baby food items, yogurt and jam. Pineapple, aside being used in food products, also has cosmetic applications including the usage as a moisturizing and emollient product, anti-aging, exfoliating and firming product, as well as hair coloring product (Taussig and Batkin, 1988).

Asante-Donyinah (2010) developed a sports drink product made from coconut water and pineapple juice. He used three different pineapple varieties (smooth cayenne, MD2 and sugar loaf) grown locally in his formulation which was combined with the coconut water. Proximate, chemical and sensory analysis of the product was conducted. The result from the sensory analysis indicated that, there were no significant differences in the entire formulations. From his various results, MD2 (55% coconut water: 45% pineapple juice) variety which is accessible all through the year was preferred.

In addition to the above study, Pereira *et al.* (2009), proposed an accepted formulation of 65 % green coconut water, 15 % of pineapple and 20 % acerola pulp. This was to serve as a ready to drink product. This combination was obtained after conducting physicochemical analysis, functional compounds and sensorial attributes analysis on ten formulated beverage mixtures and recording no significant change in the acceptance of the formulations. This formulation presented the required characteristics for a new commercial product.

2.1.2 PAWPAW FRUIT (*Carica papaya*)

The plant *Carica papaya* bears the fruit papaya with other known names as papaw or pawpaw in other countries. In the plant family *Caricaceae*, out of twenty-two (22) established species in the genus *Carica*, pawpaw is one of them. Originally, it was cultivated in Mexico some centuries ahead of the surfacing of the Mesoamerican classical evolution (Perseley, 2003). Pawpaw plant grows in three sexes. These are male which does not fruits but only produces pollen, female which produce small inedible fruits except it is pollinated and the hermaphrodite (dioecious) which produces edible fruits since its flowers contain both male stamens and female ovaries and can self-pollinate (Chia and Manshardt, 2001). The hermaphrodites are widely grown for commercial purposes. The pawpaw plant has a single stem maturing from 5 to 10 m (16 to 33 ft) tall, spirally arranged leaves curbed at the top of the trunk. It has large leaves of diameter 50– 70 cm (20–28 in) with seven lobes. The tree is usually unbranched, unless severed. The flowers emerge on the axils of the leaves, growing into large fruit of 15–45 cm (5.9–17.7 in) length and diameter 10–30 cm (3.9–11.8 in) (Crane, 2005). Pawpaw fruit is ripened when its skin colour becomes yellow to orange and the fruit sense soft, the fruit naturally falls off the tree at this state. At room temperature, ripe pawpaw fruits barely last for two or three days whereas they can last for about a week if fully ripe or three weeks if a little under ripe in a refrigerator. Pawpaw fruits that ripen on the tree are soft and the best while pawpaw plucked firm do not ripen well off the tree.

The pawpaw plant has more of its organs containing substances that can be used for therapeutic purposes or which are the precursors for the synthesis of useful drugs. These active ingredients naturally in the pawpaw plant are valued as remedy in dyspepsia and many other ailments. The seed is used as intestinal worms expellant when chewed. The root is chewed and the juice swallowed for cough, bronchitis, and other respiratory diseases. The unripe fruit is used as a remedy for ulcer and impotence. Pawpaw is also utilized for the clarification of beer (Bamisaye *et al*., 2013). Pawpaw fruit also has high levels of potassium, calcium, iron, magnesium, zinc, and copper making it an excellent food source (Duffrin and Pomper, 2006).

Given the highly perishable nature of the pawpaw fruit, it is realistic to assume that the pawpaw fruit puree incorporated into food formulations has the greatest potential for reaching consumer markets (Cosby, 2001).

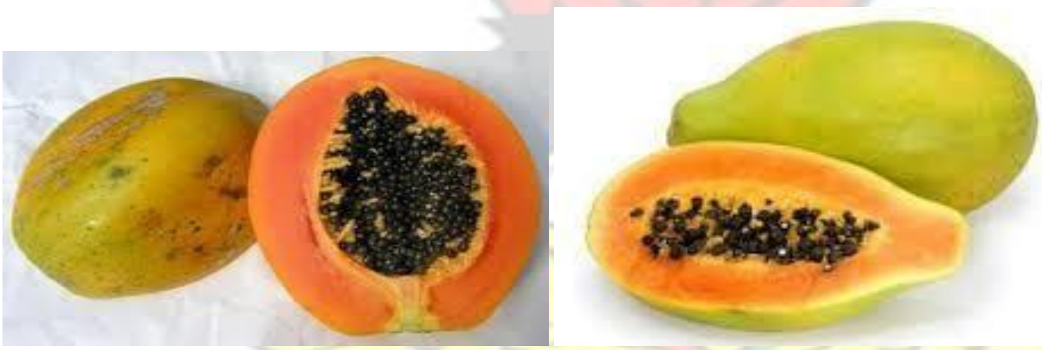


Plate 2.3: Whole and sliced Pawpaw

2.2 JAM PRODUCTIONAND FORMULATION

2.2.1 JAM PRODUCTION

In traditional jam manufacture, all the ingredients are mixed in predetermined proportions and the mix is concentrated by applying thermal treatments at normal or reduced pressure to reach the final soluble solid content. This process leads to thick consistency, destroys fruit enzymes, extracts some of the pectin from the fruit and concentrates the product to a point where as a result of its acidity and reduced water activity becomes self-preserving (Oyeyinka *et al*., 2009).

Four ingredients are needed in the right amount and proportion for a successful fruit jam. These are fruit extract, sugar, sufficient pectin and acid. They ensure a good gel formation, which is an important quality characteristic of a good jam (Afoakwa *et al.*, 2006). Aside these four main ingredients, margarine can also be added to the preparation of jam which enhances the reduction of foaming. Foaming in jam is as a result of lots of air in the jam through boiling. Unripe fruits have high levels of pectin and this affects the flavour development, which is a very critical aspect of the product quality. Ripe fruits have less pectin but greater taste and flavor (Figuerola, 2007). Jam prepared comes in two forms either in chunks or completely crushed. Mostly the chunk fruit jam is preferred but when the fruits are crushed, it aids release the natural pectin of the fruit in order to thicken. It is best to prepare jam in smaller quantities. Pectin present in the product can lose its jelling/ thickening characteristics easily through overcooking if the jam is a lot and must stay long in the presence of heat. It must also be noted that jams can be made without sugar, with low sugar, without pectin or with different types of pectin.

Jars for the holding of jam after it has been prepared are also very important since if not cleaned properly can lead to early deterioration of jam or may affect the characteristic of the jam. There are several ways that the jars are cleaned including: washing with nitric acid of 55 % concentration and 32% hydrochloric acid in the ratio of 1:3, respectively, and autoclaving at 115 ^{o}C for 10 min. Aside that, dishwasher which has a sanitize cycle can also be used. If not available, jars can be washed in hot, soapy water and rinsed then sanitized by boiling for 10 min.

These sanitized jars must be kept in hot water until they are ready for use. The lids are also cleaned by dropping them in hot but not boiling water for 5 min.

2.2.2 FORMULATIONS OF JAM

There is no one way approach in the preparation of jam and it can be prepared at different places not necessarily in an industry. Martin prepared strawberry jam at home at 105 ºC using 5- 10 min and he chose not to wash the strawberry but wipe in a damp kitchen paper before use with the idea of preventing water which will not set the jam. Larger fruits were cut into half and the fruits were gently tossed through the sugar and left uncovered at room temperature overnight or for 12 hours. The mixture was put into a preserving pan containing lemon juice and cooked under low heat.

Another formulator used 15- 20 min to prepare strawberry jam. In the process, pectin was eliminated with the reason being that, the jam being prepared is in a smaller amount and does not require a longer time to cook. What was seen in this formulation was an amount of underripe fruit mixed with ripe fruits. Underripe fruits contain more natural pectin as compared to ripe fruits which are rich in sugar.

Vibhakara and Bawa (2006) prepared jam by mixing equal parts by weight of sugar to fruit and adding the rind of a lemon and its juice. He went on to say that sugar is a preservative therefore there is no need to refrigerate nor waterbath the jam so far as the required amount of sugar was used. Again, because the lid seal after the hot jam is poured into the sterilized jars and sterilized lids and rings are applied without delay. After, there is no need to process in a waterbath or store in the fridge.

Dana (2013) prepared strawberry jam without pectin or refined sugar. She used a total cooking time of 30- 60 min and a processing time of 10 min. The ingredients used were strawberries, grated unpeeled apples, lemon juice and honey which was used as a sugar replacer. All ingredients were put into a large pot and put over high heat to boil between 30 and 60 min. The fruits in the mixture were mashed after becoming softer. Lids of jars to be used were picked with magnetic lid lifter to cover the jars filled ¾ way through with prepared jam. This was afterwards put into boiling water which covered the jars by 1 or 2 inches for 10 min. The jars were not directly to touch the bottom of the pan to allow hot water pass under the jars. With this process, it was assumed the jam could be kept up to a year if the lid pops up after the jar has been taken out of the hot water. If no pop sound was made, the jam was to be refrigerated and consumed within 3- 4 weeks. There was a concern raised on jams prepared without using refined sugar in view of it preventing bacterial growth. Jams prepared under proper pH levels and correctly processed jars in boiling water aids prevent these bacterial growths.

Fresh or frozen berries and water (1/4 cup per cup of berries) were mixed and boiled to cook the berries for 4- 5 min. Berries were mashed to break them down and artificial sweetner (liquid form of Splenda) and thickener were added. When cooked, it was spooned into clean freezer-safe container and cooled (Schafer and Wolf, 2016). Dolson realised that for a berry to be used pectin was to be added for best characteristic and there was an off flavor produced when the sweetner was added.

Whitcomb and Lowe (2007) considered people suffering from adiposity and pancreatic diabetes and prepared jam without the use of sugar and this could be processed in two ways. Water was put on an oven while currant was filled closely into a jar. It was placed into the hot water and berries were filled more when the ones in the jar had sunk down. The jar was covered with a lid when it was full and cooked for an hour. This recipe could be used for any berries and fruits except bananas and mango. Again, jam could be prepared using a microwave oven. The fruits were put into a glass bowl uncovered and put in the oven on high power. Fruits were mashed after softening and kept cooking until evaporation of water for jam to become thick and darker. This was poured into a jar, sealed and stored in the fridge for a week or two.

2.3 INGREDIENTS AND SENSORY CHARACTERISTICS

2.3.1 SUGAR

Sugar enhances the taste, flavor, colour and the texture of processed fruit products. Sugar is an important component of jam products due to its ability to prolong the shelf life. Therefore, the percentage of sugar that is used is usually high (Javanmard and Endan, 2010).Osmotic dehydration with sugar solutions is a suitable method for preserving fruit products (Oyeyinka *et al.*, 2009). In the absence of sugar, honey or agave can be substituted in equivalent amount.

The final sugar content must be 65% to 69%. The high sugar content is needed to suppress microbial growth, sweeten the product, help set the pectin, and enhance flavor (Figuerola, 2007). Sugar prevents spoilage of jams after the jar is opened. When a jar is opened, sugar puts out of action any microorganism by its capacity to attract water. This is done through osmosis where water flow from weaker solution to a more concentrated solution through a semi permeable membrane. In jams, water is inhibited from the microorganisms towards the concentrated sugar syrup which renders the microorganisms dehydrated and incapable to prevent spoilage.

Sugar is essential because it attracts and holds water during the gelling process. The sugar helps retain the colour of the fruit through its capacity to attract and hold water. It absorbs water more readily than components like fruit therefore the sugar prevents the fruit from absorbing water which could cause its colour to fade through dilution.

Barimah *et al*. (2015) did a study to evaluate the possibility of date fruit powder as a refined sugar replacer in rock buns to assist promote and broaden the use of date fruit. Date fruit powder had 1.47 % crude fiber and was high in carbohydrate (82.15 %). Carbohydrate content of samples declined (48.55-29.72 %), while crude protein (6.78-9.97 %), crude fat (22.74-33.66 %) and crude fiber (0-0.49 %) contents increased with an increasing substitution of date powder. Among the products formulated, 0 and 50 % substituted rock bun samples were the most preferred. Date powder significantly ($p < 0.05$) increased the potassium (0.55-1.57 %), calcium (0.08-1.08 %) and iron (0.53-0.625 %) contents of the samples.

Aside the date used in rockbuns, it was constituted in jam formulation. Three possible Tunisian cultivars (DegletNour, Allig and Kentichi) of second grade date fruits gave the same sugar (73.30–89.55 g/100 g dry matter), fibre (7.95–18.83 g/100 g dry matter) and total phenolics (280.6–681.8 mg of GAE/100 g) content. These varieties were used in the production of jam and evaluated in terms of chemical composition, physical (texture and water retention capacities) and sensory properties. Results illustrated a significant effect of the date variety on the physical characteristics of date jams. Allig jam was higher in reducing sugars, firmness and water retention capacity. Sensory evaluation was performed comparing the new product with quince jam (the most consumed in Tunisia) which showed Allig and Kentichi jams having a higher overall acceptability. On the other hand, quince and DegletNour jams did not give any significant differences ($p > 0.05$). The outcome of this study showed essential information that could advance the commercialization of date jam (Besbes *et al*., 2009).

2.3.2 PECTIN

The application of pectin is important in the food industry, especially jams and jellies, as a thickening agent. Frequently when sufficient pectin is added in the formulation, the producer is looking for changes in the texture or flow behavior (Endress *et al.*, 2005), gel formation and enhanced spreadability of the jam (Afoakwa *et al*., 2006). Pectin on addition must initially be added with sugar to mix better and stirred vigorously to prevent it from clumping. Pectin present in jam products aids in reducing the cooking time which in return preserves the fruit's vitamins and flavor. In jam preparation, some fruits are highly rich in pectin and do not demand addition in the jam being produced whilst others require addition either in smaller quantities or the required quantity.

Jams were prepared out of different pectins after which headspace, consistency, taste and flavor characteristics were evaluated. At normal concentrations, high methoxylated pectin stimulated an undesirable modification of typical flavor and intensity of flavor and taste, whereas low methoxylated pectin stimulated few modifications. Mechanical decrease of pectin molecular weight significantly modified only the consistency (Guichard *et al*., 1991).

2.3.3 CITRIC ACID

Citric acid is considered necessary to reduce the sweetness of the sugar and brings the pH balance in jams and jellies, to a desired range, usually around 3. This optimum pH is necessary to set the pectin. The most common cause of gel failure is insufficient acid (Vibhakara and Bawa, 2006). Lime and lemon juice are high in citric acid therefore they can be used as replacement of citric acid in jam manufacture (Javanmard and Endan, 2010).

Lemon was used in the preparation of pineapple jam and it was realised that, there was an acceptable pH of 3.2 and 3.5 and the product colour was not greatly affected by the usage of lemon as an acid source (Afoakwa *et al*., 2006).

2.4 SENSORY EVALUATION

Sensory evaluation process is an evaluation discipline whose information is based on the knowledge acquired in a sensorial way by the panel of experts that take part in the evaluation process. This is perceived by the five (5) human senses of sight ,smell, taste, touch and hearing (Martínez, 2007).

People wonder why sensory analysis is performed on food and food products but not using analytical means. The sensory quality of a food product is not a fundamental property of it but rather the outcome of relations between the food and the human being. The sensory qualities of food and food products are determined rather by their structural, physical and chemical properties or characteristics. Sensory analysis is performed on food and food products since it gives the process humans observe things through the processing of the sensory organs and the brain. This indicates why sensory analysis is the best technique to assess sensory quality of food and food products compared to analytical methods. However, to avoid errors of psychological or physiological nature because the analysis is performed by human, firm manage of the circumstances of tests application and methodology to be used is necessary. These firm managers control the preparation, coding and serving of the samples to minimize the biasing factors.

The innate inconsistency of human responses has led to special methods and procedures for their measurement. These methods have their various challenges. The fact that human beings are the tools being used for the analysis or testing makes the analysis demanding. How to design methods that bring regular, reproducible outcome is on itself a great challenge. One may be inclined to select the recognizable or convenient method to use since determining the type of test to apply can be complicated. Another challenge is the tendency of biasness occurring which needs the prerequisite of particular consideration for the test samples for human evaluation to curtail it. Another difficulty is that the assessors do not always execute as anticipated and sometimes do not show up when needed for the test leading to omitted data. The trouble of physiological and psychological tiredness are factors that disturb sensory analysis. Therefore sufficient time is allocated in between samples for the revitalization of senses. There is also the bias nature of the sequence of serving samples which is managed by blocking across assessors.

Sensory analysis is not only used in assessing food products but other products including cosmetic products. Pineapple fruit was used in the formulation of cosmetic product and proper testing was to be performed to determine the chance of allergic reaction based upon the usage rates and form of pineapple used in the formulation by the use of the senses. To know the type of sensory test to use, one must consider the resources and time available and also clear objectives based on the questions one is trying to answer. Frequently, there must be made available series of questions to be answered before a test may be selected to be used.

Human measurements are changeable, but can be made more consistent if suitable methods and measures are applied. Sensory data can make easy good decisions making on a range of concerns, and the enhancement in the quality of the information gathered will have long-term value for product choice.

Over the years, sensory evaluation has been used in many fields such as the food industry (Afoakwa *et al*., 2006), agriculture, engineering, and marketing (Krishna, 2011).In the food industry, sensory evaluation is widely used in quality inspection of food to determine systematically their characteristics by means of a group of experts (Lawless and Heymann, 2010; Lesschaeve and Noble, 2005), and for understanding consumer's behavior and exploiting new markets (Martínez, 2007).

2.4.1 TYPES OF SENSORY ANALYSIS

In sensory analysis, there are two types of methods known generally thus analytical and affective methods. Under these methods there are three classifications of test which includes discriminative test, descriptive test and affective test. These three classifications are usually used to answer three broad categories of questions that are critical to the development, maintenance, and performance of most products; "What is the product in terms of its perceived characteristics (Descriptive profiling)," "Is the product different from another product (Discrimination testing)," and "How acceptable is the product or is it preferred to some other product (Affective testing)" (Carpenter *et al*., 2012).

2.4.1.1 AFFECTIVE TESTING

Affective testing also known as consumer testing, is concerned with obtaining subjective data, or how well products are likely to be accepted. Usually large panels of untrained personnel are recruited for this type of testing, although smaller focus groups can be utilized to gain insights into products. Questions are asked in an interactive group setting where participants are free to talk with other group members. The range of affective testing can vary from simple comparative testing (e.g. Which do you prefer, A or B) to structured questioning regarding the magnitude of acceptance of individual characteristics (e.g. Please rate the "fruity aroma": dislike, neither, like) (Meilgaard *et al*., 2006; Lawless and Heymann, 2010). Affective test has classifications such as preference, paired preference, faces, ranking preference, acceptance, hedonic scaling, attribute diagnosis (rating), just-about-right, focus group, focus teams, one-on-one interviews.

The two methods most frequently used to directly measure preference and acceptance are the paired preference test and the hedonic scale (nine-point), respectively. There are however, other modified methods of the two frequently used methods including five and seven point hedonic scale or types of quality scales including Likert or Summative scales; for example, high to low, excellent to poor and palatable to unpalatable (Stone *et al*., 2012).

2.4.1.2 DISCRIMINATIVE TESTING

Discriminative test can also be called discrimination test. The various goals of discrimination testing are psychophysics (understanding how the human senses work), Sensory Evaluation I (using the human senses as instruments to evaluate food characteristics) and Sensory Evaluation II (investigating the consumer's ability to discriminate between foods). This response to whether any noticeable difference exists among products. For this test to be used, the difference among the products must not be very obvious to detect. Rather when products' ingredients, processing, packaging or storage give you an idea about slight differences which is to be perceived by people.

Discrimination testing considers the effect of experimental factors such as memory, sensory 'fatigue', sample retasting and practice (O'Mahony, 2003). It is on the basis of a perceived difference between two products that one can justify proceeding to a descriptive test in order to identify the basis for the difference, or the converse. A variety of discrimination testing methods are available. These include simple difference, triangle, duo-trio, A-not-A, difference from control, similarity, paired comparison, ranking(Stone *et al*., 2012).

A new approach for performing discriminative test in food quality control was reported (Benedetti *et al*., 2004). The technique is based on the use of an electronic nose equipped with 10 Metal Oxide Semiconductor Field Effect Transistor (MOSFET) sensors, 12 Metal Oxide Semiconductor (MOS) sensors and one humidity sensor. The pattern of the sensor responses created by the electronic nose has been used for executing "objective" triangle tests in a number of food products. The outcomes were weighed against with the data acquired by using standard methodology (triangle test) of sensory analysis (UNI ISO 4120 Norm). The e-nose is capable to classifying properly all the samples under study, while the sensory panel is able to rightly carry out the test only in 50 % of the cases. As compared with the sensory test, the electronic nose methodology is easy, fast and outcome suggests that it can be helpful tool for carrying out discriminative testing (Benedetti *et al*., 2004).

2.4.1.3 DESCRIPTIVE ANALYSIS

Descriptive analysis is a sensory methodology that provides quantitative descriptions of products, based on the perceptions from a group of qualified subjects. It seeks to profile a product on all of its perceived sensory characteristics (Stone *et al*., 2008; Murray *et al*., 2001). Descriptive analysis is the most sophisticated of the methodologies available to the sensory professional (when compared with discrimination and acceptance methods) A descriptive test involves relatively few subjects (as few as 10 to as many as 20) and there must be good evidence that the specific differences obtained are reliable and valid, and not the result of spurious responses from one or two more sensitive subjects (Stone *et al*., 2012).There are many methods of descriptive profiling which include ranking test, flavor profiling test, texture profiling test (Stone and Sidel, 2004), attribute rating (scales), time- intensity, qualitative descriptive analysis spectrum and free- choice profiling.

de Huidobro *et al.* (2005) used two methods for evaluating texture characteristics of raw and cooked meat. They used Warner–Bratzler (WB) and texture profile analysis (TPA) to test 96 samples of *m. longissimusdorsi* muscle of eight heifers and eight bulls, aged 1, 3 or 6 days postmortem. From the sensory analysis performed, they realised that hardness, juiciness, greasiness and chewings were predicted by TPA more than WB, except for springiness that was only predicted by WB. Their findings showed that texture parameters carried out on cooked meat, evaluated by a TPA are the best predictors of sensory texture in bovine meat.

2.5 FUZZY MODELING

Until recently, classical computational techniques used in sensory evaluation were based on statistics and factorial analysis, but these methods are not efficient for solving sensory evaluation problems because uncertainties in this type of problems have a non-probabilistic character since they are related to imprecision and vagueness of meanings.

Fuzzy is that which is imprecise. Fuzzy logic is the logic which is not deterministic or very precise and happens in our day to day activities or lives and cannot be determined by mathematical sets. For example, the biscuit is nice gives a vague understanding since there are so many factors or conditions that can make the biscuit nice. It can be nice in terms of the taste, appearance, odour and others. Just considering the taste, many factors come into play, being it nice in terms of the addition of sugar and milk. Even with the various factors, there are varying of degrees that will make one consider the biscuit as nice. There would be a range for the quantity of sugar added since 1 teaspoon may be considered as nice while 2 teaspoon may also be considered as nice by another. This makes fuzzy very imprecise and not deterministic since it depends on the discretion or belief of individuals. Once an input information is not exact, is unclear or ambiguous, fuzzy logic tool is used which represents the data and knowledge closer to humanlike thinking. Fuzzy has in recent years demonstrated high levels of accuracy, classifying default firms (Tang and Chi, 2005).

The fuzzy sets theory: It was first proposed by UC Berkeley Professor Lotfi Zadeh in 1965which laid the groundwork for fuzzy logic, which he also put forward in 1973 (Dubois and Prade, 2012). Fuzzy set deals with how to generalize the normal set to a set or concept of set which can capture imprecise notions like good, bad, hot, cold, tall, short, and others alike thus how much of good or bad is being talked of, how far can the tall or short be. Thus, the theory has to do with mathematical sets, or groups of items known as elements in varying degrees. In most mathematical sets, an element either belongs to the set or it does not.

In a society, considering food, it is either the food belongs to being nice or does not belong there. Therefore, fuzzy set deals with assigning degrees (ranges from 0 to 1) to the parameters or notions. For instance, degree of sweetness; there must be a range with borders, so if it is sweet with this level of sugar then assign 1, if it is not sweet with this level of sugar assign 0, after which the other levels or amounts of sugar will be used to show whether the product is slightly sweet, moderately sweet, etc.

Level of degree/ membership values: This depends on the human perspective and they are the values associated as the degrees for the parameters or notions. If degree is more say in sweetness, then it will be less in sourness. In fuzzy logic, membership grade is associating from 0 to 1 to the degrees thus when it's 0 it means it does not belong to the set (no membership). When it's 1 it implies it belongs to the set (full membership) and between 0 and 1 shows the extent to which it belongs to the set (graded membership). This membership deals with ambiguity, for instance, biscuit containing sugar of 4 g and above is sweet. This implies biscuit containing sugar of 3.9 g not being classified as sweet which in reality will not be considered as being fairly said, therefore the graded membership is used to give its extent of belongingness. Fuzzy set has soft boundaries not rigid or fixed so there are always degree of belongingness that gives rise to intersections.

Another important characteristic of fuzzy logic is the substitution of a graded or score function for a sharp threshold value of a given "yes-no" decision. Each member/ element of fuzzy set is associated with fuzzy index or membership function maximum of 1 and minimum of 0 as measures for describing qualitative properties. There are various types/ shapes of membership function including; γ-function, S-function, Triangular membership function, л-function and Gaussian membership function. Triangular membership function is widely used because it's easier to represent and calculate thus saves computation. Considering the diagram below, A, B and C are the elements of the fuzzy set, before A is 0 in other words less than A, there is no membership. Between A and B, membership function linearly increases, between B and C it linearly decreases.

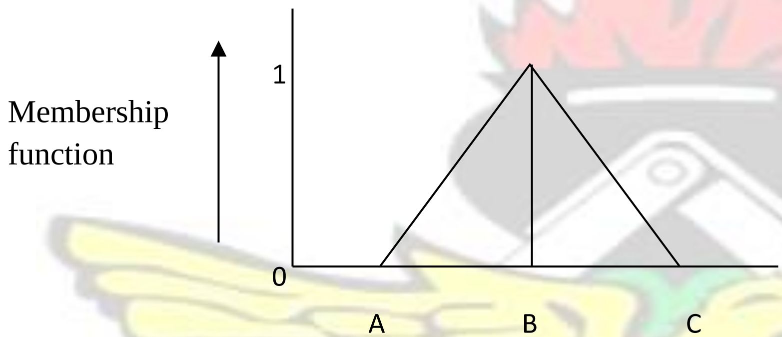


Figure 2.1: Triangular membership function

Membership function of members in a set are manipulated and wherever is minimum is retained since it linearly increases approaching 1 but the rest are discarded once it linearly decreases approaching 0.

Fuzzy linguistic: Fuzzy linguistic approach (Perrot *et al.*, 2006), provides a systematic way to represent linguistic variables for successful and meaningful decision-making (Lin and Chen, 2004), in a natural evaluation procedure. A linguistic variable such as ''many'', ''low'', ''medium'', ''often'' and ''few'' are the predicate of a sentence and typically is an adjective (often qualified by an adverb) and for it to be agreeable to fuzzy logic, it must have an underlying numerical quantity. Fuzzy logic and its expression in fuzzy sets offer a discipline that can make better models of authenticity for the various concepts enhanced clearly by words than by mathematics. It does not require an individual to provide a precise value at which an uncertain factor exists. So it can be used as a tool to deal with uncertainty (Martínez, 2007).

Fuzzy inference/ If- Then Rules: Fuzzy logic uses the rule-based procedure. Fuzzy sets and fuzzy operators are used as the subject and verbs of fuzzy logic to form rules which is called Fuzzy inference/ If- Then Rules. For example, If X is A, then Y is B; where A and B are linguistic terms defined by fuzzy sets on the sets X and Y respectively. In fuzzy logic if A is true to some degree, then B is true to some degree.

Fuzzification: In fuzzy logic, two or more test values can be assessed to corresponding qualitative expressions ("fuzzification") (Schneider *et al.*, 2005). Fuzzification is converting a crisp value such as weight of 6 g to a membership value of a fuzzy set such as heavy or light.
Fuzzified values serve as input to the fuzzy rules.

Defuzzification: This on the other hand, is converting a fuzzy term such as small to a crisp value such as 0.5 g.

Modeling, prediction, control, classification, fuzzy clustering, rule based inference, multisensory data fusion, optimization and identification of food properties and processing, have been the subjects of many researchers in the food engineering and agricultural fields (Perrot *et.al.*, 2003; Huang *et al*., 2010).Fuzzy model has been used with other models in various studies including the food sector. It was observed through reviewing journals that fuzzy model and its derivatives gave a positive expectation of its use.

Ghoush *et al*. (2007) were comparing the accuracy of neuro-fuzzy model and factorial classification in complete randomized design. They realized that, neuro-fuzzy model gave about 96 % of satisfactory prediction accuracy when used in formulating emulsion stability and viscosity of gum-protein emulsifier in a model mayonnaise system as compared to the other model.

Kavdir and Guyer (2004) initiated an apple grading system using fuzzy logic model. They observed 89% general agreement with results obtained from human expert with the grading which provided good flexibility in reflecting the expert's outlook and grading standards into the results. Fuzzy logic was then applied as a decision-making platform to grade apples.

Again, fuzzy and neuro-fuzzy techniques based on expertise and knowledge for a given industrial size rotary dryer was applied by Tsourveloudis and Kiralakis (2002) to a rotary drying process to olive stones. They also used Adaptive neuro-fuzzy inference system (ANFIS) controller based on data taken from an empirical model of the dryer.

Fuzzy modeling has been used in various formulations and proved to be a helpful mathematical tool. In the development of a new product, product must be assessed by consumers to know the best formulation which will be accepted. In view of this, the five senses are used to assess the newly developed product through sensory analysis. Responses given by consumers through sensory analysis are out of the consumers' own discretion which may not be exact. Fuzzy logic which is used to represent the data and knowledge closer to human-like thinking is then best to evaluate the responses given by the consumers.

CHAPTER THREE

MATERIALS AND METHODS

3.1 MATERIALS

Ripe pineapple and pawpaw were the fruits used in this study. One hundred pineapple fruits and 50 pawpaw fruits were purchased in November, 2014 from Bantama market in Kumasi. The pawpaw and pineapple fruits were sorted out, washed in adequate amount of clean water to rid of the dirt, then transferred into a bowl of clean water with bleach which was aimed at removing microorganisms attached to the fruits in a ratio of five drops of the bleach to a liter of water kept for ten minutes and later rinsed thoroughly under running water. The fruits were then peeled and chopped into smaller pieces which were to be used for the jam preparation.

Citric acid, pectin, and 150 ml transparent glass bottles were also purchased from the open market. Each of the bottles was thoroughly washed with nitric acid of 55 % concentration and 32% hydrochloric acid in the ratio of 1:3 respectively and autoclaved at 115°C for 10 min.

3.2 METHODS

3.2.1 PRELIMINARY FORMULATION FOR COMBINATION OF PAWPAW AND PINEAPPLE

Fruits have their individual taste and preference by many people. Hence, in an attempt to combine fruits into a mixture, there must be an acceptable taste that will be appealing and appreciated by many. Comparing pawpaw and pineapple fruits, pawpaw is known to have a strong flavor than pineapple. In view of this, developing a product with these two fruits must have a right and accepted combination or blend that will appeal to many. For this reason, preliminary mixture design Design Expert 9, 2014) was run to ascertain the percentage of pawpaw and pineapple to use for the formulation of the jam.

In order to subdue the flavor of pawpaw, the minimum required percentage set was 20 while the minimum required percentage for pineapple was also set at 80. Due to these minimum set values, the maximum values set for pawpaw and pineapple was 40 % and 60 % respectively. The values for both minimum and maximum were to sum up to a 100 % each. With these set minimum and maximum percentages for the pawpaw and pineapple fruits, the mixture design (Design Expert 9, 2014) was run and thirteen proportions of pawpaw and pineapple blends were obtained as shown in Table 3.1. The mixture design used was quadratic.

3.2.2 FORMULATION FOR PAWPAW AND PINEAPPLE (*PAWPINE*) BLEND

An amount of 200 g blend was prepared from each of the thirteen proportions of pawpaw and pineapple blends. In each formulation, the pineapple and pawpaw samples that were used separately ranged between 40 g and 160 g as illustrated in Table 3.2. Each composition of fruit in a proportion was weighed accordingly as in Table 3.2 and milled together for 15 seconds using a TOMADO blender of BL-209B model (TM-4006, Germany) until a uniform mixture was formed. This was done for all the thirteen proportions. All thirteen obtained blends were labeled with three digit codes. The three digit codes were generated manually by choosing from 0 to 9 any three numbers.

Table 3.1: Thirteen proportions for pawpaw and pineapple blends using Design Expert 9

Run	Component A: Pawpaw %	Component B: Pineapple %
1	20.000	80.000
2	20.000	80.000
3	20.000	80.000
4	20.000	80.000
5	30.000	70.000
6	40.000	60.000
7	40.000	60.000
8	40.000	60.000
9	50.000	50.000
10	60.000	40.000
11	60.000	40.000
12	60.000	40.000
13	60.000	40.000

In doing this, it was ensured that there was no repetition of numbers in a code eg. 222, 333 since it was believed to might have an influence on the decision or choice making of the panelist. Again, the numbers did not follow any particular order.

Table 3.2: Coded proportions used for formulation of pawpaw and pineapple blends

Pawpaw (g)	Pineapple (g)	Code
40.000	160.00	325
40.000	160.00	614
40.000	160.00	771
40.000	160.00	244
60.000	140.00	429
80.000	120.00	874
80.000	120.00	557
80.000	120.00	119
100.00	100.00	967
120.00	80.000	122
120.00	80.000	667
120.00	80.000	821
120.00	80.000	463

3.2.3 SENSORY EVALUATION

Sensory evaluation was performed using the summative scale method (Stone and Sidel, 2004) (Appendix A 1) with a scale ranging from 1cm (least accepted) to 11cm (highly accepted) with midpoint of 5.5cm (neither like nor dislike). This scale was used aiming at obtaining the best product out of the thirteen formulations which was desired by the consumers in terms of their preference towards the taste of pawpaw-pineapple blends. Two hundred and one (201) females and one hundred and ninety (190) males were selected at random to assess each of the products and indicate on the scale how best they liked each product in terms of taste.

The data was collected and each scale measured with a ruler to get the preferred values. This was then fed into the mixture design (Design Expert 9, 2014) and processed to optimize the most liked product which was then used to formulate the *pawpine* jam.

After the preliminary combination studies of the pawpaw and pineapple, the best selected ratio or proportion for the jam formulation was 60 % to 40 % respectively as explained under Section 4.1.

3.2.4 FORMULATION OF *PAWPINE* JAM BY FUZZY LOGIC

3.2.4.1 THE CONCEPT OF FUZZY DESIGN

Generally, fuzzy logic provides a presumption structure that facilitates appropriate human reasoning ability. Fuzzy sets theory has to do with mathematical sets, or groups of items known as elements in varying degrees. In most mathematical sets, an element either belongs to the set or it does not which applies in fuzzy. Fuzzy set has soft boundaries and always gives degree of belongingness that gives rise to intersections/ overlaps seen in Figures 3.1, 3.2 and 3.3. Taking Figure 3.1 into consideration, it can be observed that, citric acid of 2 g is a member of two fuzzy sets thus low and medium all with a membership grade of 0.2 which indicates its belongingness to both sets, therefore the overlap obtained. Fuzzy logic and its expression in fuzzy sets offer a discipline that can make better models of authenticity for the various concepts enhanced clearly by words than by mathematics. Fuzzy logic generally deals with fuzzification- fuzzy set- membership function- if-then rules- defuzzification.

3.2.4.2 FORMULATION OF *PAWPINE* JAM

The citric acid, sugar and pectin contents influence jam making. Based on formulations made by processors, the set ranges for citric acid, sugar and pectin, are; 0- 6 g, 100- 140 g, and 9- 12 g respectively. Every individual ingredient has a range of mass that will be needed in the desired character or quality of jam prepared. Due to this, the ranges of weight per ingredient were fed into the fuzzy tool (MATLAB, 2013). In the fuzzy tool box are some important tools which were used including; fuzzy inference system (FIS) editor, the membership function editor (MF), the rule base editor, the rule viewer editor and the surface viewer.

The ranges were divided into three parts and also fed to the fuzzy tool. This then resulted into the three intersecting triangles for the input variables as seen in Figures 3.1- 3.3. The triangles were manipulated on the fuzzy tool to obtain equal sized or interval triangles.

Setting the fuzzy input and output variables

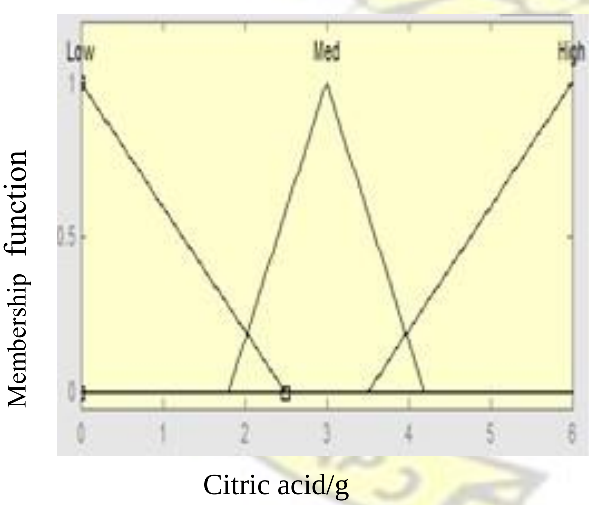


Figure 3.1: Functions of members for input variable citric acid

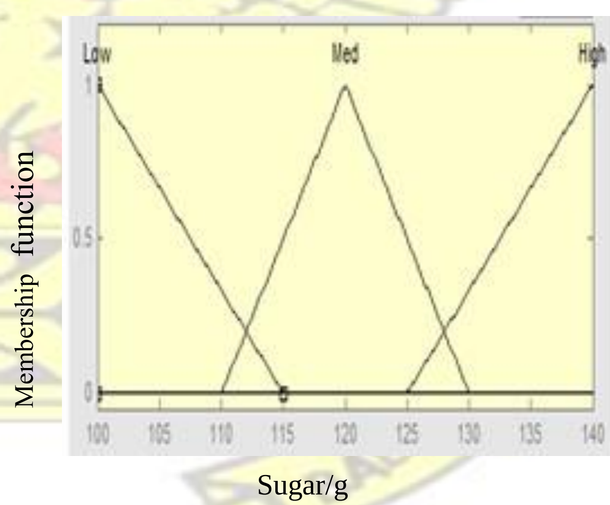
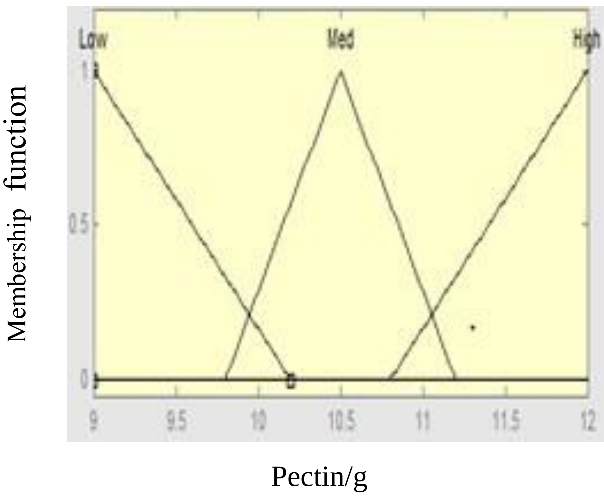


Figure 3.2: Functions of members for input variable sugar



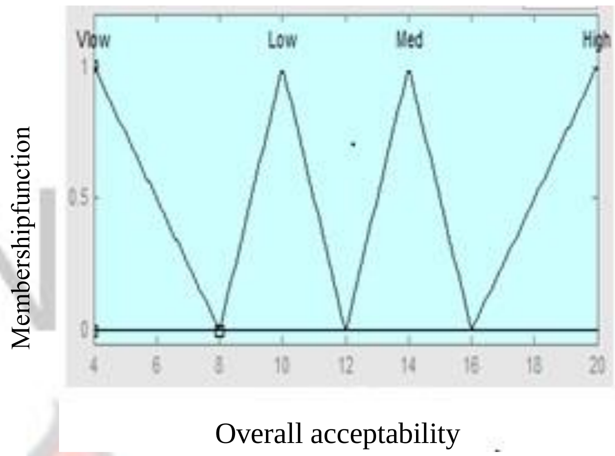


Figure 3.3: Functions of members for input variable pectin

Figure 3.4: Functions of members for output variable overall acceptability

The fuzzy set and membership functions of both the input and output variables were defined using linguistic variables (Very low (VL), Low (L), Medium (M) and High (H)) for each ingredient. A total of twenty seven (27) formulations were obtained via 3 by 3 factorial (Table 3.2). The setting of the output variables is elaborated under Section 3.2.8.

Table 3.3: Sensory evaluation data-driven linguistic fuzzy sets with 3 input variables (citric acid, sugar and pectin) and one output variable as modal overall acceptability

	Input Variables						**Output Variable**	
Product code	Citric Acid/ g	Fuzzy set	Sugar/g	Fuzzy set	Pectin/g	Fuzzy set	Overall acceptability	Fuzzy set
325	0.0	L	100	L	9.0	L	16	H
614	1.0	L	102	L	10.0	M	14	M
771	2.0	L	104	L	11.0	H	16	H
244	1.0	L	110	M	10.0	L	16	H
429	2.0	L	112	M	10.9	M	16	H
874	0.2	L	114	M	12.0	H	17	H
557	2.5	L	125	H	9.0	L	17	H
119	0.5	L	127	H	10.0	M	18	H
967	1.0	L	129	H	11.0	H	16	H

122	2.4	M	106	L	10.0	L	16	H
667	3.2	M	108	L	10.0	M	17	H
821	4.0	M	110	L	11.0	H	13	M
463	3.0	M	116	M	9.7	L	15	M
593	3.0	M	120	M	10.5	M	16	H
462	2.0	M	120	M	11.0	H	15	M
213	4.2	M	131	H	9.0	L	15	M
986	2.0	M	135	H	11.0	M	17	H
603	3.0	M	135	H	11.0	H	15	M
731	4.0	H	112	L	10.0	L	14	M
419	5.0	H	114	L	10.0	M	14	M
532	5.5	H	115	L	10.8	H	15	M
176	5.8	H	112	M	9.1	L	15	M
359	6.0	H	124	M	11.0	M	14	M
912	3.5	H	130	M	11.2	H	16	H
845	4.7	H	137	H	10.0	L	17	H
635	3.6	H	139	H	11.0	M	16	H
378	6.0	H	140	H	12.0	H	15	M

3.2.5 PREPARATION OF *PAWPINE* JAM

Pineapple fruit of 80 g and pawpaw fruit of 120 g were weighed separately according to the most liked formulation from the prior sensory evaluation performed. These fruits were milled together at speed one for 15 seconds using a TOMADO blender of BL-209B model (TM-4006, Germany), to obtain masses of fruit which was constructed for all the 27 runs.

According to the particular experimental run, the specified amounts of the ingredients thus citric acid sugar and pectin (Table 3.3) were weighed and homogenized into a smooth mixture. The smooth mixture was poured into previously sterilized transparent glass bottles, pasteurized in a water bath at a temperature of 65 ^{o}C for 20 min, sealed and labeled.

3.2.6 TRAINING PANELISTS FOR SENSORY EVALUATION

Prior to the sensory evaluation on the *pawpine* jam, preliminary sensory evaluation was performed on 4 prepared yoghurt samples which were to be used to train and recruit the best panelists for the *pawpine* jam sensory analysis. Twenty- five panelists were selected and trained on how to assess products using their senses. Panelists were made to know there are different methods or tools or scales used to perform sensory evaluation which is always stated on the assessment sheet to be followed. The panelists were made aware that they must know the major ingredients of the product to know if they are allergic to any of the ingredients. Considering the sensory attributes, when assessing odour, the panelist must take the product close to the nose and blow air over the product towards the nose using the hand. Panelists were adviced not to smell the product directly with the nose since some products have sharp or chocking smell. Again on taste, panelists were trained to take a piece of the product and put into the mouth then roll the tongue over it to be able to determine whether sweet, bitter or sour. Product is not to be chewed since it may interfere with the other products. On colour, the panelists were trained to observe by critically looking at the product. Finally on texture, the product was to be tilted slightly to observe if it easily flows or not, touched afterwards and felt in between the thumb and index finger.

The panelists were to know that for every sensory evaluation conducted with more than one product, there must be water or a sugar free biscuit (cracker) available which is used to clean or wash the mouth/ pallet in between products assessed to prevent product mixing/ interference. Through the training, four yoghurt samples were given to the panelists to assess. The bulk yoghurt was divided into five parts which one part was put aside. The four other parts were manipulated with extra sugar added to some and to the others addition of extra flavor and colour giving unique taste, odour and colour. The yoghurt samples were to be assessed using ranking test (Stone and Sidel, 2004) . The 4 yoghurt samples were to be ranked from the least to the most in terms of the intensity of taste, odour and colour (Appendix A2).

After the training, 18 out of the 25 panelists precisely assessed the yoghurt products. Therefore, 18 panelists (11 females and 7 males) were recruited to run the sensory evaluation on the *pawpine* jam.

3.2.7 SENSORY EVALUATION OF *PAWPINE*JAM

Each of the 18 panelists assessed the 27 products (Table 3.3) in 3 different sessions, with 9 products per session previously obtained by randomization and was used as the serving order (Appendix B 4, B 5, B 6). A 5 point hedonic scale (Preference test) (Stone *et al*., 2012) which ranged from dislike extremely (1) to like extremely (5) and neither like nor dislike (3) as midpoint (Appendix A 3) was used by the 18 panelists to assess the *pawpine* jam. Each panelist showed preference to the 27 jam products based on 4 sensory characteristics; taste, colour, texture and odour.

3.2.8 STATISTICAL DESIGN

Each value preferred by the panelist was computed into excel sheet where the modal values were obtained in respect of the various sensory attributes of colour, sweetness, texture and odour for each of the 27 products. After modal values were obtained for various parameters for each product, the overall acceptability was calculated by adding for each product the modal values which was in a range of 4- 20.

The overall acceptability/ desirability were the output information obtained from the sensory data after assessment by the sensory panelists. Panelists were to grade each jam product with four characteristics namely colour, odour, sweetness and texture from a scale of 1- 5 using the 5 point hedonic scale. With this in mind, taking an individual product, a panelist can give a total grade ranging between 4 and 20. This is so because if a panelist scores each characteristic/ quality with the lowest grade on the scale that will be 4 (characteristics) by 1 (lowest scale mark) which is 4 and vice versa 4 (characteristics) by 5 (highest scale mark) which is 20.

After the addition of the modal values of the four characteristics to obtain the overall acceptability/ desirability values, the 4- 20 range of response was subdivided to four equal intervals with no overlaps to represent very low, low, medium and high. Range from 4- 7.9 was represented as very low, 8- 11.9 as low, 12-15.9 as medium and 16- 20 as high. There were no overlaps since every mark in the range belongs to only one fuzzy set (Figure 3.4).

From Table 3.3 using the linguistic variables for the coded products and the linguistic variables for the overall acceptability/ desirability (output), rules were set using the fuzzy tool (If-Then rule).Using the fuzzy tool, for product coded 325 this was how the rule was set and the same process was used for the remaining products; "If citric acid is Low and sugar is Low and pectin is Low, Then overall acceptability is High" (Appendix B27). This rules set was viewed in the surface viewer which is represented in Figures 4.2, 4.3 and 4.4.

CHAPTER FOUR

RESULTSAND DISCUSSION

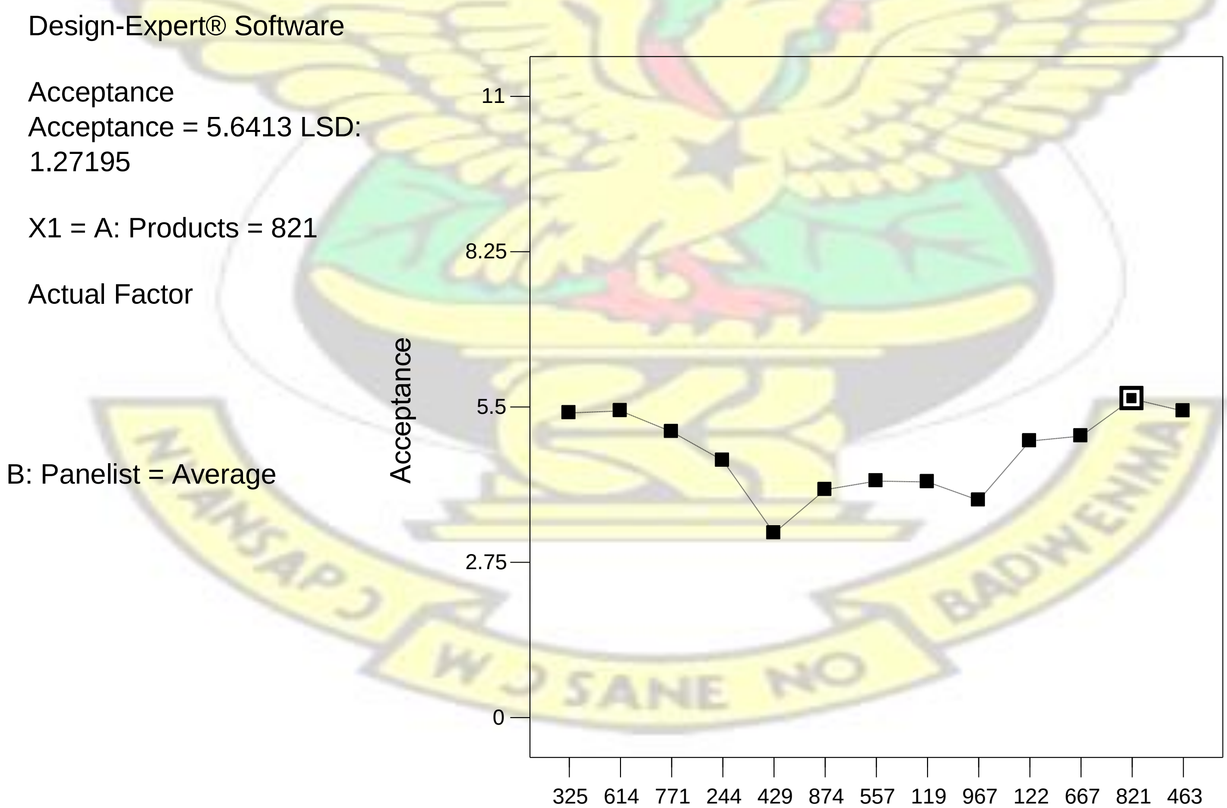
4.1 RESULTS

4.1.1 ACCEPTANCE OF *PAWPINE* FORMULATION

Mixture design (Design Expert, 2014) showed the average representation of the sensory scores that were given by the 391 consumers for the acceptance of the preferred formulation for the pawpaw and pineapple blend, (Figure 4.1).

From the graph (Figure 4.1), it is observed that, the least accepted *pawpine* formulation was Run 5 which was coded as 429 and the most accepted being Run 12 which was coded as 821. On the x-axis it was observed that only two of the first four runs as well as one run from the last four products were accepted. However, the acceptance of the runs were not on the same level with each other.

From Appendix B1, it can be seen that the first four runs on the graph had the same formulation but some panelist could not tell which gave rise to the different acceptance readings. Run 6, 7, 8 had the same formulation which can be seen in the graph as so since the panelists were able to decipher. Run 10, 11, 12 and 13 also had the same formulation but can be seen from the graph that panelist had a great likeness for Product 12 which they scored very high. This also indicates they were not able to make out the similarities but only for Runs 10 and 11.



A: Products

Figure 4.1: Consumer preference of 13 products blended from pawpaw and pineapple fruits

Table 4.1 gives a summary of the evaluated data received after the sensory evaluation performed. It shows the various products in terms of the codes as well as the modal values of the sensory attributes, the overall acceptability in terms of the summation of individual products' modal values and the fuzzy linguistic representatives for the output varables. The overall acceptable product in terms of the model score of the respondents on the various measured characteristics of the jam was found to be product coded 119, the product had a high modal score on sweetness, colour and odour, nevertheless, the food panelists were indifferent in terms of the texture of the this product. On the other hand, four (4) products were less likely accepted among the panelist and there were products coded as 614, 731, 359 and 419 as shown on Table 4.1.

The findings from the sensory panelist showed that there were significant differences ($p > 0.05$) among how the *pawpine* jams were assessed using the sensory attributes (Appendix C1). This showed that how each panelist assessed the various products taking into consideration the sensory attributes (colour, taste, texture and odour) were different.

Again, all the products had a significant difference ($p > 0.05$) among themselves in terms of all the four evaluated sensory attributes. The p values of the sensory attributes were; colour $p = 0.0136$, that of taste was $p = 0.0002$, texture was $p = 0.0100$ and odour was $p = 0.0305$.

Despite the differences among the jam products in terms of the sensory attributes and the differences in how each panelist assessed the product, fuzzy logic modeling gave the desirability ranges for the ingredient composition as well as the most desired products.

Table 4.1: Modal values of sensory attributes and overall acceptability values calculated after sensory evaluation

Products	Modal Values				Overall acceptability	Output Vaiables
	Colour	Sweetness	Texture	Odour		
325	3	5	4	4	16	High
614	3	4	4	3	14	Medium
771	4	3	5	4	16	High
244	4	4	4	4	16	High
429	4	4	4	4	16	High
874	4	5	4	4	17	High
557	5	5	4	3	17	High
119	5	5	3	5	18	High
967	5	4	4	3	16	High
122	5	4	4	3	16	High
667	5	4	4	4	17	High
821	4	3	3	3	13	Medium

463	4	4	3	4	15	Medium
593	4	4	4	4	16	High
462	4	4	3	4	15	Medium
213	5	4	2	4	15	Medium
986	5	4	4	4	17	High
603	4	4	3	4	15	Medium
731	5	3	3	3	14	Medium
419	5	3	3	3	14	Medium
532	5	3	4	3	15	Medium
176	4	4	3	4	15	Medium
359	5	2	3	4	14	Medium
912	4	4	4	4	16	High
845	5	4	4	4	17	High
635	4	4	4	4	16	High
378	5	4	3	3	15	Medium

4.1.2 OBSERVATION OF DESIRABILITY FOR FORMULATIONS AFTER SENSORY EVALUATION

Figure 4.2 shows citric acid masses from 0- 6 g and sugar masses from 100 – 140 g. From the figure, portions shaded deep yellow represent the highest/ most desired combinations for sugar and citric acid. While portions shaded deep blue represent the lowest/ least desired combination for sugar and citric acid. Other colours are in between the highest and lowest desired combinations.

It can also be observed that at the extreme ends of citric acid (0 g- 2.50 g; 4 g- 6 g) combining with sugar (100 g-115 g), it showed lowly desired formulations/ combinations. Citric acid of 2.5 g-4 g and sugar of 100 g-140 g gave rise to highly desired formulations/ combinations. From the graph, it can be observed that the higher the level of sugar added (130 g-140 g) to any level of citric acid gave a highly desired formulation/ combinations as well as sugar of levels 115 g-140 g with citric acid of 0 g-4 g also.

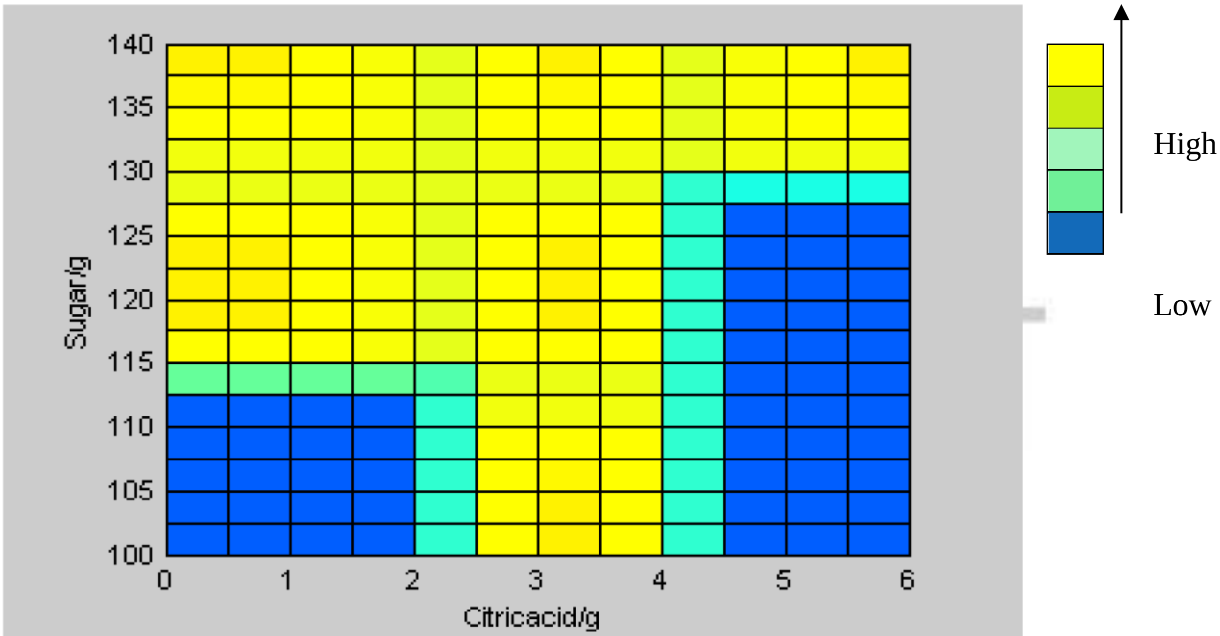


Figure 4.2: Summary of desirability of sugar against citric acid formulations

Figure 4.3 shows pectin of masses from 9- 12 g and citric acid masses from 0- 6 g. Areas shaded deep yellow indicate highly desired combinations/ formulations of pectin and citric acid whilst areas shaded deep blue are lowly desired combinations/ formulations.

It can be observed that low masses of citric acid (0- 2 g) combined with any mass of pectin gave a highly desired formulation. As citric acid increased to its maximum (4.5 g-6 g) and pectin also increased to its maximum (11.25 g-12 g), a highly desired formulation was also observed. Pectin levels 9 g-10 g and citric acid levels 2.5 g-6 g showed lowly desired formulations. At the extreme end of pectin with levels 11.25 g-12 g and any level of citric acid gave a highly desired formulation with the exception of levels of citric acid from 2 g – 4.5 g.

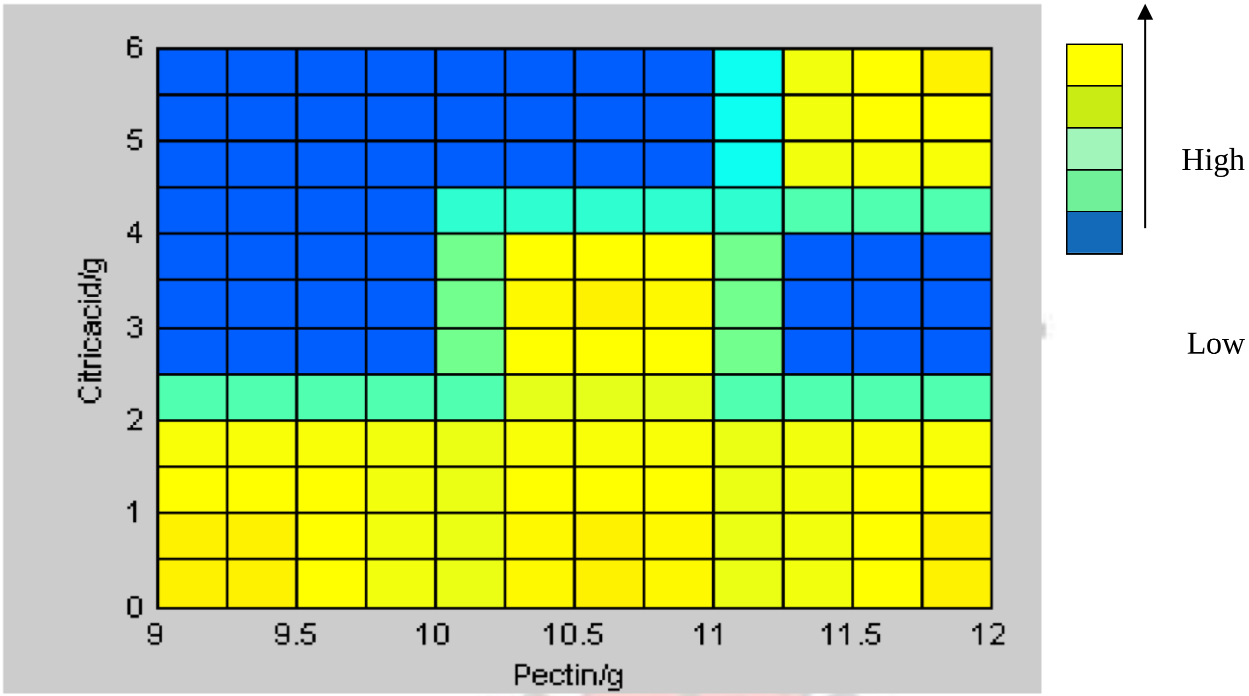


Figure 4.3: Summary of desirability of citric acid against pectin formulations

Figure 4.4 represents pectin masses from 9- 12 g and sugar masses from 100 g- 140 g. Deep yellow shaded regions indicate a high desired combination/ formulation for pectin and sugar whilst deep blue shaded regions represent low desired combination/ formulation.

From this figure, it is observed that the highest mass of pectin combined with any mass of sugar gave rise to a low desired formulation. Also sugar of levels 115 g- 140 g combined with pectin of levels 9 g- 10 g gave low desired combinations. While low levels of pectin and low levels of sugar gave high desired formulation. Pectin from 10.25 g- 11 g combined with any level of sugar gave a high desired formulation.

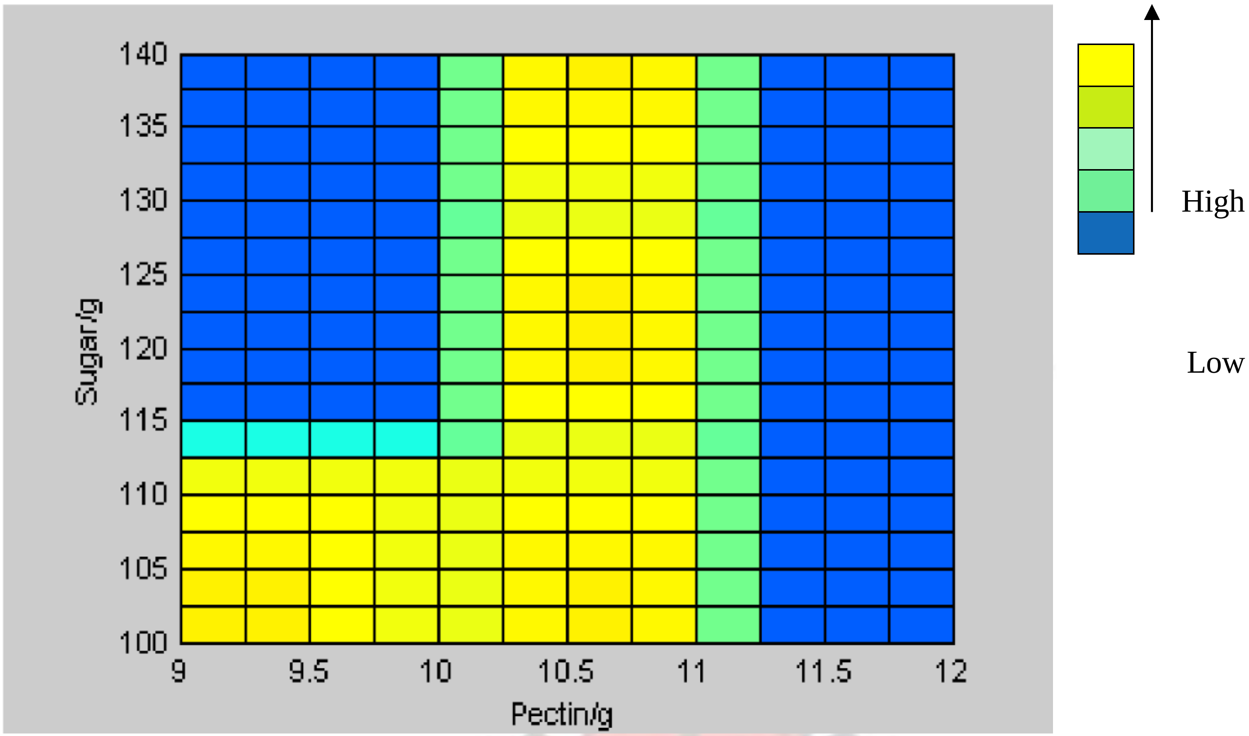


Figure 4.4: Summary of desirability of sugar against pectin formulations

4.2 DISCUSSION

Each of the 18 panelists used their own discretion to grade the 27 products based on taste, texture, odour and colour. The greatest challenge is that, the formulator who relies solely on the information given by the panelists, might be deceived in coming out with the right product. A suitable mathematical formulation is not easy in this type of problems because human perceptions are subjective and not objective, therefore the assessments provided by the individuals are vague and uncertain (Martínez, 2007). To contain such problems, fuzzy logic model relied on the responses by the 18 panelists and the varied concentrations of the ingredients (citric acid, sugar and pectin) at a constant *pawpine* formulation (60 % pawpaw and 40 % pineapple).

Fuzzy logic model (MATLAB, 2013) is able to take care of all contingencies in the analysis/ data. Taking Product 771 which had low citric acid (2 g), low sugar (104 g) and high pectin (11 g) as example, the high value in pectin (11 g) intercepted or overlapped with the medium range of values (9.8 g - 11.2 g). However, according to the fuzzy logic model, 11 g showed a stronger belongingness to the medium range than the high range of values (10.8 g - 12 g). Fuzzy logic model therefore categorized the low citric acid (2 g), low sugar (104 g) and high pectin (11 g) under low citric acid, low sugar and medium pectin. Fuzzy logic is widely used in many fields including the food industry (Martínez, 2007), medicine (Schneider*et al*., 2005), business (Tang and Chi, 2005). This is due to its high sensitivity and specificity. Fuzzy logic model has been shown to be superior to many other Mathematical methods including Multiple Regression Analysis (Schneider *et al*., 2005), Parametric model (Elaalem, 2013), and Logit model (Tang and Chi, 2005).

Although 27 products were assessed, 16 had distinct formulations whereas the other 11 products were seen to have merged with the 16 distinct formulations, according to fuzzy logic model. The desirability for the cumulative responses given by the 18 panelists for each formulated product was set as high (16- 20), medium (12- 16), low (8-12), and very low (4- 8). From the study, 9 (56.25 %) out of the 16 products had high desirability when assessed with fuzzy model. Seven (7) (43.75 %) out of 16 products had a medium desirability. None of the products had a very low or low desirability. The absence of very low or low desirability grade points in any of the 16 distinct products at varying citric acid, sugar and pectin levels, suggests that pawpaw and pineapple fruits that are blended into a product (*pawpine*), in the proportions of 60 % and 40 % respectively could be recommended for many fruit products especially jam. Additionally, this study indicates that the type of fruit extracts, plays a major role in consumers' choice in the end product (jam) since most jam products are made up of 40 % to 70 % of the fruit components (Wicklund *et al*., 2005, Ngo *et al*., 2007).

Pawpine jams that were formulated with low citric acid (0 g), low sugar (100 g) and low pectin (9 g) as well as medium citric acid (3 g), medium sugar (120 g) and medium pectin (10.5 g), gave the highly accepted desirability of 18.7 (93.5 %). The formulator may therefore choose to produce either of the 2 products in order to save labour and time. Additionally, the formulator has the option to cut down on cost and just to go in for a *pawpine* jam with only low citric acid, low sugar and low pectin formulation which would still meet consumers' demand. Variety is a good way of marketing. The producer can also introduce two (2) varieties of *pawpine* jams into the market. These varieties can be introduced into the market simultaneously or one after the other, since consumer's preference for both, shared the same level of desirability.

The formulator has the option to choose wide ranges of concentrations from all the three ingredients; citric acid (0- 1.7), sugar (100- 109.9) and pectin (9- 9.7) to produce low, low, low, or citric acid (2.6- 3.4), sugar (115.1- 124.9) and pectin (9.9- 10.7) to produce medium, medium, medium. Care should however be taken not to choose from set ranges that overlap (Figures 3.1, 3.2, and 3.3). This is because, there might be errors made in the assessment by the panelists since they would not be able to distinguish between the products. When the errors are made in the assessment by the panelists, the formulator would not be able to produce distinct products. This study therefore emphasizes that, the formulator's choice of the concentration of ingredients is very important when coming out with a variety of *pawpine* jams. This could also apply to other food products.

Additive effect of pectin, sugar, and citric acid concentrations on the sensory quality

Pectin, sugar and citric acid together bring out the characteristic features in jam products. However, formulators knowledge on the additive effects of these ingredients is key to coming out with the best desired product. The effect of these ingredients balancing is significant on the quality characteristics of the final product. This study highlights the correct ingredient formulation for *pawpine* jam using fuzzy logic.

Formulation with low citric acid (0 g- 2.0 g) and low sugar (100 g- 112.5 g) gave an undesired sensory quality (Figure 4.2). This could be in relation to the product being tart. It was observed especially in Figure 4.2 that as sugar was increasing the level of tartness was assumed to be decreasing. This conforms to the study by Whitcomb and Lowe in 2007 when jell from ¼ cup of sugar and 1 cup of juice was very tart and as the proportions of sugar was increasing, the tartness was progressively decreasing.

However, the addition of pectin at a low concentration (9 g- 9.7 g) enhanced the sensory quality of the *pawpine* jam. This suggests that, the combined effect of low sugar and low pectin in the right concentrations improved the texture of the jam (Figure 4.4). In Figure 4.4, as sugar increased in the presence of small amount of pectin, an undesired character was obtained. From Whitcomb and Lowe's study, it was realised that increasing the amount of sugar above the proportion that yields an optimum jelly, the jelly becomes softer until a proportion of sugar is finally reached which results in a fluid syrup instead of a jell. This could explain why at very low and high levels of pectin added to sugar gave undesired products but in between them at pectin levels of 10.5- 11 g and all levels of sugar gave a desired character. It therefore indicates that for sugar to be increased throughout the set range, pectin must be in the above stated range to balance the consistency in texture.

Again, high sugar in combination with low pectin gave undesired character. This could be because the sugar could crystallize from the jelly. Pectin tends to keep sugar from crystallizing but if sugar is at a high concentration of 70 % (Whitcomb and Lowe, 2007) it may still crystallize even in the presence of pectin.

It should be noted that pineapple and pawpaw contain some levels of sugar, pectin and citric acids (Afoakwa *et al*., 2006). Therefore, no or low citric acid (0 g- 1.7 g) formulation in *pawpine* jam could still yield desired products. The additive effects of medium citric acid (2.6 g- 3.4 g) and medium sugar (115.1 g- 124.9 g) and medium pectin (9.9 g- 10.7 g), give desired jam products. High concentrations of citric acid (3.6 g- 6 g) and sugar (130.9 g- 140 g) gave highly desired formulation. However, the inclusion of pectin at a high concentration (10.9 g- 12 g) gave a very poor texture. Ideally, jam must have a good spreadability characteristic.

Sugar, pectin and citric acid as determined from this discussion, reveals there is a relation between the proportions of these ingredients and the temperature to which the pectin is cooked to. Increases and decreases of ingredients may be made within certain limits which are illustrated by the yellow shaded portions of Figures 4.2, 4.3 and 4.4. This study agrees with the finding of Afoakwa *et al*. (2006) in relation to the significant effects of ingredients balancing on the quality characteristics of the jam.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This study showed that, pawpaw and pineapple could be blended into one jam product, and also fuzzy logic model used to assess the desirability by consumers. Pawpaw and pineapple fruits that were blended (*pawpine*), in the proportions of 60 % and 40 %, respectively could be recommended for making jam.

In addition to the pawpaw (60 %) and pineapple (40 %) proportions, varied formulations of citric acid, sugar and pectin at concentrations of low citric acid (0 g), sugar (100 g) and pectin (9 g) or medium citric acid (3 g), medium sugar (120 g) and medium pectin (10.5 g) both gave the highest desirability for the *pawpine* jam. This emphasized the dependency of the quality of *pawpine* jam on the additive effects of the pectin, sugar, and citric acid.

5.2 RECOMMENDATION

Sensory assessment of the *pawpine* jam enabled the formulator to decide on the right formulation to bring onto the market. The ability of fuzzy logic model to precisely predict the most accurate level of desirability of the *pawpine* jam made it recommendable for formulation and assessment of foods and even other products.

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APPENDIX A

SENSORY TOOLS

A 1: Sensory Acceptance Test: Using Likert or Summative Scale

Assessor Questionnaire

Date………………………………… Assessor Name…………………………………

You are presented with 13 samples of blended pawpaw and pineapple mix and are asked to indicate how much you like or dislike the taste of each sample. Evaluate each sample in the order presented starting from left. Mark and score each sample on the scale provided.

Key **1= least** **5.5= Midpoint** **11= Maximum**

325 1 11 .5

614

771

244

429

874

557 1 5.5 11

119

967

122

667

821

463 1 5.5 11

A 2: Sensory Descriptive Test for recruiting panels: Ranking Test

Date: **Assessor name:**

You are presented with 4 samples of yoghurt and are asked to identify the intensity of the following characteristics by arranging them in ascending order thus least to most. Odour (fruitiness), Taste (sweetness) and colour. Rank the coded sample as illustrated below.

NB: clean your palate with the biscuit provided in between samples

Key: L- Least **M-Most**

Eg Colour Taste Odour

L 122 L 603 L

731

122

986 731,122

986

603

M 731 M 986 M 603

A B C

B shows 2 codes ranked equally and this is because the assessor identified the samples to have the same level of sweetness.

Colour **Taste** **Odour**

L	**L**	**L**
M	**M**	**M**

A 3: Sensory Preferrence Test for *Pawpine* Jam by the use of 5 point hedonic scale

Sex: **Assessor No.**: **Date**:

Instruction: You are provided with nine samples to observe, taste, feel andsmell. Assess each sample from left to right and record your results below scoring from 1 to 5.

NB: Take a bite of the cracker before tasting the samples.

Key for scoring

1. Dislike extremely 2. Dislike moderately

3. Neither like nor dislike 4. Like moderately 5. Like extremely

Table for scoring Sensory Attributes

Code	Colour	Sweetness (Taste)	Jelly(Texture)	Fruitiness (Odour)

APPENDIX B

B 1: Codes for *pawpine*blends

Run	Component A: Pawpaw %	Component B: Pineapple %	Code
1	20	80	325
2	20	80	614
3	20	80	771
4	20	80	244
5	30	70	429
6	40	60	874
7	40	60	557
8	40	60	119
9	50	50	967
10	60	40	122

11	60	40	667
12	60	40	821
13	60	40	463

B 2: Ranges of input variables (pectin, sugar, citric acid) for fuzzy logic

Factors	**Fuzzy set**		
	Low	**Medium**	**High**
Pectin/g	9.00- 10.20	9.80-11.20	10.80-12.00
Sugar/g	100.00- 115.00	110.00-130.00	125.00-140.00
Citric acid/g	0.00- 2.50	1.80- 4.20	3.50- 6.00

B 3: Showing codes for various formulations

Product Code	**Input Variables**		
	Citric Acid	**Sugar**	**Pectin**

325	Low	Low	Low
614	Low	Low	Medium
771	Low	Low	High
244	Low	Medium	Low
429	Low	Medium	Medium
874	Low	Medium	High
557	Low	High	Low
119	Low	High	Medium
967	Low	High	High
122	Medium	Low	Low
667	Medium	Low	Medium
821	Medium	Low	High
463	Medium	Medium	Low
593	Medium	Medium	Medium
462	Medium	Medium	High
213	Medium	High	Low
986	Medium	High	Medium
603	Medium	High	High
731	High	Low	Low
419	High	Low	Medium
532	High	Low	High
176	High	Medium	Low
359	High	Medium	Medium
912	High	Medium	High
845	High	High	Low
635	High	High	Medium
378	High	High	High

B4: Table showing the serving order for the sensory panelist 1 to panelist 6

Pan 1	Pan 2	Pan 3	Pan 4	Pan 5	Pan 6
P 11	P 20	P 15	P 21	P 3	P 2
P 22	P 19	P 22	P 22	P 23	P 17
P 20	P 15	P 25	P 12	P 21	P 9
P 17	P 27	P 11	P 9	P 24	P 11
P 6	P 26	P 3	P 4	P 9	P 1
P 24	P 7	P 8	P 25	P 11	P 3
P 9	P 12	P 21	P 14	P 15	P 5
P 15	P 8	P 4	P 3	P 7	P 16
P 13	P 17	P 16	P 15	P 4	P 19
P 27	P 18	P 14	P 7	P 19	P 22
P 23	P 2	P 27	P 19	P 22	P 26
P 4	P 21	P 20	P 2	P 1	P 15
P 18	P 5	P 26	P 8	P 2	P 24
P 21	P 3	P 7	P 5	P 20	P 23
P 14	P 9	P 24	P 6	P 13	P 18
P 3	P 1	P 1	P 1	P 14	P 27
P 7	P 16	P 10	P 11	P 12	P 20
P 25	P 4	P 17	P 24	P 8	P 13
P 16	P 25	P 5	P 23	P 17	P 12
P 1	P 14	P 12	P 10	P 5	P 25
P 12	P 22	P 19	P 27	P 10	P 4
P 19	P 10	P 2	P 17	P 27	P 21
P 5	P 13	P 23	P 26	P 6	P 10
P 2	P 24	P 9	P 20	P 25	P 14
P 8	P 6	P 18	P 13	P 18	P 6
P 10	P 11	P 13	P 16	P 16	P 7
P 26	P 23	P 6	P 18	P 26	P 8

B 5: Table showing the serving order for the sensory panelist 7 to panelist 12

Pan 7	Pan 8	Pan 9	Pan 10	Pan 11	Pan 12
P 11	P 23	P 27	P 19	P 22	P 25

P 8	P 26	P 25	P 27	P 18	P 5
P 12	P 25	P 20	P 11	P 12	P 27
P 16	P 13	P 6	P 10	P 9	P 1
P 20	P 22	P 17	P 14	P 27	P 9
P 7	P 9	P 21	P 3	P 13	P 4
P 5	P 21	P 3	P 20	P 6	P 21
P 15	P 10	P 22	P 1	P 24	P 7
P 2	P 2	P 4	P 7	P 3	P 11
P 18	P 6	P 11	P 16	P 11	P 3
P 10	P 17	P 16	P 2	P 21	P 14
P 3	P 12	P 1	P 8	P 25	P 19
P 14	P 1	P 24	P 24	P 8	P 22
P 21	P 27	P 10	P 26	P 14	P 24
P 25	P 19	P 26	P 6	P 10	P 15
P 27	P 5	P 9	P 23	P 16	P 10
P 23	P 24	P 7	P 12	P 2	P 12
P 22	P 20	P 12	P 21	P 19	P 16
P 9	P 16	P 8	P 9	P 5	P 18
P 13	P 15	P 15	P 22	P 4	P 6
P 17	P 11	P 18	P 17	P 15	P 13
P 1	P 7	P 13	P 18	P 17	P 2
P 6	P 14	P 14	P 5	P 23	P 20
P 19	P 8	P 19	P 4	P 1	P 26
P 24	P 18	P 5	P 15	P 20	P 8
P 4	P 4	P 23	P 25	P 26	P 23
P 26	P 3	P 2	P 13	P 7	P 17

B 6: Table showing the serving order for the sensory panelist 12 to panelist 18

Pan 13	Pan 14	Pan 15	Pan 16	Pan 17	Pan 18
P 27	P 18	P 26	P 18	P 20	P 14
P 21	P 12	P 18	P 17	P 22	P 13
P 4	P 14	P 15	P 21	P 6	P 5
P 25	P 22	P 16	P 2	P 19	P 8
P 26	P 27	P 20	P 22	P 5	P 27

P 10	P 8	P 14	P 12	P 3	P 25
P 1	P 26	P 13	P 9	P 16	P 21
P 19	P 19	P 3	P 4	P 8	P 19
P 12	P 10	P 25	P 7	P 1	P 22
P 20	P 1	P 10	P 25	P 2	P 2
P 22	P 7	P 24	P 6	P 10	P 3
P 8	P 3	P 27	P 20	P 7	P 24
P 6	P 17	P 19	P 13	P 9	P 16
P 3	P 21	P 8	P 3	P 26	P 26
P 18	P 4	P 5	P 1	P 12	P 10
P 13	P 11	P 22	P 8	P 27	P 11
P 24	P 6	P 4	P 5	P 24	P 17
P 16	P 9	P 6	P 24	P 13	P 1
P 2	P 25	P 17	P 19	P 4	P 20
P 5	P 20	P 11	P 14	P 14	P 9
P 15	P 23	P 21	P 27	P 15	P 12
P 9	P 16	P 12	P 26	P 25	P 4
P 23	P 5	P 1	P 11	P 11	P 15
P 17	P 13	P 2	P 15	P 18	P 18
P 7	P 24	P 23	P 10	P 17	P 23
P 11	P 2	P 7	P 23	P 23	P 7
P 14	P 15	P 9	P 16	P 21	P 6

B 7: Sensory evaluation of the *pawpine*jam by panelist

B 8: Raw data for Panelist 1 after sensory evaluation

	Factor 1	Factor 2	Response 1	Response 2	Response 3	Response 4
Run	A:Products	B:Panelist	Colour	Sweetness	Texture	Odour
1	325	P1	3	3	3	3
2	614	P1	4	3	3	3
3	771	P1	4	5	3	4
4	244	P1	4	4	4	3
5	429	P1	4	3	3	3
6	874	P1	4	5	4	5
7	557	P1	5	5	3	3
8	119	P1	3	4	3	4
9	967	P1	2	4	3	4
10	122	P1	5	5	5	5
11	667	P1	2	4	4	4
12	821	P1	4	3	3	3
13	463	P1	4	5	4	5
14	593	P1	5	5	4	4
15	462	P1	4	5	3	5
16	213	P1	4	3	3	2
17	986	P1	5	5	2	5
18	603	P1	4	3	3	3
19	731	P1	5	3	4	4
20	419	P1	4	5	3	5
21	532	P1	5	3	4	3
22	176	P1	4	4	3	4
23	359	P1	5	3	4	5
24	912	P1	2	4	4	4
25	845	P1	5	4	4	3
26	635	P1	4	4	5	4
27	378	P1	4	3	3	3

B 9: Raw data for Panelist 2 after sensory evaluation

Run	A: Product	B: Panelist	Colour	Sweetness	Texture	Odour
28	325	P2	1	2	2	3
29	614	P2	2	1	1	2
30	771	P2	1	1	1	1

31	244	P2	2	2	3	1
32	429	P2	2	1	1	2
33	874	P2	4	3	1	2
34	557	P2	5	4	4	5
35	119	P2	5	5	3	4
36	967	P2	3	4	4	3
37	122	P2	4	4	4	3
38	667	P2	3	3	2	2
39	821	P2	5	4	3	3
40	463	P2	3	3	3	2
41	593	P2	4	2	2	3
42	462	P2	4	5	3	2
43	213	P2	5	3	5	4
44	986	P2	5	4	4	4
45	603	P2	2	1	2	3
46	731	P2	5	5	4	3
47	419	P2	5	5	4	3
48	532	P2	1	2	1	1
49	176	P2	2	2	2	3
50	359	P2	2	2	1	2
51	912	P2	4	4	3	3
52	845	P2	2	2	3	2
53	635	P2	4	4	4	4
54	378	P2	5	4	3	3

B 10: Raw data for Panelist 3 after sensory evaluation

Run	A: Product	B: Panelist	Colour	Sweetness	Texture	Odour
55	325	P3	3	2	3	4

56	614	P3	2	3	2	3
57	771	P3	4	2	5	5
58	244	P3	5	5	4	1
59	429	P3	3	5	4	4
60	874	P3	4	5	4	5
61	557	P3	4	4	4	4
62	119	P3	5	5	4	5
63	967	P3	5	5	5	5
64	122	P3	5	4	4	4
65	667	P3	5	4	5	4
66	821	P3	4	4	4	4
67	463	P3	4	5	4	5
68	593	P3	5	3	4	2
69	462	P3	4	5	5	4
70	213	P3	5	2	2	1
71	986	P3	5	5	4	5
72	603	P3	5	4	3	4
73	731	P3	3	4	3	4
74	419	P3	4	3	3	3
75	532	P3	4	4	2	3
76	176	P3	4	4	4	2
77	359	P3	4	3	3	4
78	912	P3	4	5	3	4
79	845	P3	5	2	5	2
80	635	P3	4	4	3	3
81	378	P3	5	4	3	4

B 11: Raw data for Panelist 4 after sensory evaluation

Run	A: Product	B: Panelist	Colour	Sweetness	Texture	Odour
82	325	P4	4	4	4	3
83	614	P4	3	2	3	4
84	771	P4	3	5	4	4
85	244	P4	3	4	4	4
86	429	P4	4	4	4	4
87	874	P4	4	3	4	3
88	557	P4	2	3	2	3
89	119	P4	3	4	3	4
90	967	P4	4	4	4	3
91	122	P4	4	3	3	3
92	667	P4	5	4	3	4
93	821	P4	4	4	3	3
94	463	P4	4	3	3	3
95	593	P4	4	4	3	3
96	462	P4	5	5	4	4
97	213	P4	4	4	3	4
98	986	P4	4	3	3	3
99	603	P4	4	5	4	4
100	731	P4	3	3	3	3
101	419	P4	5	3	2	2
102	532	P4	3	2	3	2
103	176	P4	4	3	3	2
104	359	P4	3	4	3	3
105	912	P4	3	3	4	4
106	845	P4	4	4	3	4
107	635	P4	3	4	4	3
108	378	P4	4	4	4	3

B 12: Raw data for Panelist 5 after sensory evaluation

Run	A: Product	B: Panelist	Colour	Sweetness	Texture	Odour
109	325	P5	5	5	5	5
110	614	P5	3	4	5	5
111	771	P5	4	4	5	5
112	244	P5	4	4	5	3
113	429	P5	5	2	4	4
114	874	P5	3	5	5	4
115	557	P5	2	1	4	5
116	119	P5	3	4	4	5
117	967	P5	4	3	5	5
118	122	P5	3	5	4	5
119	667	P5	4	3	5	4
120	821	P5	3	3	5	5
121	463	P5	5	4	5	5
122	593	P5	3	1	4	5
123	462	P5	4	5	4	5
124	213	P5	3	1	4	1
125	986	P5	5	2	4	5
126	603	P5	3	4	3	5
127	731	P5	5	2	5	5
128	419	P5	3	1	5	5
129	532	P5	4	4	3	4
130	176	P5	3	4	5	4
131	359	P5	5	1	4	5
132	912	P5	4	5	5	5
133	845	P5	5	2	5	4
134	635	P5	3	4	5	5
135	378	P5	5	5	5	5

B 13: Raw data for Panelist 6 after sensory evaluation

Run	A: Product	B: Panelist	Colour	Sweetness	Texture	Odour
136	325	P6	2	5	4	4
137	614	P6	2	2	2	3
138	771	P6	2	3	3	3
139	244	P6	3	4	4	4
140	429	P6	5	2	2	3
141	874	P6	4	4	5	4
142	557	P6	2	2	5	3
143	119	P6	2	5	4	4
144	967	P6	4	5	2	3
145	122	P6	3	1	4	3
146	667	P6	5	2	2	4
147	821	P6	3	5	4	3
148	463	P6	3	2	2	2
149	593	P6	3	1	4	4
150	462	P6	3	4	2	4
151	213	P6	2	2	1	1
152	986	P6	3	2	3	4
153	603	P6	3	1	2	3
154	731	P6	5	2	1	3
155	419	P6	2	1	4	4
156	532	P6	2	2	4	4
157	176	P6	3	1	4	3
158	359	P6	4	1	4	4
159	912	P6	3	4	4	4
160	845	P6	2	1	5	3
161	635	P6	2	1	4	4
162	378	P6	3	1	2	3

B 14: Raw data for Panelist 7 after sensory evaluation

Run	A: Product	B: Panelist	Colour	Sweetness	Texture	Odour
163	325	P7	5	4	5	5

164	614	P7	5	2	4	3
165	771	P7	4	3	4	4
166	244	P7	5	5	3	4
167	429	P7	4	2	3	4
168	874	P7	5	3	5	4
169	557	P7	5	3	4	3
170	119	P7	4	5	3	5
171	967	P7	5	5	5	5
172	122	P7	3	3	4	3
173	667	P7	5	5	5	5
174	821	P7	4	4	4	3
175	463	P7	5	4	5	4
176	593	P7	5	4	3	4
177	462	P7	5	2	4	3
178	213	P7	4	4	3	3
179	986	P7	5	5	4	5
180	603	P7	4	4	3	4
181	731	P7	5	2	5	3
182	419	P7	5	3	5	4
183	532	P7	4	3	5	4
184	176	P7	4	5	4	4
185	359	P7	5	5	5	4
186	912	P7	5	5	5	5
187	845	P7	4	3	5	4
188	635	P7	4	3	3	5
189	378	P7	3	4	5	5

B 15: Raw data for Panelist 8 after sensory evaluation

Run	A: Product	B: Panelist	Colour	Sweetness	Texture	Odour

190	325	P8	4	5	4	5
191	614	P8	5	4	4	4
192	771	P8	4	4	4	4
193	244	P8	4	4	5	4
194	429	P8	4	4	4	4
195	874	P8	5	5	4	4
196	557	P8	4	5	4	4
197	119	P8	4	5	4	5
198	967	P8	5	5	5	4
199	122	P8	5	4	4	3
200	667	P8	4	3	4	4
201	821	P8	5	4	4	4
202	463	P8	5	4	4	4
203	593	P8	3	4	4	4
204	462	P8	4	4	3	4
205	213	P8	4	2	2	3
206	986	P8	5	4	3	3
207	603	P8	4	4	3	4
208	731	P8	4	4	3	3
209	419	P8	4	3	4	4
210	532	P8	5	3	2	2
211	176	P8	4	3	3	4
212	359	P8	4	4	3	2
213	912	P8	4	3	5	3
214	845	P8	4	5	4	4
215	635	P8	4	5	4	4
216	378	P8	4	2	4	3

B 16: Raw data for Panelist 9 after sensory evaluation

Run	A: Product	B: Panelist	Colour	Sweetness	Texture	Odour
217	325	P9	2	4	1	4
218	614	P9	3	4	3	3
219	771	P9	3	5	3	3

220	244	P9	4	5	3	3
221	429	P9	3	4	2	2
222	874	P9	4	5	4	3
223	557	P9	2	3	2	2
224	119	P9	3	4	3	3
225	967	P9	4	4	4	3
226	122	P9	3	4	4	3
227	667	P9	3	3	3	2
228	821	P9	3	4	3	2
229	463	P9	3	3	3	2
230	593	P9	3	4	4	4
231	462	P9	4	4	3	2
232	213	P9	4	3	4	4
233	986	P9	5	4	1	1
234	603	P9	2	3	2	2
235	731	P9	2	2	3	3
236	419	P9	5	4	3	2
237	532	P9	5	2	1	2
238	176	P9	1	1	1	1
239	359	P9	3	2	2	4
240	912	P9	4	3	3	3
241	845	P9	5	4	2	1
242	635	P9	3	3	2	2
243	378	P9	5	5	4	5

B 17: Raw data for Panelist 10 after sensory evaluation

Run	A: Product	B: Panelist	Colour	Sweetness	Texture	Odour
244	325	P10	3	5	4	4
245	614	P10	5	5	4	5

246	771	P10	2	2	2	3
247	244	P10	4	3	4	4
248	429	P10	4	5	5	4
249	874	P10	4	3	3	4
250	557	P10	5	5	5	5
251	119	P10	5	5	4	4
252	967	P10	5	4	5	4
253	122	P10	4	3	5	3
254	667	P10	3	4	5	3
255	821	P10	2	3	2	4
256	463	P10	3	4	3	3
257	593	P10	4	4	3	4
258	462	P10	4	4	4	3
259	213	P10	4	4	2	4
260	986	P10	3	4	4	4
261	603	P10	4	1	3	3
262	731	P10	4	4	3	3
263	419	P10	5	3	4	3
264	532	P10	3	4	4	3
265	176	P10	3	4	2	3
266	359	P10	4	1	2	4
267	912	P10	5	3	3	4
268	845	P10	5	4	3	3
269	635	P10	5	4	3	5
270	378	P10	5	4	4	3

B 18: Raw data for Panelist 11 after sensory evaluation

Run	A: Product	B: Panelist	Colour	Sweetness	Texture	Odour
271	325	P11	3	5	2	4
272	614	P11	3	3	1	3
273	771	P11	4	3	1	3
274	244	P11	4	5	3	3
275	429	P11	3	4	4	4

276	874	P11	5	5	3	4
277	557	P11	5	4	3	3
278	119	P11	5	5	5	5
279	967	P11	5	3	3	4
280	122	P11	5	4	5	3
281	667	P11	5	4	4	5
282	821	P11	4	3	2	3
283	463	P11	4	4	3	4
284	593	P11	4	4	4	4
285	462	P11	4	4	5	4
286	213	P11	3	4	4	4
287	986	P11	3	4	4	4
288	603	P11	4	4	4	4
289	731	P11	3	4	3	4
290	419	P11	3	3	3	4
291	532	P11	3	5	5	4
292	176	P11	5	4	4	5
293	359	P11	3	3	3	4
294	912	P11	4	3	4	3
295	845	P11	3	5	4	5
296	635	P11	4	5	3	4
297	378	P11	5	2	3	5

B 19: Raw data for Panelist 12 after sensory evaluation

Run	A: Product	B: Panelist	Colour	Sweetness	Texture	Odour
298	325	P12	5	5	4	5
299	614	P12	5	5	5	4
300	771	P12	4	4	5	4
301	244	P12	5	4	3	4
302	429	P12	4	5	5	2
303	874	P12	5	5	5	5
304	557	P12	4	5	4	4
305	119	P12	5	4	3	3
306	967	P12	5	3	4	3

307	122	P12	5	4	5	4
308	667	P12	5	3	4	3
309	821	P12	5	3	3	4
310	463	P12	4	4	4	3
311	593	P12	4	4	4	4
312	462	P12	5	5	5	5
313	213	P12	5	3	2	4
314	986	P12	4	3	2	4
315	603	P12	3	3	3	4
316	731	P12	5	3	4	3
317	419	P12	5	3	3	2
318	532	P12	5	2	5	5
319	176	P12	5	3	3	4
320	359	P12	3	2	3	3
321	912	P12	5	4	5	5
322	845	P12	5	4	4	3
323	635	P12	5	4	4	4
324	378	P12	5	2	4	4

B 20: Raw data for Panelist 13 after sensory evaluation

Run	A: Product	B: Panelist	Colour	Sweetness	Texture	Odour
325	325	P13	2	1	1	1
326	614	P13	4	4	4	2
327	771	P13	2	3	4	3
328	244	P13	3	2	4	3
329	429	P13	5	3	3	3
330	874	P13	3	3	4	3
331	557	P13	3	2	3	2
332	119	P13	2	2	3	2
333	967	P13	3	4	4	2
334	122	P13	2	2	3	2
335	667	P13	2	2	3	3

336	821	P13	5	3	5	2
337	463	P13	3	2	3	3
338	593	P13	2	2	3	3
339	462	P13	4	4	4	3
340	213	P13	5	3	2	2
341	986	P13	4	3	4	3
342	603	P13	3	2	3	3
343	731	P13	5	3	4	1
344	419	P13	5	5	4	2
345	532	P13	5	4	4	4
346	176	P13	4	2	3	2
347	359	P13	5	2	3	3
348	912	P13	4	4	4	3
349	845	P13	5	2	2	2
350	635	P13	3	1	3	2
351	378	P13	4	3	3	4

B 21: Raw data for Panelist 14 after sensory evaluation

Run	A: Product	B: Panelist	Colour	Sweetness	Texture	Odour
352	325	P14	2	4	3	4
353	614	P14	4	4	5	3
354	771	P14	2	3	5	3
355	244	P14	4	2	5	3
356	429	P14	2	4	3	3
357	874	P14	4	5	5	4
358	557	P14	2	3	4	3
359	119	P14	4	4	3	2
360	967	P14	4	5	4	3
361	122	P14	4	5	5	4
362	667	P14	4	3	4	3
363	821	P14	4	1	3	5
364	463	P14	2	4	4	3

365	593	P14	3	2	3	3
366	462	P14	4	3	2	3
367	213	P14	5	2	3	3
368	986	P14	4	3	4	3
369	603	P14	3	2	5	4
370	731	P14	4	4	3	4
371	419	P14	4	2	4	2
372	532	P14	3	3	2	3
373	176	P14	3	3	3	3
374	359	P14	5	3	3	2
375	912	P14	3	5	4	4
376	845	P14	4	2	3	2
377	635	P14	4	4	4	3
378	378	P14	3	3	5	3

B 22: Raw data for Panelist 15 after sensory evaluation

Run	A: Product	B: Panelist	Colour	Sweetness	Texture	Odour
379	325	P15	3	5	4	3
380	614	P15	3	3	2	3
381	771	P15	3	4	5	3
382	244	P15	2	3	2	3
383	429	P15	3	4	5	3
384	874	P15	3	2	1	3
385	557	P15	2	3	3	3
386	119	P15	2	3	3	2
387	967	P15	3	3	3	2
388	122	P15	2	2	3	2
389	667	P15	3	3	4	3
390	821	P15	3	3	4	3
391	463	P15	4	3	4	4
392	593	P15	3	4	5	3
393	462	P15	2	3	3	3
394	213	P15	3	2	3	4
395	986	P15	3	2	4	3
396	603	P15	2	2	1	2

397	731	P15	3	3	4	3
398	419	P15	3	3	5	4
399	532	P15	3	3	5	3
400	176	P15	3	4	4	2
401	359	P15	1	2	1	1
402	912	P15	3	3	4	3
403	845	P15	3	5	4	3
404	635	P15	3	2	2	3
405	378	P15	3	3	2	1

B 23: Raw data for Panelist 16 after sensory evaluation

Run	A: Product	B: Panelist	Colour	Sweetness	Texture	Odour
406	325	P16	2	4	1	4
407	614	P16	4	5	4	4
408	771	P16	4	3	2	4
409	244	P16	4	5	4	2
410	429	P16	3	4	4	4
411	874	P16	5	3	1	4
412	557	P16	4	2	4	1
413	119	P16	5	5	4	5
414	967	P16	2	5	2	3
415	122	P16	5	4	4	4
416	667	P16	4	4	3	5
417	821	P16	5	2	2	2
418	463	P16	5	2	3	4
419	593	P16	3	5	5	4
420	462	P16	5	4	2	4
421	213	P16	2	4	2	4
422	986	P16	5	5	4	4
423	603	P16	3	4	3	4
424	731	P16	5	4	4	5
425	419	P16	4	2	3	3
426	532	P16	3	4	3	3
427	176	P16	5	2	3	4

428	359	P16	5	2	2	3
429	912	P16	3	4	5	4
430	845	P16	4	4	5	4
431	635	P16	4	3	5	4
432	378	P16	4	3	2	4

B 24: Raw data for Panelist 17 after sensory evaluation

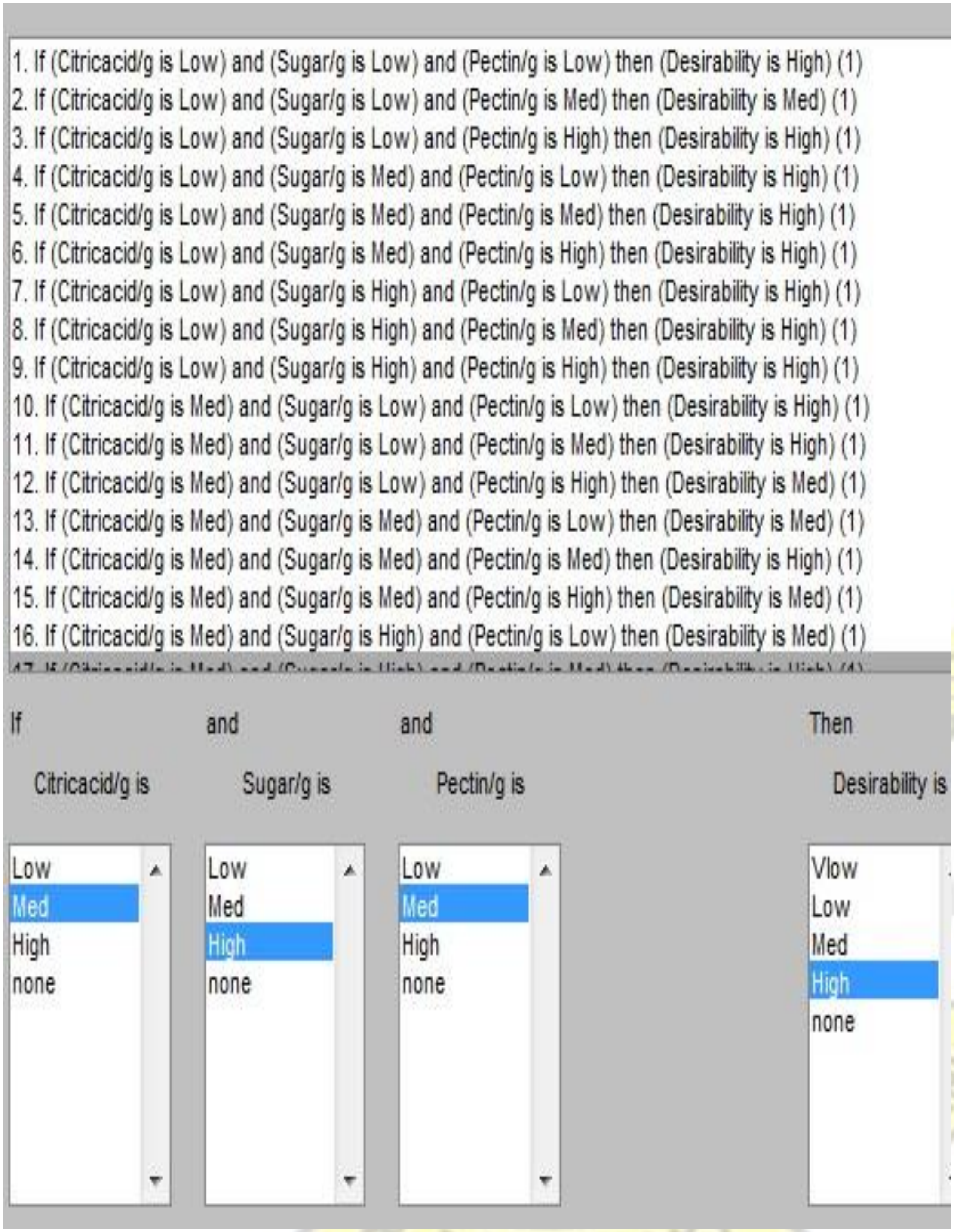
Run	A: Product	B: Panelist	Colour	Sweetness	Texture	Odour
433	325	P17	5	3	4	4
434	614	P17	4	5	4	4
435	771	P17	5	5	5	4
436	244	P17	4	4	5	4
437	429	P17	5	4	5	4
438	874	P17	5	4	5	5
439	557	P17	5	5	4	4
440	119	P17	5	5	4	5
441	967	P17	3	4	2	4
442	122	P17	4	4	3	3
443	667	P17	4	4	4	5
444	821	P17	4	2	3	4
445	463	P17	4	2	3	4
446	593	P17	4	3	4	5
447	462	P17	4	3	4	4
448	213	P17	5	4	4	5
449	986	P17	5	4	4	5
450	603	P17	4	4	3	5
451	731	P17	5	3	5	4
452	419	P17	5	4	2	5
453	532	P17	4	3	4	3
454	176	P17	5	2	3	5
455	359	P17	4	4	4	2
456	912	P17	4	4	4	4
457	845	P17	4	3	4	4

458	635	P17	3	3	4	4
459	378	P17	3	2	3	4

B 25: Raw data for Panelist 18 after sensory evaluation

Run	A: Product	B: Panelist	Colour	Sweetness	Texture	Odour
460	325	P18	4	3	1	2
461	614	P18	3	5	3	4
462	771	P18	4	5	3	4
463	244	P18	4	4	2	4
464	429	P18	5	2	5	4
465	874	P18	5	2	1	3
466	557	P18	4	4	4	2
467	119	P18	5	4	3	4
468	967	P18	4	5	4	5
469	122	P18	4	3	2	2
470	667	P18	5	4	3	4
471	821	P18	4	3	4	4
472	463	P18	5	5	4	4
473	593	P18	4	5	5	4
474	462	P18	4	3	3	4
475	213	P18	5	5	5	5
476	986	P18	3	1	2	4
477	603	P18	5	5	2	5
478	731	P18	5	3	2	4
479	419	P18	4	2	1	3
480	532	P18	5	4	4	4
481	176	P18	5	5	5	4
482	359	P18	2	5	1	3
483	912	P18	5	5	5	5
484	845	P18	5	5	5	5
485	635	P18	4	5	2	5
486	378	P18	5	4	5	5

B 27: Setting of Rules for 27 Products



APPENDIX C

C 1: Analysis of Variance for the four sensory attributes used

ANOVA for Colour

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	122.4547	17	7.20322	9.446277258	3.06E-21	1.645923
Columns	34.65844	26	1.333017	1.748113599	0.013611	1.520741
Error	337.0453	442	0.762546			
Total	494.1584	485				

ANOVA for Taste

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	90.26337	17	5.30961	4.976083	6.54E-10	1.645923
Columns	65.55967	26	2.521526	2.363134	0.000224	1.520741
Error	471.6255	442	1.067026			
Total	627.4486	485				

ANOVA for Texture

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	95.49794	17	5.617526	5.917227	2.49E-12	1.645923
Columns	44.38683	26	1.707186	1.798266	0.01002	1.520741
Error	419.6132	442	0.949351			
Total	559.4979	485				

ANOVA for Odour

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	95.49794	17	5.617526	5.917227	2.49E-12	1.645923
Columns	44.38683	26	1.707186	1.798266	0.01002	1.520741

Error	419.6132	442	0.949351
Total	559.4979	485	

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C 2: Anova: Two Factor Without Replication for Colour

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
P1	27	108	4	0.846153846
P2	27	90	3.333333	2.076923077
P3	27	114	4.222222	0.641025641
P4	27	100	3.703704	0.524216524
P5	27	103	3.814815	0.849002849
P6	27	80	2.962963	0.96011396
P7	27	121	4.481481	0.413105413
P8	27	115	4.259259	0.276353276
P9	27	91	3.37037	1.165242165
P10	27	106	3.925926	0.686609687
P11	27	107	3.962963	0.883190883
P12	27	125	4.62963	0.396011396
P13	27	97	3.592593	1.327635328
P14	27	94	3.481481	0.797720798
P15	27	74	2.740741	0.353276353
P16	27	107	3.962963	1.037037037
P17	27	116	4.296296	0.447293447
P18	27	117	4.333333	0.615384615
Q1	18	58	3.222222	1.594771242
Q2	18	64	3.555556	1.08496732
Q3	18	59	3.277778	1.153594771
Q4	18	68	3.777778	0.77124183
Q5	18	68	3.777778	1.006535948
Q6	18	76	4.222222	0.535947712
Q7	18	65	3.611111	1.663398693
Q8	18	70	3.888889	1.39869281
Q9	18	70	3.888889	1.045751634
Q10	18	70	3.888889	1.045751634
Q11	18	71	3.944444	1.114379085
Q12	18	71	3.944444	0.761437908
Q13	18	70	3.888889	0.810457516
Q14	18	66	3.666667	0.705882353
Q15	18	73	4.055556	0.526143791
Q16	18	72	4	1.058823529
Q17	18	76	4.222222	0.77124183
Q18	18	62	3.444444	0.849673203
Q19	18	76	4.222222	1.006535948
Q20	18	75	4.166667	0.852941176

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Q21	18	67	3.722222	1.388888889
Q22	18	67	3.722222	1.27124183
Q23	18	67	3.722222	1.506535948
Q24	18	69	3.833333	0.735294118
Q25	18	74	4.111111	1.045751634
Q26	18	66	3.666667	0.588235294
Q27	18	75	4.166667	0.735294118

C 3: Anova: Two Factor Without Replication for Taste

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
P1	27	107	3.962963	0.729345
P2	27	82	3.037037	1.806268
P3	27	105	3.888889	1.102564
P4	27	98	3.62963	0.626781
P5	27	88	3.259259	2.122507
P6	27	66	2.444444	2.179487
P7	27	100	3.703704	1.139601
P8	27	106	3.925926	0.763533
P9	27	96	3.555556	1.025641
P10	27	106	3.925926	0.68661
P11	27	99	3.666667	1.153846
P12	27	99	3.666667	0.923077
P13	27	73	2.703704	0.985755
P14	27	88	3.259259	1.19943
P15	27	82	3.037037	0.729345
P16	27	98	3.62963	1.165242
P17	27	97	3.592593	0.866097
P18	27	106	3.925926	1.45584
Q1	18	69	3.833333	1.558824
Q2	18	64	3.555556	1.555556
Q3	18	64	3.555556	1.437908
Q4	18	69	3.833333	1.088235
Q5	18	62	3.444444	1.437908
Q6	18	70	3.888889	1.281046
Q7	18	63	3.5	1.558824
Q8	18	78	4.333333	0.705882
Q9	18	75	4.166667	0.617647
Q10	18	64	3.555556	1.202614
Q11	18	62	3.444444	0.614379

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Q12	18	58	3.222222	0.888889
Q13	18	63	3.5	1.088235
Q14	18	61	3.388889	1.663399
Q15	18	72	4	0.823529
Q16	18	55	3.055556	1.114379
Q17	18	63	3.5	1.441176
Q18	18	56	3.111111	1.751634
Q19	18	58	3.222222	0.771242
Q20	18	55	3.055556	1.46732
Q21	18	57	3.166667	0.852941
Q22	18	56	3.111111	1.51634
Q23	18	49	2.722222	1.624183
Q24	18	71	3.944444	0.643791
Q25	18	61	3.388889	1.663399
Q26	18	63	3.5	1.441176
Q27	18	58	3.222222	1.24183

C 4: Anova: Two Factor Without Replication for Texture

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
P1	27	94	3.481481	0.490028
P2	27	73	2.703704	1.447293
P3	27	99	3.666667	0.846154
P4	27	90	3.333333	0.384615
P5	27	122	4.518519	0.413105
P6	27	87	3.222222	1.487179
P7	27	113	4.185185	0.695157
P8	27	101	3.740741	0.584046
P9	27	73	2.703704	0.985755
P10	27	92	3.407407	1.173789
P11	27	95	3.518519	1.02849
P12	27	105	3.888889	0.871795
P13	27	90	3.333333	0.692308
P14	27	101	3.740741	0.891738

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P15	27	90	3.333333	1.615385
P16	27	86	3.185185	1.464387
P17	27	103	3.814815	0.695157
P18	27	86	3.185185	2.079772
Q1	18	55	3.055556	1.937908
Q2	18	59	3.277778	1.624183
Q3	18	64	3.555556	1.908497
Q4	18	67	3.722222	0.918301
Q5	18	66	3.666667	1.411765
Q6	18	64	3.555556	2.379085
Q7	18	66	3.666667	0.705882
Q8	18	63	3.5	0.382353
Q9	18	68	3.777778	1.124183
Q10	18	71	3.944444	0.761438
Q11	18	67	3.722222	0.918301
Q12	18	61	3.388889	0.839869
Q13	18	64	3.555556	0.614379
Q14	18	68	3.777778	0.653595
Q15	18	63	3.5	0.970588
Q16	18	54	3	1.294118
Q17	18	60	3.333333	0.941176
Q18	18	52	2.888889	0.810458
Q19	18	63	3.5	1.088235
Q20	18	62	3.444444	1.202614
Q21	18	61	3.388889	1.781046
Q22	18	59	3.277778	1.035948

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Q23	18	51	2.833333	1.323529
Q24	18	74	4.111111	0.575163
Q25	18	70	3.888889	1.045752
Q26	18	64	3.555556	0.96732
Q27	18	64	3.555556	1.084967

C 5: Anova: Two Factor Without Replication for Odour

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
P1	27	103	3.814815	0.77208
P2	27	73	2.703704	0.985755
P3	27	98	3.62963	1.396011
P4	27	89	3.296296	0.447293
P5	27	123	4.555556	0.794872
P6	27	91	3.37037	0.549858
P7	27	109	4.037037	0.575499
P8	27	100	3.703704	0.524217
P9	27	71	2.62963	1.011396
P10	27	106	3.925926	0.45584
P11	27	99	3.666667	0.461538
P12	27	102	3.777778	0.717949
P13	27	68	2.518519	0.566952
P14	27	85	3.148148	0.51567
P15	27	75	2.777778	0.564103
P16	27	100	3.703704	0.831909
P17	27	113	4.185185	0.541311
P18	27	106	3.925926	0.840456
Q1	18	67	3.722222	1.153595
Q2	18	62	3.444444	0.732026
Q3	18	64	3.555556	0.849673
Q4	18	57	3.166667	0.970588
Q5	18	61	3.388889	0.604575
Q6	18	69	3.833333	0.735294
Q7	18	59	3.277778	1.271242
Q8	18	71	3.944444	1.232026
Q9	18	65	3.611111	0.957516
Q10	18	59	3.277778	0.800654
Q11	18	67	3.722222	0.918301

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Q12	18	61	3.388889	0.839869
Q13	18	64	3.555556	0.96732
Q14	18	67	3.722222	0.565359
Q15	18	66	3.666667	0.823529
Q16	18	58	3.222222	1.712418
Q17	18	69	3.833333	1.088235
Q18	18	66	3.666667	0.823529
Q19	18	62	3.444444	0.849673
Q20	18	60	3.333333	1.176471
Q21	18	57	3.166667	0.970588
Q22	18	59	3.277778	1.271242
Q23	18	58	3.222222	1.24183
Q24	18	70	3.888889	0.575163
Q25	18	58	3.222222	1.24183
Q26	18	68	3.777778	0.888889
Q27	18	67	3.722222	1.153595