DEPARTMENT OF CULINARY ARTS
MANIPAL UNIVERSITY

FUTURE OF IDLIS':

A SCIENTIFIC ASSESSMENT

A STUDY ON SOUTH INDIA'S MOST PREFERRED BREAKFAST CEREAL

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ABSTRACT

The purpose and scope of the study is to evaluate the quality of Idlis (a steamed rice cake originating from India) for its colour, taste, aroma and textural quality and to identify the various properties of the raw materials and Idli batter, which, along with temperature, time and various environmental factors and biological agents contribute to a scientifically good Idli.

Through the standardization of various factors like viscosity, pH, amylose content, density, we can further mix various grains and lentils in different proportions to meet these set points thus creating an even more healthier and nutritious Idli which could be used as a health specific food product that would maintain all of the original properties of texture, chewiness, softness.

ACKNOWLEDGEMENTS

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CHAPTER 1
INTRODUCTION

Cereal products are amongst the most important staple foods of mankind. Nutrients provided by bread consumption in industrial countries meet close to 50% of the daily requirement of carbohydrates, one third of the proteins and 50–60% of vitamin B. (H.-D. Belitz, 2009) Fermentation is the oldest known form of food biotechnology; records of barley conversion to beer date back more than 5000 years (Borgstrom, 1968).

The consumption of sprouted cereals is becoming popular in various parts of the world. Sprouting of grains for a limited period causes increased activities of hydrolytic enzymes, improvement in the contents of certain essential amino acids, total sugars, and B-group vitamins, and a decrease in dry matter, starch, and anti-nutrients. The digestibility of storage proteins and starch are improved due to their partial hydrolysis during sprouting (Chavan et al. 1989).

The Idli is a very popular fermented breakfast food staple consumed in the Indian subcontinent, especially in southern parts. The major ingredients are rice (*Oryza sativum*) and black gram (*Phaseolus mungo*). The Idli is the most preferred breakfast product due to its soft texture, mild pleasant flavour and aroma, easy digestibility and known health and nutritional benefits. In all ways the Idli has proven to be an ideal human food for all ages and at all times.

Traditionally, Idli preparation is as follows:
[1] Soaking the rice and black gram separately for 6-8 hours.
[2] After draining the water, grinding rice and black gram separately with occasional addition of water during the grinding process
[3] Mixing rice and black gram batters together with addition of a little salt
[4] Allowing fermentation overnight at room temperature
[5] Depositing the fermented batter in special Idli pans and steaming.

Several aspects such as methods of Idli preparation, effect of raw materials, effect of temperature, effect of pH, micro-organisms involved, biochemical and nutritive changes have been reviewed by many authors.

Idli batter fermentation has been the subject of many research investigations covering aspects of optimization of ingredients, microbiological factors affecting fermentation, physio-chemical properties and nutritional value. The two significant changes occurring in Idli batter fermentation are leavening and acidification.

The stabilization of the batter is very important with respect to Idli texture. The polysaccharide in black gram stabilizes the soft porous texture of Idli. An important way to stabilize the foam is through the formation of a rigid system by means of crystallization, denaturation or gelatinization of the continuous phase. Black gram starch and mucilage combined results in an enhanced foam stability, probably due to increased viscosity caused by synergistic interactions between these polysaccharides. (Muralikrishna, 1987)
Hence the batter is strengthened and develops a firm structure.

CHAPTER 2
LITERATURE REVIEW

The review of literature of the current study is done under the following headings:

SIGNIFICANCE OF FERMENTED FOODS:

Fermented foods are foods which have been subjected to the action of microorganisms or their enzymes to produce desirable biochemical changes and results in significant modification to the food. Fermented foods provide variety to the diet supplying nutrients predominantly proteins and amino acids. The process of fermentation also aids in detoxification. Fermentation plays diverse roles like enhancing the diet with wide range of flavours, aromas and textures, preserving substantial amounts of food through lactic acid, alcoholic, acetic acid, alkaline fermentations, enriching food substrates with nutrients and also reducing cooking times and fuel requirements. Lactic acid fermented foods are common in tropical countries and these foods give improved organoleptic qualities. Fermentation affords a natural way to reduce the volume of the material to be transported, abolish undesirable components, enhance the nutritive value and improve appearance of the food, decrease the energy required for cooking and make a safer product. Fermented foods are produced worldwide by various manufacturing techniques, raw materials and microorganisms. Traditional fermented foods prepared from most common types of cereals (such as rice, wheat, corn or sorghum) are well known in various parts of the world. Some are utilized as colorants, spices, beverages and breakfast or light meal foods, while a few of them are used as key foods in the diet. The microbiology of many of these fermented products is quite complex and not known. In most of these products, fermentation is natural and involves mixed cultures of yeasts, bacteria and fungi. Some microorganisms may participate in parallel, while others act in a sequential manner with exchanging dominant flora during the course of the fermentation. The common bacteria involved in fermentation are species of Leuconostoc, Lactobacillus, Streptococcus, Pediococcus, Micrococcus and Bacillus.

NUTRITIONAL COMPOSITION OF IDLI

Idli, a very popular fermented breakfast food consumed in the Indian subcontinent, consists mainly of rice and black gram. Idli fermentation was carried out in the conventional way in a batter having rice to black gram in the ratios of 2:1, 3:1 and 4:1 at room temperature. It makes an important contribution to the diet as a source of protein, calories and vitamins, especially B-complex vitamins, compared to the raw unfermented ingredients. It can be produced locally and used as a dietary supplement in developing countries to treat people suffering from protein calorie malnutrition and kwashiorkor (a form of malnutrition that occurs when there is not enough protein in the diet) Adding *Saccharomyces cerevisiae*, along with natural bacterial flora of the ingredients, is commonly used to standardize Idli fermentation in terms of improved organoleptic characteristics, leavening and nutritional constituents. Traditional Idli fermentation involves several bacteria and yeasts, contributed by the ingredients rice (*Oryza sativa*), black gram (*Phaseolus mungo*) and the environment, with overall dominance of the former in bringing about various changes. Idli fermentation is accompanied by an increase in total acids, batter volume, soluble solids, reducing sugars, non-protein nitrogen, free amino acids, amylases, proteinases and water soluble vitamins. B1, B2 and B12 contents, thus accounting for improved digestibility and nutritional value of the staples.

OPTIMIZATION OF PROCESS PARAMETERS FOR SENSORY EVALUATION OF IDLY PREPARATION BY GUARGUMS AS STABILIZER

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The present work is focused on the sensory quality of idly produced by guar gum. The parameters like: pH (4-6), temperature (10-500C), fermentation time (0-12 hrs.) and guar gum (0-0.2%) were optimized using response surface methodology (RSM). The design contains a total of 31 experimental runs involving replications of the central points in a randomized factorial design and organized. Data obtained from RSM on idly batter preparation were subjected to the analysis of variance (ANOVA) and were analysed using a second order polynomial equation. Sensory analysis for colour, taste, aroma and texture in the idly batter preparation were performed. The optimum parameters compositions for the best sensory score of the four outputs were: pH 4.54 temperature 30.60C Fermentation time12.4hrs and guar gum 0.09% idly batter preparation under the optimum conditions was subjected to evaluation of sensory values and the results were compared with the RSM predictions.

RHEOLOGY AND PARTICLE SIZE CHANGES DURING IDLI FERMENTATION

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Received 13 July 1999; accepted 16 October 1999

Idli, a very popular fermented breakfast food staple consumed in the Indian subcontinent, consists mainly of rice and black gram. Idli fermentation was carried out in the conventional way in a batter having rice to black gram in the ratios of 2:1, 3:1 and 4:1 at room temperature. The rheology of the product was assessed using a Brookfield viscometer having disc spindles. Power law model with yield stress adequately fitted the data. Yield stress values were in the range of 13±43 Pa and reached a maximum value at 7 h of fermentation. Flow behaviour indices were in the range 0.287±0.605. Flow behaviour indices at 23 h were significantly lower than those at 0 h. Consistency index values, at any fermentation time, increased as the rice to black gram ratio increased. Mean particle size ranged from 500 to 600 lm and there was no definite trend noticed with respect to time of fermentation and rice to black gram ratio. There was a steep change in volume increase after 4-h fermentation. At the end of the fermentation, diameter and depth of batter deposits in the automatic Idli manufacturing unit developed at the author's laboratory were measured. Whereas the depth remains almost same for the batter types, there was a decrease in diameter as the ratio of rice to black gram increases.

STATISTICAL OPTIMIZATION OF INGREDIENTS FOR SENSORY EVALUATION OF IDLY PREPARATION USING RESPONSE SURFACE METHODOLOGY (RSM)

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The study aims to make idly batter using xanthan. The ingredients like, pH (4-6), temperature (0-300C), fermentation time (0-12 hrs.) and xanthan (0-0.1%) were optimized using response surface methodology (RSM). The design contains a total of 31 experimental runs involving replications of the central points in a randomized factorial design and organized. Data obtained from RSM on idly batter preparation were subjected to the analysis of variance (ANOVA) and were analysed using a second order polynomial equation. Sensory analysis for colour, taste, aroma and texture in the idly batter preparation were performed. The optimum ingredient compositions for the best sensory score of the four outputs were: pH- 4.48, temperature 30.40C, Fermentation time12.02hrs and xanthan0.072% idly batter preparation under the optimum conditions was subjected to evaluation of sensory values and the results were compared with the RSM predictions.

CHAPTER 3
INGREDIENTS

HISTORY, ROLE IN FERMENTATION AND NUTRITIONAL PROPERTIES

RICE

Rice is the seed of the monocot plants *Oryza sativa* (Asian rice) or *Oryza glaberrima* (African rice). As a cereal grain, it is the most widely consumed staple food for a large part of the world's human population. It is the grain with the second-highest worldwide production, after corn, according to data for 2010. (FAO)
There are thought to be more than 1,00,000 varieties of rice throughout the world. They all fall into one of the two traditionally recognized sub-species of *Oriza sativa. Indica* rice's are generally grown in lowland tropics and subtropics, accumulate a large amount of amylose starch and produces a firm grain. *Japonica* rice's with upland varieties, accumulate substantially less amylose starch than the *indicas*, and produce a shorter, stickier grain. Generally, the higher the amylose content in a rice the more organized and stable the starch granules, and so more water, heat, and time it takes to cook the grains. (McGee, revised 2004)

Starch, amylose and amylopectin content from several types of rice (g/100 g)

Type of rice	Starch	Amylose	Amylopectin	Classified of amylose content*
Cisadane	85.85	19.50	66.35	Low (2-19% amylose)
IR 64	83.46	23.88	59.58	Intermediate (20-25% amylose)
IR 42	85.08	28.24	56.84	High (25-33% amylose)

* IRRI, 2009

Table 3.1
IR 64: Indica, Long Grain, Parboiled
IR 42: Indica, Medium Grain

Amylose content in rice may be empirically estimated by the starch-iodine-blue test. However, it has been shown to be of limited use for certain types of rice. (Engineers, 2006)

Characteristic	White Kar	IR20
Amylose Content (%)	71.6	65.6
Amylopectin Content (%)	28.4	34.4
Water Uptake at 70C (%)	37.5	62.5
Relative Gelatinization Temperature	High	Low

Table 3.2: Characteristics of White Kar and IR20 Rice Varieties
Source: Purushothaman et al., 1977

RAW RICE

Raw Rice is the enriched white long or medium grained rice viz. usually the steamed rice in Indian cuisine. Raw rice may be ground into flour for many uses. The stored proteins of maize and rice are sometimes called glutens, but their proteins differ from true gluten *(it does contain rice gluten, but it is not the gluten that triggers the autoimmune response of a celiac)*. Thus Rice flour does not contain gluten, so it is suitable for people on a gluten-free diet.

The starch components of rice, particularly the amylose content or amylose: amylopectin ratio, its temperature of gelatinization, and its pasting characteristics, are largely responsible for major differences in rice cooking and processing behaviours. High-protein rice tends to have a creamier appearance and high protein content increases the cooking time while lowering the water-absorption capacity. The lipid components of rice are important factors influencing storageability of rice. Some processors have low specifications for fat content as a precaution against the development of rancidity, and for the high viscosity effect it has in certain fermenting applications.

In India, during festivals like Ganesh Chaturthi, Varalakshmi Puja etc., it is a tradition to offer Idli as an offering to the gods. On this occasion the Idli is prepared with raw rice. This Idli is slightly hard as compared to Idli's that are prepared using parboiled rice.
To make the Idlis softer more urad dal (split black gram) is added. Some households also add extra fenugreek seeds as well.

The amylose content in rice is considered the single most important characteristic used in describing and predicting rice cooking and processing qualities, and numerous reports point out this relation. (Engineers, 2006)

PARBOILED RICE OR IDLI RICE

For more than 2.000 years, rice producers in India have parboiled non-aromatic varieties before they remove the hull and mill them to white rice. They steep the freshly harvested grain in water, boil or steam it, and then dry it again before hulling and milling. This precooking brings about several advantages. It improves the nutritional quality of the milled grain by causing vitamins on the bran and germ to diffuse into the endosperm and causing the aleurone layer to adhere to the grain. Pre-cooking the starch also hardens the grain and makes its surface less sticky, so when cooked again, parboiled rice produces separate firm intact grains. Parboiled rice also has a distinctive nutty flavour; the soaking activates enzymes that generate **sugars** and **amino acids** that then participate in browning reactions during drying; and partial breakdown of lignin in the attached hull provides vanillin and related compounds. Parboiled rice takes longer to cook than ordinary white rice, a third to half again the time and its texture is so firm that it can seem course. (McGee, revised 2004, pp. 473-475)
Parboiled rice can be expected to contain around 0.7 to 1.1% total sugars, and about 0.16% reducing sugars. Parboiled rice is usually graded from "parboiled light" to "parboiled dark", depending upon the degree of coloration resulting from the parboiling treatment. The trend in commercial processing is toward "parboiled light", which is accomplished through various parboiling techniques and bleaching processes. (Engineers, 2006)

Component	***Brawn***	***Milled Raw***	***Milled Parboiled***
Moisture (%)	12.0	12.0	10.3
Calories/ 100g	360	363	369
Protein (%)	7.5	6.7	7.4
Fat (%)	1.9	0.4	0.3
N-Free Extract	77.4	80.4	81.3
Fiber (%)	0.9	0.3	0.2
Ash (%)	1.2	0.5	0.7
Thiamine, mg. (%)	0.34	0.07	0.44
Riboflavin, mg. (%)	0.05	0.03	-
Niacin mg./100gm	4.7	1.6	3.5

Table3.3 Nutritional Statistics for Brawn, Raw and Parboiled Rice Varieties
Extracted from: Wheat, Rice, Corn, Oat, Barley and Sorghum Processing Handbook (Cereal Food Technology) by NIIR Board of Consultants & Engineers ***ISBN****: 8178330024*

BROWN RICE

Brown rice is unmilled. Its bran, germ and aleurone layers intact. Any kind of rice whether long grained, short grained or aromatic may be sold in its brown form. It takes two to three times longer to cook than the milled version of the same variety, and has a chewy texture and a rich aroma, often described as nutty. Thanks to the oil in its bran and germ it is more susceptible to staling than polished rice.

Amylose content was highest (27.71%) in white rice (local, medium grain type) with lowest recorded for brown rice variety (3.36%) as seen in a study on Physiochemical properties of rice varieties (Thomas, Nadiah, & Bhat, 2012). In this study, white rice variety required minimum cooking time of 10 minutes whereas brown rice took longest 'minimal cooking time' of 31.67 min. Differences in the observed amylose content between different rice varieties can also affect the cooking properties (Singh, Kaur, Singh, & Sekhon, 2005). This could be due to the fact that the fibrous bran layer might have not yet been removed, and hence it requires longer time for the starchy endosperm to cook. (Juliano & Bechtel, 1985).

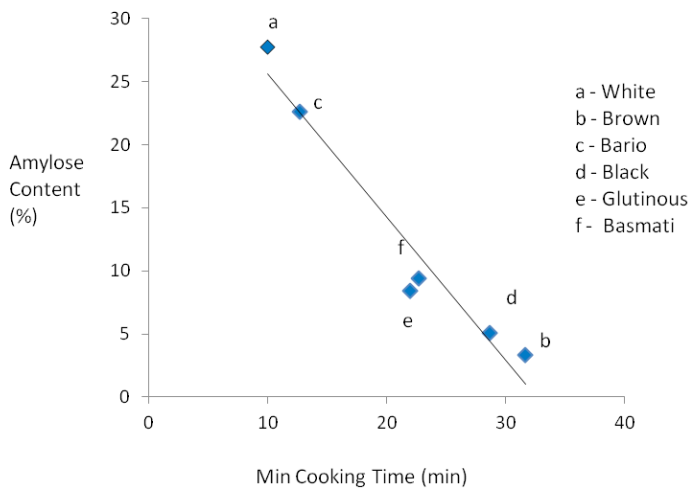


Table 3.4 Relationship between amylose content and cooking time of various rice varieties (Thomas, Nadiah, & Bhat, 2012)

FACTOR	Wheat	Maize	Brown Rice
Available CHO (%)	69.7	63.6	64.3
Energy (kJ/100 g)	1570	1660	1610
Digestible energy (%)	86.4	87.2	96.3
Vitamins (mg/100 g)			
Thiamine	0.45	0.32	0.29
Riboflavin	0.10	0.10	0.04
Niacin	3.7	1.9	4.0
Amino acids (g/16 g N)			
Lysine	2.3	2.5	3.8
Threonine	2.8	3.2	3.6
Met. & Cys.	3.6	3.9	3.9
Tryptophan	1.0	0.6	1.1
Protein quality (%)			
True digestibility	96.0	95.0	99.7
Biological value	55.0	61.0	74.0
Net protein utilization	53.0	58.0	73.8
Utilization protein	5.6	5.7	5.4

Table 3.5: Comparative nutritive value of cereal grains (FAO, NUTRITIONAL QUALITY OF CEREALS)

BLACK GRAM

Vigna mungo, known as black gram or black lentil is a bean grown in Indian subcontinent. The product sold as "black lentil" is usually the whole *urad* bean or *urad dal.* Black gram originated in India, where it has been in cultivation from ancient times and is one of the most highly prized pulses of India and Pakistan. The coastal region in Andhra Pradesh is famous for black gram after paddy.

Black gram is seen as a high protein source in Idli making. The springiness of the Idli depends on the quantity of the dal used because the soft spongy texture observed in the leavened steamed Idli made out of black gram is due to the presence of two components, namely surface active protein (globulin) and a polysaccharide (arabinogalactan) in black gram (Susheelamma & Rao, 1974).The specialty of black gram in Idli preparation is due to the mucilaginous property which helps in the retention of carbon-dioxide evolved during fermentation (Durgadevi & Shetty, 2012)

Black gram, the leguminous component of Idli batter, serves not only as an effective substrate but also provides the maximum number of micro-organisms for fermentation.

Table 3.6 Black Gram Varieties used in Idli Making
L. mesenteroides, S. fecalis, T. candida and T. pullulans are the micro-organisms present in fermented Black Gram that result in a mildly acidic batter.
(FAO, CEREAL FERMENTATIONS IN COUNTRIES OF THE ASIA-PACIFIC REGION)

Decorticated whole Urad is preferred during Idli making. Unfortunately decortication involves introducing moisture to remove the skin. The pulse is split mechanically that generates heat and destroys much of the wild yeast. To compensate for the lost wild yeast, fenugreek is added to compensate a preliminary during the fermentation process

	Energy Kcals	*Moisture (g)*	*Protein (g)*	*Fat (g)*	*Mineral (g)*	*Carbohydrates (g)*	*Fibre (g)*	*Calcium (mg)*	*Phosphorus (mg)*	*Iron (mg)*
Black gram, dal	347	11	24	1	3	1	1	154	385	4

Table 3.7 Nutritive Value of Black Gram (100gms)
(Post-Harvest Technology:: Agriculture :: Pulses, 2013)

	Riboflavin		**Total B6**	
Dals	**mg per 100 g**	**Cooking loss (%)**	**mg per 100 g**	**Cooking loss (%)**
Chick-pea	0.23	35.0	0.38	15.2
Pigeon-pea	0.25	17.8	0.32	13.2
Green gram	0.24	14.8	0.31	12.9
Black gram	***0.25***	***13.2***	***0.24***	***12.8***

Table 3.8: Cooking Losses of Riboflavin and Total B6 Content of Dals (Deosthale, 1984)

OTHER INGREDIENTS

WATER

Water plays an important role in the grinding and fermentation process of Idli making. It also contributes to the final consistency and also is the solvent or medium for substances like sugar and enzymes that are indispensable for fermentation. Water is also needed for swelling and gelatinization of the starch. The distribution of the heat through the Idli during steaming is done by water in the batter. Thus water influences the organoleptic properties of the final product.

Water helps the wild yeast convert sugars into carbon dioxide and alcohol in anaerobic conditions and to water and carbon dioxide when oxygen is available. When dry, yeast becomes dormant and they revive when water and food such as sugar and minerals are available at suitable temperatures. Fermentation involves many enzymes which are large protein molecules for catalyzing specific reactions. These reactions will not take place if there is no water available. (Class of Foods, 2012) Chlorinated water can destroy the wild yeast and bacteria and thus inhibits fermentation.

YEASTS, BACTERIA AND OTHER MICROORGANISMS

Yeasts metabolize sugars for energy and produce carbon dioxide gas and alcohol as byproducts of that metabolism**.** (McGee, revised 2004, p. 532) The fermentation of Idli batter is mixed auto fermentation. The micro-organisms present on the ingredients and those from the air bring about the fermentation. A number of wild yeasts together with different types of bacteria are implicated in fermentation; the bacteria recognized in Idli fermentation are *lactobacillus delbrueckii, L. lactis, Strptociccus lactis, S. faecalis, Leuconostoc mesenteroides* and *Pedicococcus cerevisiae.*

Fermentation is mediated and influenced by both, the fermenting components, black-gram and rice. Though its auto-fermenting power is poor, rice contributes microorganisms and also acts as a substrate. Black gram plays a major role in fermentation both as a good source of microorganisms and also as a vigorous fermenting substrate.

Microorganisms developed during the pre-soaking of black gram have a high auto-fermenting ability and also more potentialities to act on rice. Acid and gas production during fermentation is mostly due to the bacteria. A temperature of 25°-30° C is favourable to the microorganisms for fermentation. Temperature up to 40°C accelerates the rate but some undesirable smell develops at a high temperature. The optimal conditions for good microbial activity is 30°C for 16 hours (Manay, 2001)

SALT

Salt is a commonly occurring mineral, the chemical name of which is sodium chloride. By slowing down the yeast action, it allows the fermentation to be controlled and retards bacteria growth. Salt has a retarding effect on the activity of the yeast. The cell wall of yeast is semipermeable, and by osmosis it absorbs oxygen and nutrients, as it gives off enzymes and other substances into the batter. Salt by its nature is hygroscopic, that is, it attracts moisture.

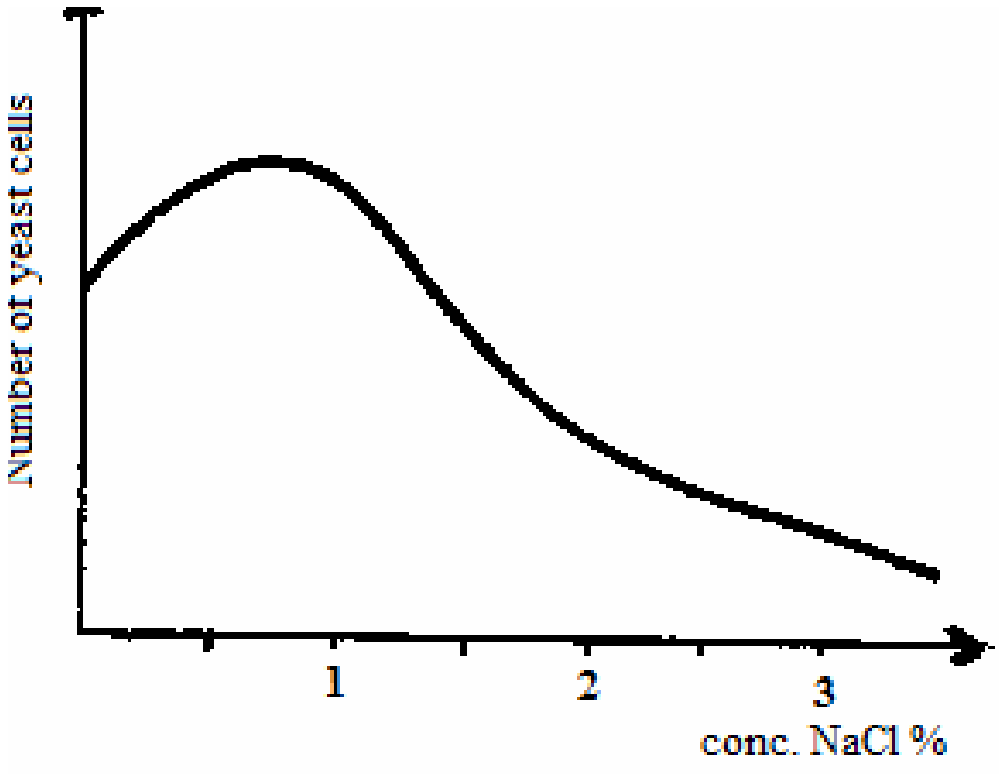


Table 3.9 Influence of Salt on Yeast Propagation
(LUCHIAN & CANJA, 2010)

Lactic acid bacteria tolerate high salt concentrations. The salt tolerance gives them an advantage over other less tolerant species and allows the lactic acid fermenters to begin metabolism, which produces acid, which further inhibits the growth of non-desirable organisms. *Leuconostoc* is noted for its high salt tolerance and for this reason, initiates the majority of lactic acid fermentations. (Battcock & Azam-Ali, 1998)

TEMPERATURE

The best ambient temperature for incubation is 29º C to 32º C. If the temperature is below 29º C, it will take longer to achieve acceptable level of fermentation. If the temperature is higher than 32º C, the batter may become sour. Acceptable level of fermentation is when the batter has reached 250% in volume (Two and a half times the original volume).

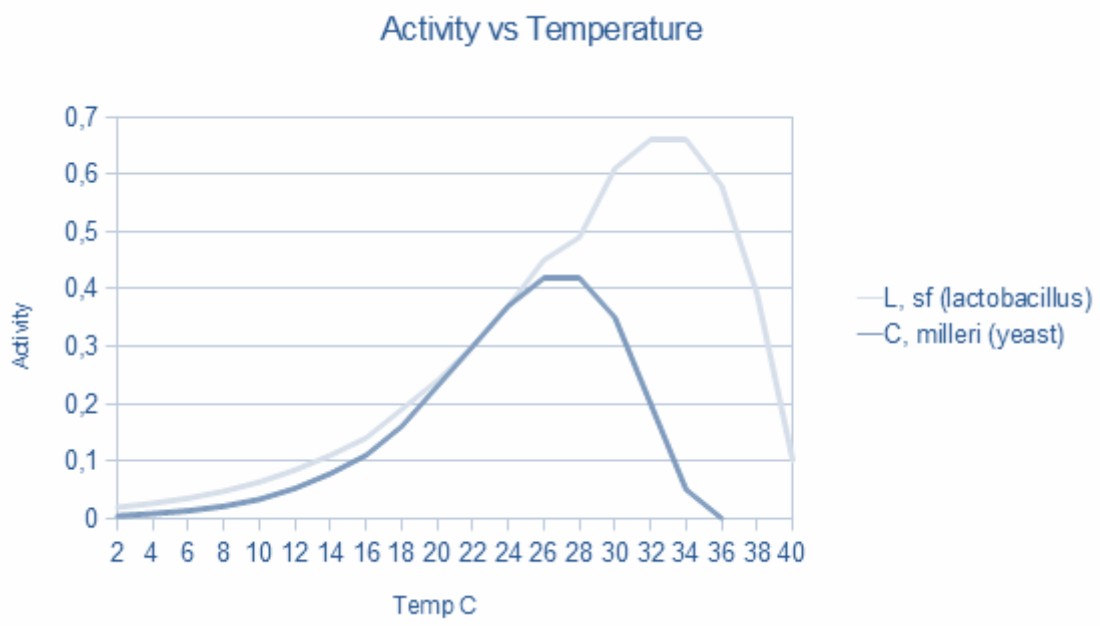


Table 3.10 Yeast & Bacterial Activity in Response to Changing Temperature

FENUGREEK SEEDS

Trigonella foenum-graecum is an annual plant in the family Fabaceae with leaves consisting of three small obovate to oblong leaflets. It is cultivated worldwide as a semi-arid crop, and its seeds are a common ingredient in dishes from the Indian subcontinent.

Fenugreek seeds draw the same type of wild yeast as the Black Gram. In the traditional method, the seeds are put in the Rice pan so that both the pans (Black Gram, as well as the Rice) will draw wild yeast.

In a study in 2008 at the California State Science Fair, fenugreek was seen to have improved not only the flavour but also the texture. Most importantly, it changes the microbial population distribution by favouring growth of *L. mesenteroides* and *Lactococcus* lactis. The heterofermentative *Leuconostoc* are likely responsible for the rise of the batter and its aroma, while the homofermentative *Lactococcus* provide flavour. Fenugreek was able to alter flavour by stimulating the growth of *Lactococcus* while its ability to promote smoother texture arose from its stimulation of *L.mesenteroides*, a producer of dextran. (Guhan, 2008)

CHAPTER 4
METHODOLOGY

FERMENTATION AND COOKING PROCESS

IDLI PREPARATION AND FERMENTATION

In this study four base recipes were used based on proportion of rice and black gram (3:1, 2:1) and the addition or exclusion of fenugreek. A total of **24 Samples** were obtained combining with three rice varieties and two black gram varieties with the selected proportions and the usage of fenugreek. The Rice and Gram were soaked at ambient temperature of 26°C and Humidity 82% (28th February 2014) and was fermented at an ambient temperature of 24°-29°C, humidity 82%- 65% (1st March 2014) (World Weather Online).

Sample Number	Type of Rice	Type of Gram	Proportion	Fenugreek
1	BROWN	SPLIT URAD	02:01	No
2	BROWN	SPLIT URAD	02:01	Yes
3	BROWN	SPLIT URAD	03:01	No
4	BROWN	SPLIT URAD	03:01	Yes
5	BROWN	WHOLE URAD	02:01	No
6	BROWN	WHOLE URAD	02:01	Yes
7	BROWN	WHOLE URAD	03:01	No
8	BROWN	WHOLE URAD	03:01	Yes
9	WHITE RICE	SPLIT URAD	02:01	No
10	WHITE RICE	SPLIT URAD	02:01	Yes
11	WHITE RICE	SPLIT URAD	03:01	No
12	WHITE RICE	SPLIT URAD	03:01	Yes
13	WHITE RICE	WHOLE URAD	02:01	No
14	WHITE RICE	WHOLE URAD	02:01	Yes
15	WHITE RICE	WHOLE URAD	03:01	No
16	WHITE RICE	WHOLE URAD	03:01	Yes
17	PARBOILED RICE	SPLIT URAD	02:01	No
18	PARBOILED RICE	SPLIT URAD	02:01	Yes
19	PARBOILED RICE	SPLIT URAD	03:01	No
20	PARBOILED RICE	SPLIT URAD	03:01	Yes
21	PARBOILED RICE	WHOLE URAD	02:01	No
22	PARBOILED RICE	WHOLE URAD	02:01	Yes
23	PARBOILED RICE	WHOLE URAD	03:01	No
24	PARBOILED RICE	WHOLE URAD	03:01	Yes

Table 4.1: Sample Specifications

Ingredient	***Quantity***
Black Gram	75 gm
Rice	150 gm
Fenugreek Seeds	--
Salt	5 gm
Water (Rice)	150 ml
Water (Black gram)	300 ml
Proportion 2:1	No Fenugreek Seeds
RECIPE 'A'	

Ingredient	***Quantity***
Black Gram	75 gm
Rice	150 gm
Fenugreek Seeds	5 gm
Salt	5 gm
Water (Rice)	150 ml
Water (Black gram)	300 ml
Proportion 2:1	With Fenugreek Seeds
RECIPE 'C'	

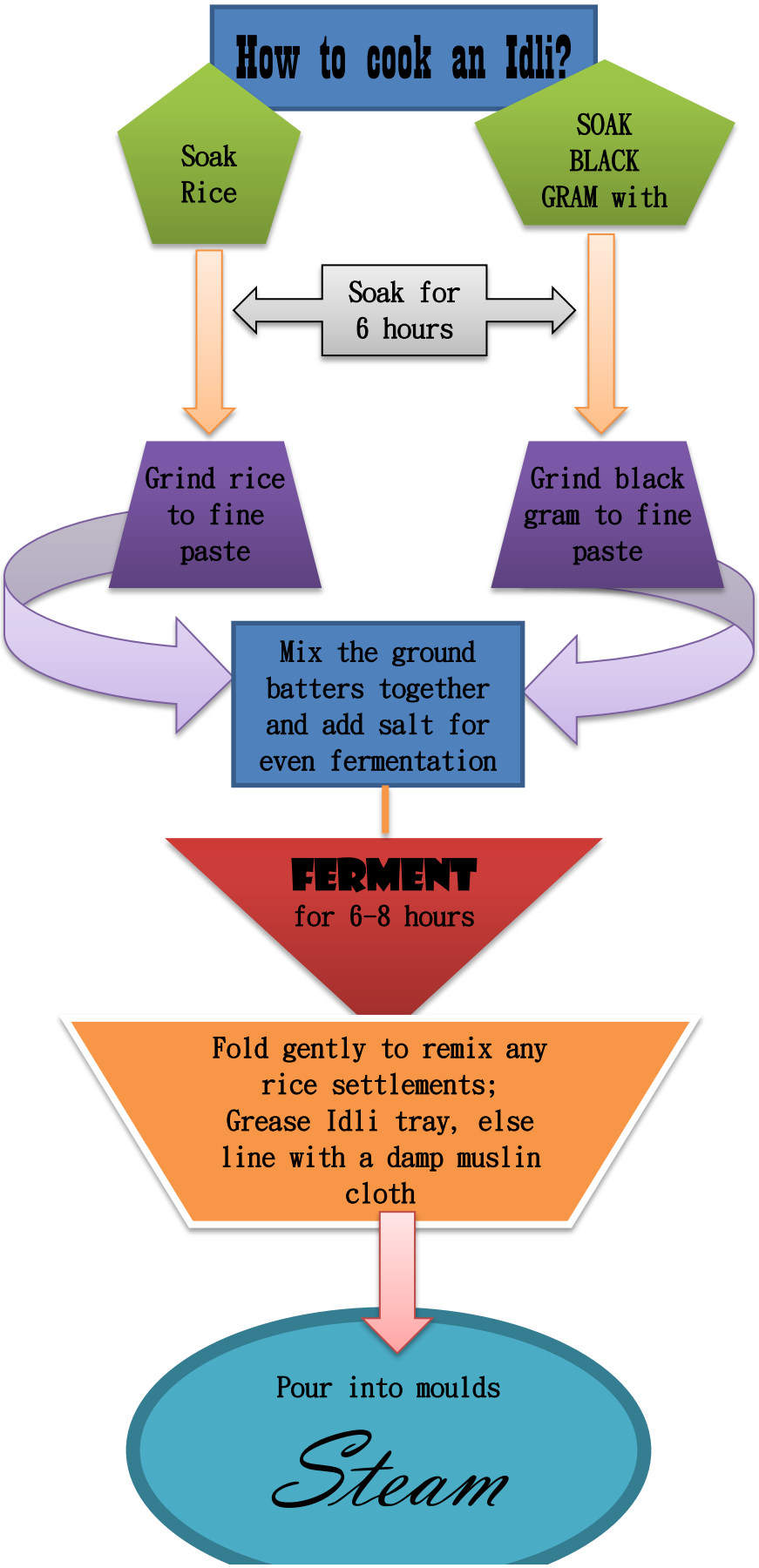
Ingredient	***Quantity***
Black Gram	75 gm
Rice	225 gm
Fenugreek	--
Salt	5 gm
Water (Rice)	150 ml
Water (Black gram)	450 ml
Proportion 3:1	No Fenugreek Seeds
RECIPE 'B'	

Ingredient	***Quantity***
Black Gram	75 gm
Rice	225 gm
Fenugreek	5 gm
Salt	5 gm
Water (Rice)	150 ml
Water (Black gram)	450 ml
Proportion 3:1	With Fenugreek Seeds
RECIPE 'D'	

Method:

1. Weigh the rice and black gram separately.
2. Wash and soak for 6-8 hours. (If fenugreek is used, soak the Fenugreek Seeds with the Black Gram)
3. Grind separately into a fine paste.
4. Mix the pastes together with salt.
5. Allow to ferment for 8 hours
6. Grease Idli trays or line with muslin
7. Gently fold the fermented batter and scoop onto the trays
8. Steam
    a. White Rice: 8 minutes
    b. Parboiled Rice: 6 Minutes
    c. Brown Rice: 25 minutes

Table 4.2: Recipes and Method



Illustrative Procedure for Fermentation and Preparation of Idli Making

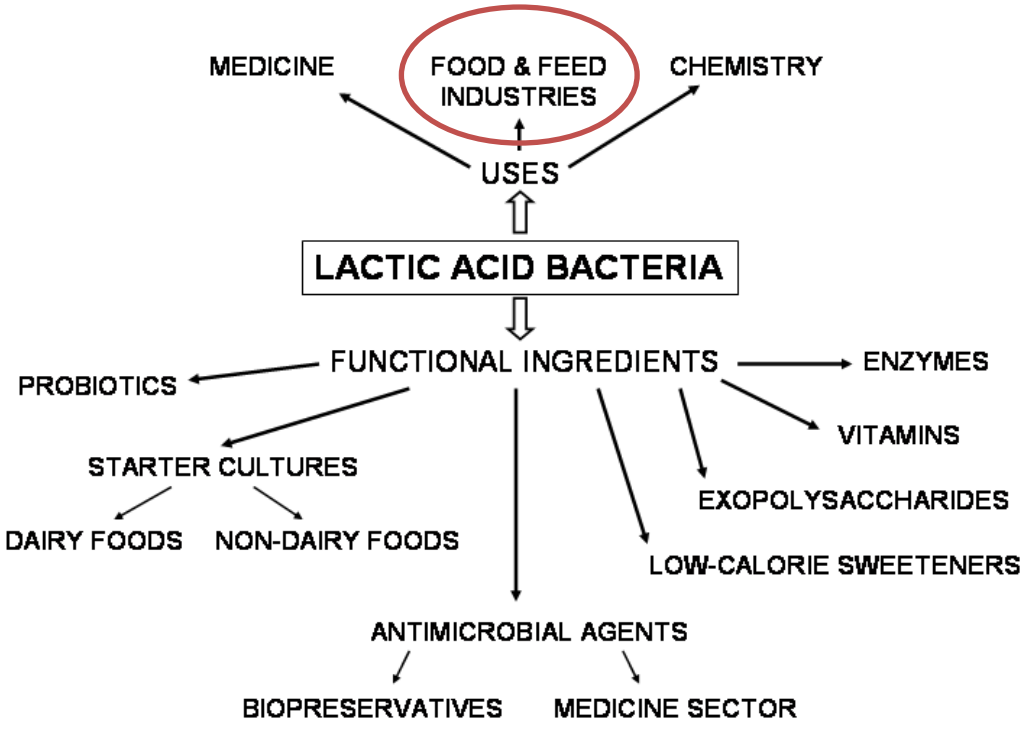
$_{p}$H AND LACTIC ACID BACTERIA

In chemistry, $_{p}$H is a measure of the acidity or basicity of an aqueous solution. Solutions with a pH less than 7 are said to be acidic and solutions with a pH greater than 7 are basic or alkaline. Pure water has a pH of 7.

Sourness is the taste that detects acidity. The sourness of substances is rated relative to dilute hydrochloric acid, which has a sourness index of 1. By comparison, tartaric acid has a sourness index of 0.7, citric acid an index of 0.46, and carbonic acid an index of 0.06. Sour taste is detected by a small subset of cells that are distributed across all taste buds in the tongue. Sour taste cells can be identified by expression of the protein PKD2L1, although this gene is not required for sour responses. There is evidence that the protons that are abundant in sour substances can directly enter the sour taste cells. This transfer of positive charge into the cell can itself trigger an electrical response. It has also been proposed that weak acids such as acetic acid, which are not fully dissociated at physiological pH values, can penetrate taste cells and thereby elicit an electrical response

Acidic fermentation in the Idli batter is due to the major role played by Lactic Acid Bacteria (LAB) These bacteria produce lactic acid as the major metabolic end-product of carbohydrate fermentation. This trait has, throughout history, linked LAB with food fermentations, as acidification inhibits the growth of spoilage agents and hence the batter is protected against food poisoning and pathogenic organism due to acidity. Furthermore, lactic acid and other metabolic products contribute to the organoleptic and textural profile of a food item.

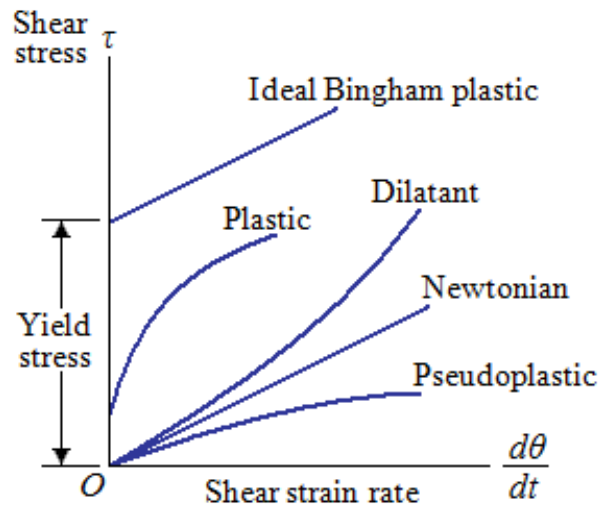
THE pH OF THE BATTER AFTER FERMENTATION TIME WAS RECORDED USING A DIGITAL pH METER AT THE DENTAL MATERIALS TESTING LABORATORY, MANIPAL UNIVERSITY.



VISCOSITY

By definition, viscosity is the "resistance to change of form" *(Handbook of Chemistry and Physics, 61st Edition*) or the "resistance to flow within a fluid" (*Fowler, C.M.R, 1990, The Solid Earth, Cambridge University Press, p. 462*). The viscosity of a substance is a property that determines how rapidly the substance will respond to shear stress; for liquids, this is most obviously reflected in how rapidly a liquid will flow down an inclined surface.

Four different terms are used to describe the ways in which liquids response to shear stress: Newtonian, Bingham, Plastic, and Pseudo-plastic (see figure to the right). **Newtonian** fluids respond instantaneously to shear stress and deform at a constant rate. **Bingham** fluids must experience a critical shear stress, called the yield strength, before they will start to flow; once the yield strength is reached their behaviour mimics Newtonian fluids. **Plastic** fluids develop infinite strain rates as soon as their yield strength is reached, while **Pseudo-plastic** fluids deform in a logarithmic fashion until their yield strength is reached. (Edwards)
Jeffery's equation was used to calculate viscosity of the Idli batter.



Jefferys Equation (1925) derived a formula to calculate the viscosity of a fluid based on its physical properties and flow characteristics. The formula is:

$$V = \frac{g\ h^2\ \rho \sin A}{3\ \mu}$$

where **V** is the mean velocity of the flow, **g** is the acceleration of gravity, **A** is the angle of the slope, **h** is the depth of the flowing liquid, **p** is the specific gravity of the liquid, and **n** is the coefficient of viscosity.

Geologists realized they could apply this equation to flowing lava to estimate its viscosity. Macdonald (1954) calculated the viscosity of lava during Mauna Loa eruptions he observed in 1940, 1942, 1949, and 1950. In the field he measured the angle of the slope, depth of the lava, and velocity of the flow. Angle of the slope can be measured from a compass or calculated from a topographic map. The depth of the lava channel is used as an approximation of the depth of the lava. Velocity is calculated by throwing a stick on the surface of a flow and measuring the amount of time it travels a premeasured distance. The acceleration of gravity and the specific gravity of the liquid are constants. The acceleration of gravity is 9.8 m/sec2.

AMYLOSE IN RICE GRAINS

Amylose is a spiral polymer made up of D-glucose units. This polysaccharide is one of the two components of starch, making up approximately 20-30% of the structure. The other component is amylopectin, which makes up 70-80% of the structure. Because of its tightly packed structure, amylose is more resistant to digestion than other starch molecules and is therefore an important form of resistant starch, which has been found to be an effective probiotic

1. Simplified Method on Amylose Content Determination of Single Rice Grain

Luo Yukun; Shen Yuezheng; Min Shaokai; Xiong Zhenmin

A simplified method on amylose content determination of single rice grain, without grinding and boiling, but directly gelatinized with cold alkali solution at 30℃, was presented. For the list, a single milled rice grain was put into a 20ml graduated tube; add 0.2 ml of 95% ethanol and 1 ml of 1.8M NaOH solution, kept in incubator for 24 hr. at 30℃. After the sample shaken with vibrator, it was made up to full volume with distilled water for colorimetric assay with Autoanalyzer. The amylose content was calculated based on dry weight of single rice grain. The result was closely agreed with that from the standard method. This method has the advantages such as smaller sample, simpler procedure and easier operation, and may be used for physiological and genetical studies of amylose content of rice grain and for the screening of breeding materials.

2. Estimation of Amylose Content in Rice Grains

The formation of a helical complex between amylose and iodine gives rise to the typical deep blue colour of starch dispersions stained with iodine and forms the basis for quantitative determination of amylose content. In I_2/KI solutions, polyiodide ions such as I^{3-} and/or I^{5-} interact with amylose forming single left-handed V-type helices. The formation of these complexes is determined by colorimetry.

Materials and Reagents

95% Ethanol	*100 ml volumetric flask*
1N NaOH	*Water bath*
1N Acetic acid	*Spectrophotometer*
Iodine - Potassium iodide solution	*Quartz cuvette*
Standard amylose	
Distilled water	

Composition of reaction mixtures

A. 1N NaOH solution
Dissolve 40g of NaOH in 1000ml distilled water

B. 1N Acetic acid solution
Dilute 57.5 ml glacial acetic acid to 1000ml using distilled water

C. Iodine - Potassium iodide solution
Dissolve 0.26 g of Iodine in 10 ml of Potassium iodide solution containing 2.6 g of KI

D. Standard Amylose Solution:

Take 40mg of pure potato starch (amylose) in a 100 ml volumetric flask and add 1 ml of 95% ethanol and 9.0 ml of 1N NaOH. Shake well and boil over water bath for 10 minutes and make up the solution to 100 ml using distilled water.

Procedure

1. Weigh 100 mg well powdered milled rice into 100 ml volumetric flask.
2. Add 1 ml 95% ethanol and 9 ml 1 N NaOH.
3. Heat the sample for 10 minutes in boiling water bath, cool it and make up the volume to 100 ml.
4. Pipette 5 ml from the 100 ml into another 100 ml volumetric flask.
5. Add 1 ml I N acetic acid and then 2 ml iodide solution and make up the volume to 100 ml.
6. Shake, stand for 20 minutes and determine the per cent Transmittance at 620 nm using a colorimeter.
7. Prepare a series of standard starch solution containing 0, 20, 40, 60, 80 and 100% amylose as in the steps 1 to 5
8. Read the transmittance of the standards at 620nm and plot a standard graph.
9. Amylose content of the sample is determined in reference to the standard curve and expressed on percent basis.
10. Making of amylose standards:

a. Pipette out 1, 2, 3, 4 and 5 ml of the standard amylose into 100 ml volumetric flasks in three replications.
b. Keep one flask as blank without adding anything.
c. Add 1.0 ml 1N acetic acid and 2.0 ml I-KI solution to all the flasks including blank.
d. Make up all the flasks to 100ml using distilled water and cover all the flasks with a black cloth or aluminium foil to prevent direct light exposure. I-KI disintegrates on exposure to light.
e. Keep for 20 minutes and take reading at 620nm in a spectrophotometer.

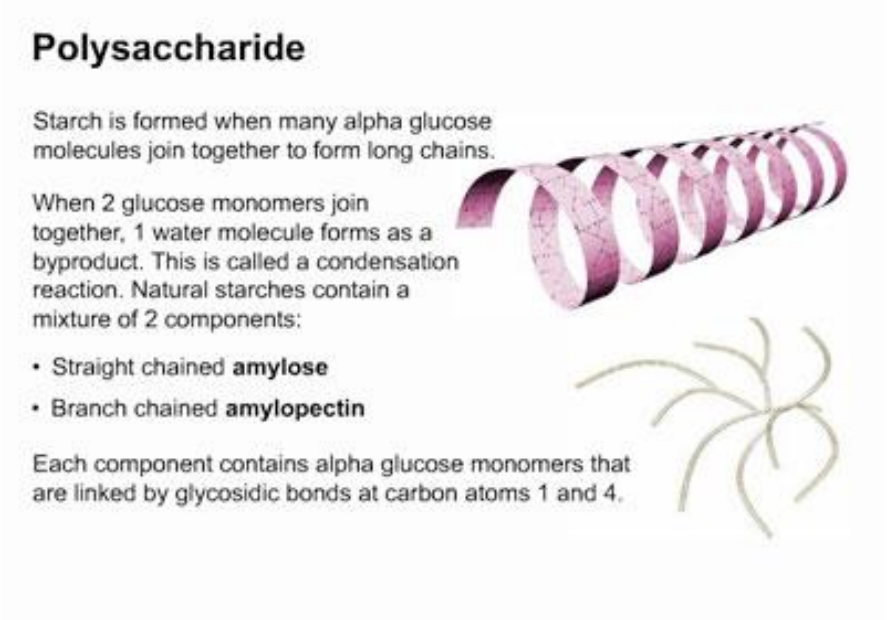
Spectrophotometry is the quantitative measurement of the reflection or transmission properties of a material as a function of wavelength

f. The standards including blank, correspond to 0%, 4%, 8%, 12%, 16% and 20% of amylose.
g. Draw a standard curve using the absorbance reading.

Based on the amylose percentage varieties can be grouped as follows

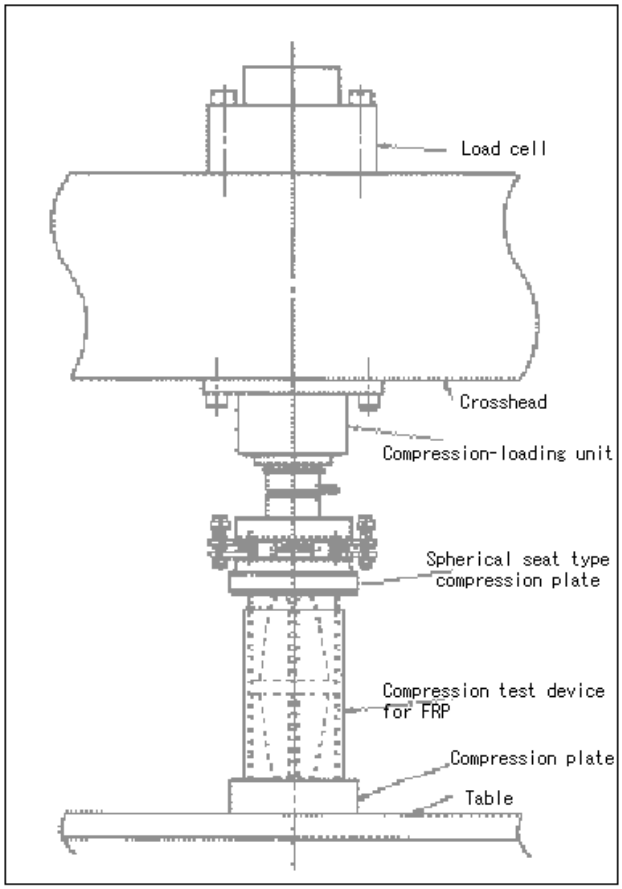
(Juliano, 1971)

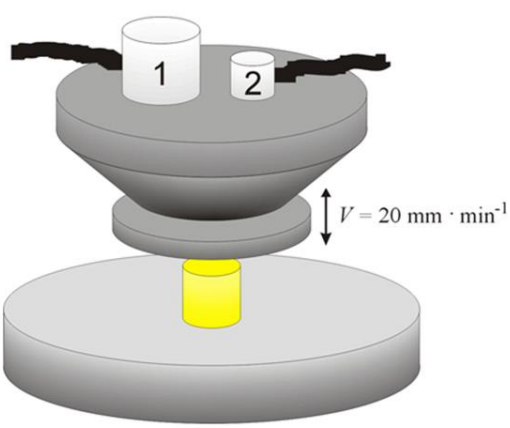
Category	Amylose Content (%)
Waxy	1-2
Very low amylose	2-9
Low	10-20
Intermediate	20-25
High	25-30

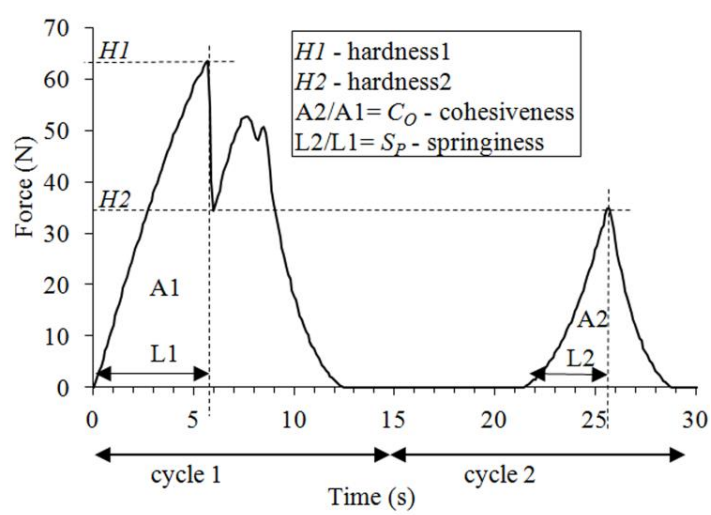


COMPRESSION TESTING

Food compression testing is one of the most common tests done on food products. Typically a sample is placed on a flat surface and an upper compression platen is lowered into the sample. For a true compression test, the compressed sample is never smaller in diameter than the two compression platens. Tests are performed by compression to a given force, a given position or a percentage of the original height of the sample. Compression testing can also be useful in measuring the adhesive or stickiness of the product. It is common in stickiness measurements to compress to a preset degree, hold the position for a given amount of time, and then pull back up quickly to accentuate the adhesive result. Compression platens come in many different sizes and are made from various materials such as stainless steel, aluminium and plastics. Selection of the proper variant depends upon the product and the test sample's geometry.

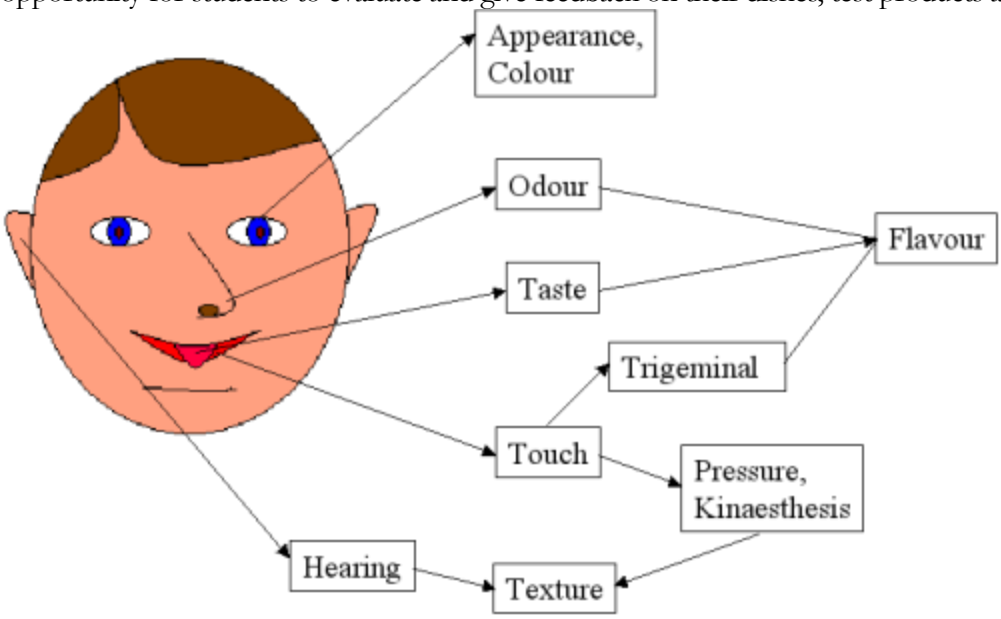






SENSORY EVALUATION

Sensory evaluation is a scientific discipline that analyses and measures human responses to the composition of food and drink, e.g. appearance, touch, odour, texture, temperature and taste. In schools it provides an ideal opportunity for students to evaluate and give feedback on their dishes, test products and experimental designs.



Descriptive Sensory Analysis

Descriptive analysis is concerned with trying to provide description of the sensory qualities of food. It is one of three basic types of sensory test

- Difference Tests make comparisons between foods
- Affective Tests evaluate liking for foods. These are sometimes called consumer tests
- Descriptive Tests describe the sensory attributes of a food

Difference Tests are usually quantitative, whereas descriptive and affective tests can be qualitative or quantitative and involve detection and description of both Qualitative and Quantitative sensory attributes

Qualitative aspects of foods include

- Aroma
- Flavour
- Texture
- Sound

Most of what we perceive (or describe as taste) is actually smell

E.g. "This ice cream tastes like strawberry and banana";

It actually smells like banana and possibly tastes sweet and sour

Difference test panels should be able to detect and describe sensory aspects of a product, differentiate and rate the intensity of each attribute and define the degree to which each attribute is present. This requires use of trained panels

Panel size may vary widely: 5 - 100 judges with small panels being sufficient for grocery products. For mass produced products such as beer, soft drinks, confectionery where small differences can be important, large panels are usually necessary.

Descriptive Profiles

Perceived sensory parameters which define the product are referred to variously as; attributes characteristics, character notes, descriptive terms, descriptors. The terms used should define the sensory profile, picture or thumbprint of the product.

The variables used in this project were—

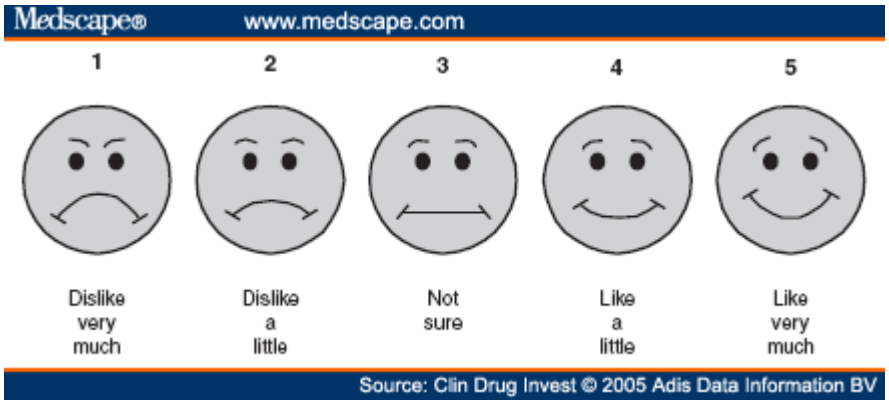
- Appearance
- Taste
- Texture
- Flavour
- Chewing Ability
- Colour

Quantitative aspects of descriptive analysis

The quantitative aspect or intensity expresses the degree to which a characteristic is present and is expressed by assigning a value on a **scale**. The validity and reliability of the analysis is dependent on the selection of scaling technique which should encompass full range of intensities but be sufficiently sensitive to pick up small differences

Likert scale: A Likert scale is a psychometric scale commonly involved in research that employs questionnaires. It is the most widely used approach to scaling responses in survey research. The scale is named after its inventor, psychologist Rensis Likert.

The 9-point Hedonic Scale: The most widely used scale for measuring food acceptability is the 9-point hedonic scale. David Peryam and colleagues developed the scale at the Quartermaster Food and Container Institute of the U.S. Armed Forces, for the purpose of measuring the food preferences of soldiers. The scale was quickly adopted by the food industry, and now is used not just for measuring the acceptability of foods and beverages, but also of personal care products, household products, and cosmetics.



Children age appropriate Hedonic Scale

For this study a seven point hedonic scale was used with the markers as

- Very Much Disliked
- Much Disliked
- Disliked
- Neutral
- Liked
- Much Liked
- Very Much Liked

Analysis of Data:

Qualitative tests are analysed with reference to standard descriptions. These are often based on standard samples having particular sensory attributes. It is important that the descriptors are agreed beforehand and the panellists have a shared view of the meaning of the descriptors. Hence the importance of trained panels for descriptive analysis

Quantitative data is usually analysed statistically. This can be as simple as calculating mean and standard deviation and presenting the results graphically, however, where comparisons are being made, it is necessary to use inferential statistics. A range of inferential tests are available. The choice of test depends on the nature of the data and hence on the sensory test being used. (Walker)

For this study the top five samples were taken based on their mean variable ranking and compared on the basis of their ingredients, proportions and sensory scores.

Date	Time	Activity	Experiment	Materials Required
28th Feb	1300 hrs.	Soak rice and Black Gram	Measure ingredients and water used to soak	Mixing bowls Labels
	1800 hrs	Grinding Rice & Black Gram Fermentation	Measure extra water added while grinding	Ground rice and Black Gram; mixing together w/ or w/o fenugreek; label and leave to ferment overnight
1st March	0900 hrs	Collect samples for Batter testing	1. Test Acidity 2. Test Viscosity	Sample plastic containers, Labels
	0930	Parboiled Rice Idli (8 samples x 4 trays) Flag and send one for testing Cut one Idli into 6 parts for sampling	1. Time taken to cook 2. Tensile strength at Dental Materials Lab 3. Penetrometer 4. Sensory evaluation (12 Subjects)	Label all samples, Stop Watch
	0950	White Rice Idli (8 samples x 4 trays)	1. Time Taken to Cook 2. Tensile 3. Penetrometer 4. Sensory evaluation (12 Subjects)	
	1010	Brown Rice Idli (8 samples x 4 trays)	1. Time Taken to Cook 2. Tensile strength 3. Penetrometer 4. Sensory evaluation (12 Subjects)	

PLAN OF WORK

CHAPTER 5
RESULTS & DISCUSSIONS

SENSORY EVALUATION, EXPERIMENTS AND RESULTS

From the 24 samples, the top 5 were assessed based on their mean score with respect to their characteristic variables (Taste, Texture, Flavour, Appearance, Colour, Chewing Ability)

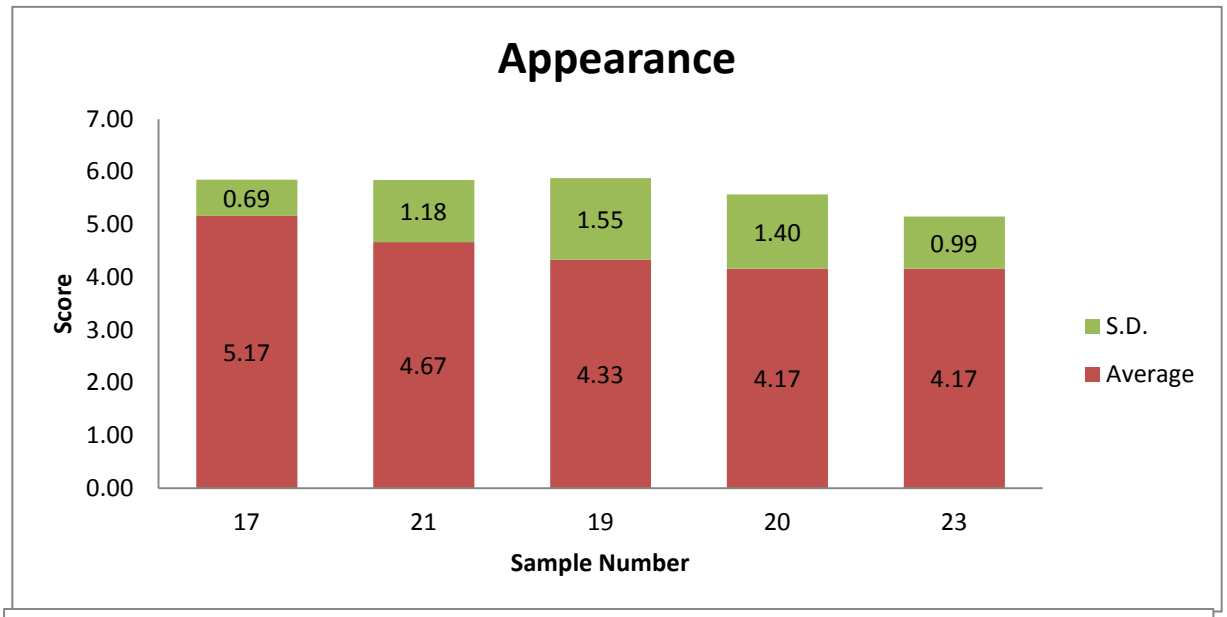
Variables	Rank	Appearance	Chewing Ability	Colour	Flavour	Taste	Texture
Top 5 ranking highest to lowest based on average scores	1st	Sample 17	Sample 17	Sample 17	Sample 17	Sample 17	Sample 17
	2nd	Sample 21	Sample 20	Sample 20	Sample 21	Sample 19	Sample 10
	3rd	Sample 19	Sample 10	Sample 10	Sample 19	Sample 20	Sample 20
	4th	Sample 20	Sample 23	Sample 23	Sample 20	Sample 21	Sample 23
	5th	Sample 23	Sample 22	Sample 22	Sample 23	Sample 10	Sample 19

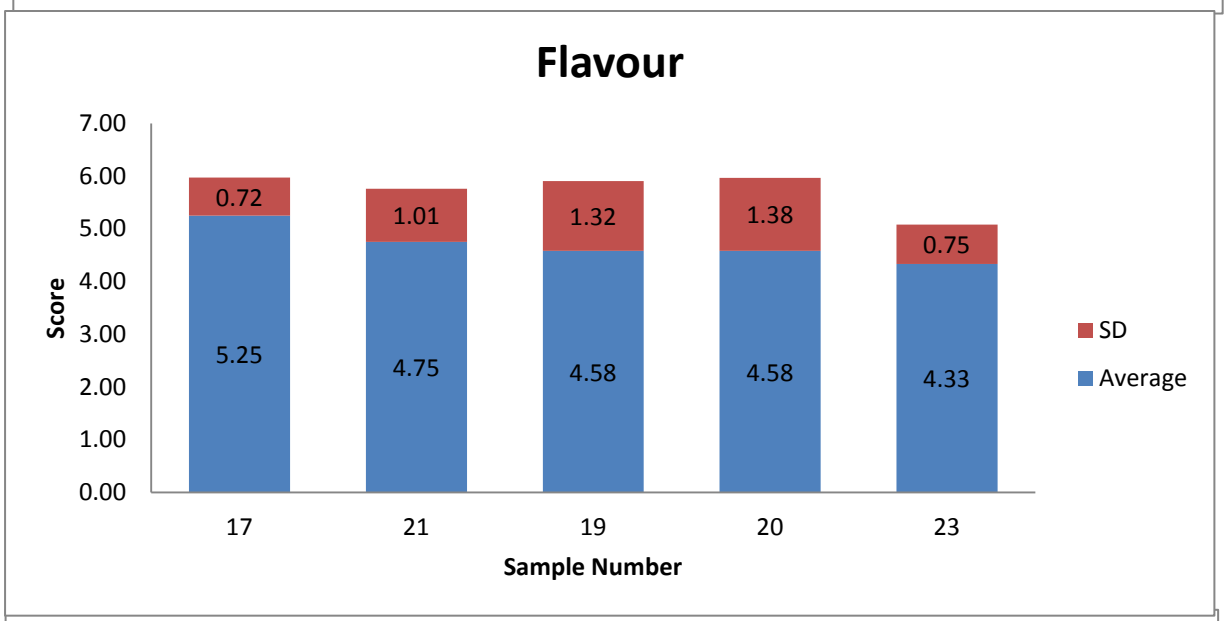
Table 5.1: Top Five Samples Ranking as per Attributes

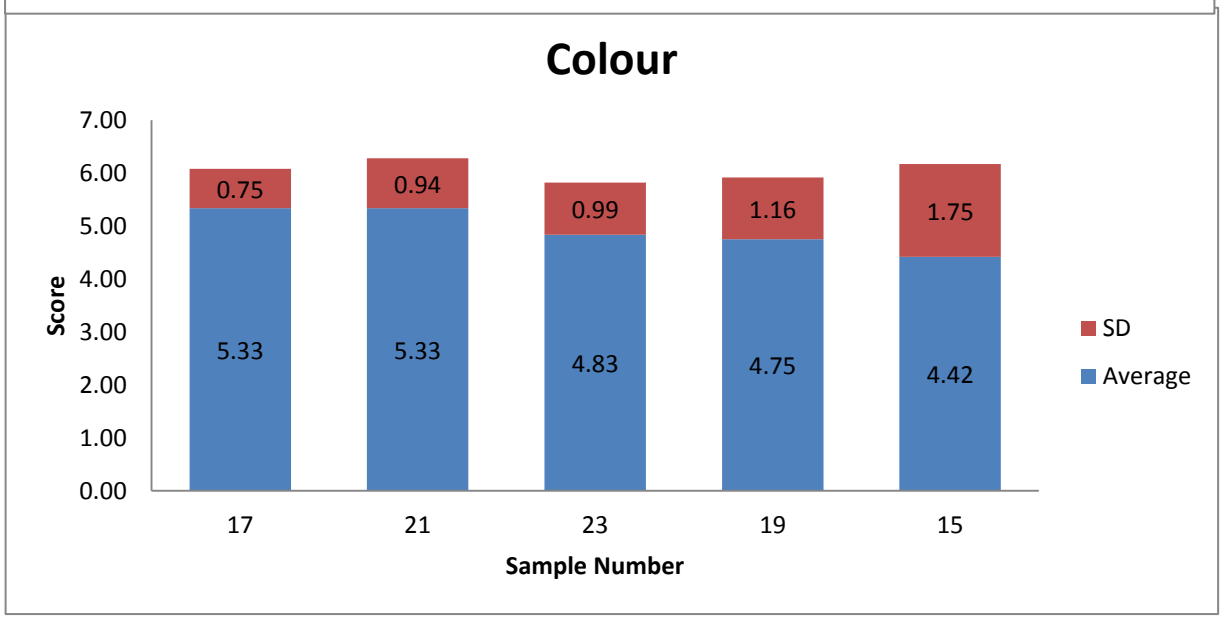
From the above table we can say that **sample 17** has been the most preferable sample, ranking first in all descriptive profiles.

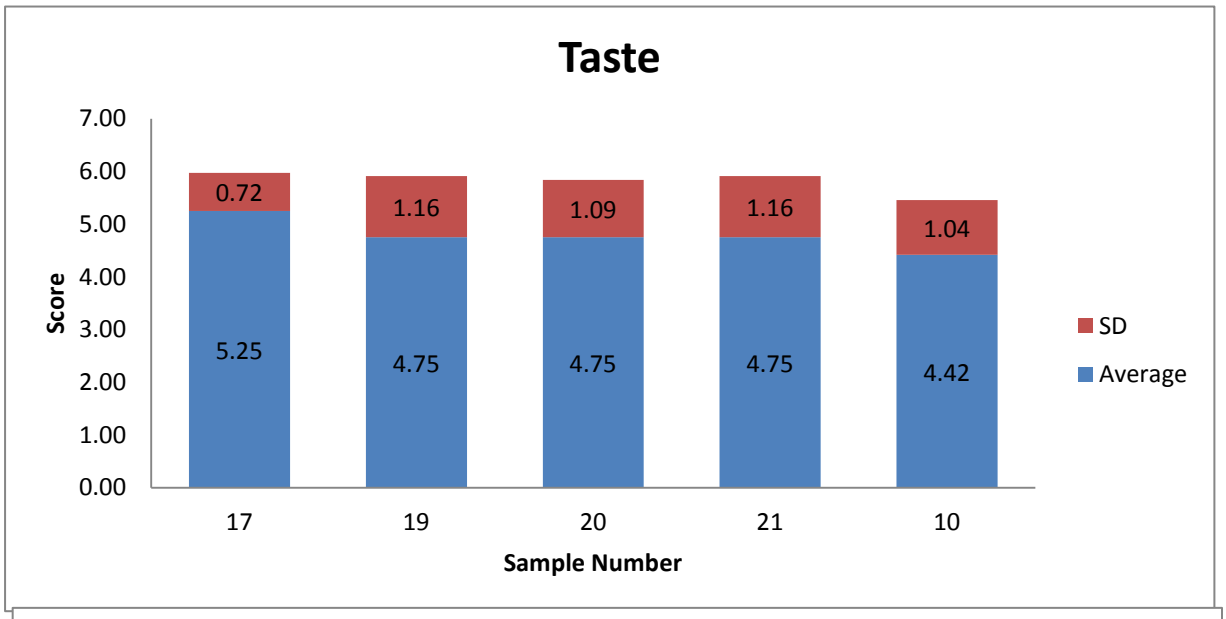
Sample Number	Type of Rice	Type of Dal	Proportion	Fenugreek	Viscosity (Poise)	pH
17	PARBOILED RICE	SPLIT URAD	02:01	No	1405.29	4.88
20	PARBOILED RICE	SPLIT URAD	03:01	Yes	404.25	4.49
21	PARBOILED RICE	WHOLE URAD	02:01	No	287.10	4.52
22	PARBOILED RICE	WHOLE URAD	02:01	Yes	448.83	4.49
23	PARBOILED RICE	WHOLE URAD	03:01	No	1392.41	4.52
19	PARBOILED RICE	SPLIT URAD	03:01	No	77.19	4.67
10	WHITE RICE	SPLIT URAD	02:01	Yes	280.12	4.57

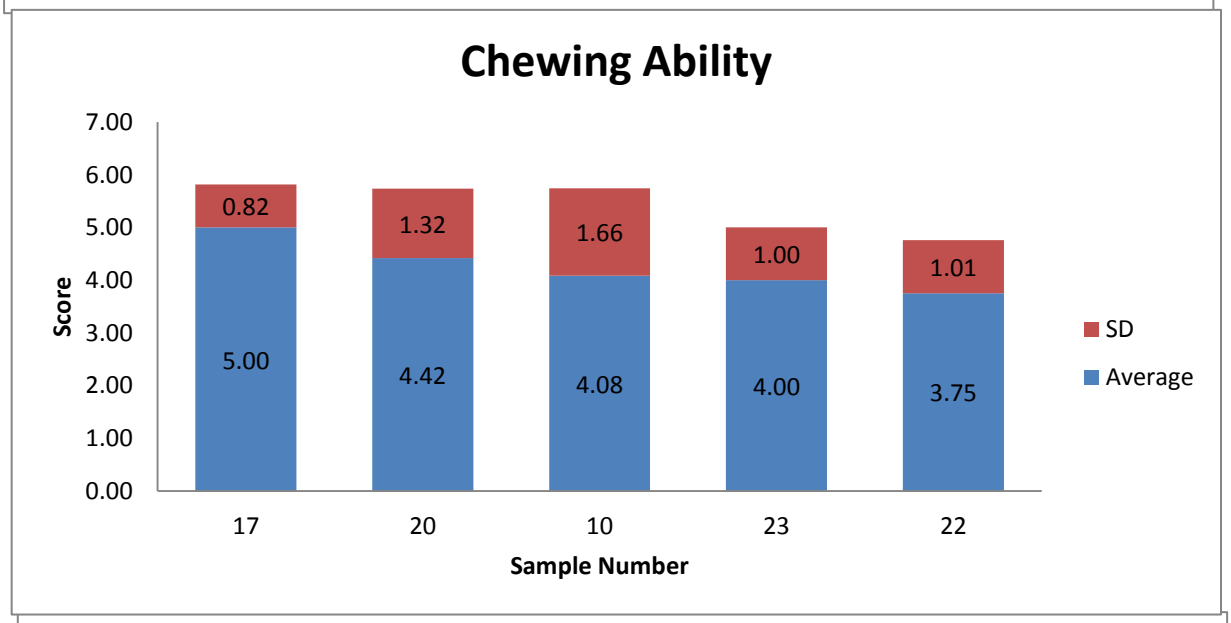
Table 5.2 Ingredients and Properties of Ranking Samples

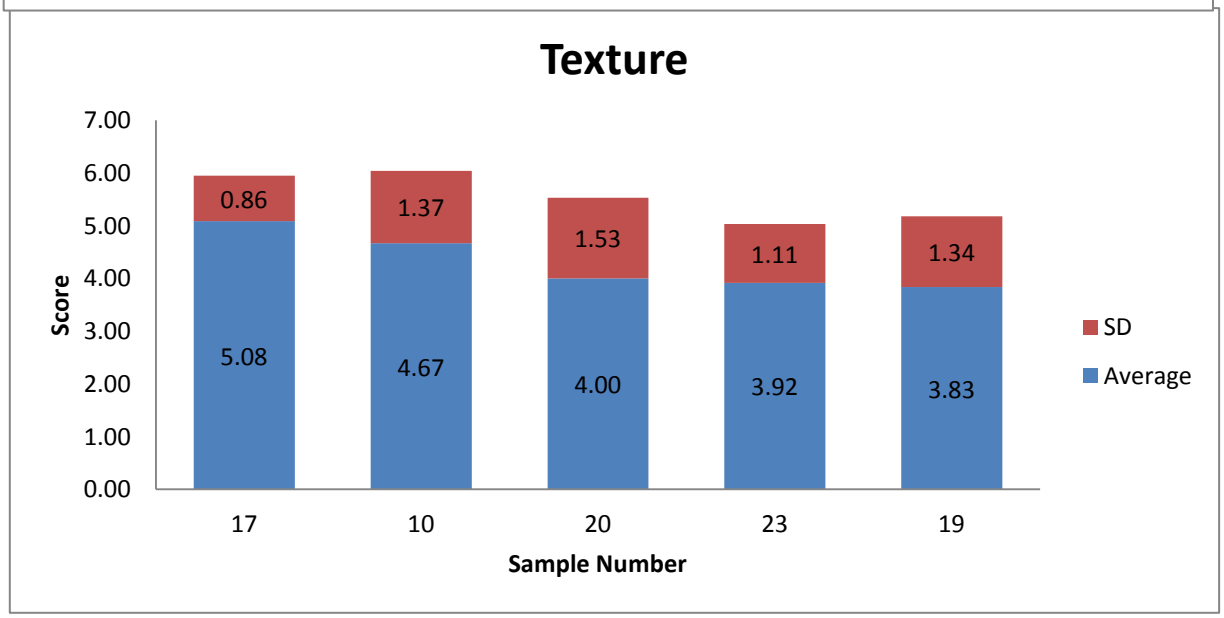

Appearance
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Score
0.69
1.18
1.55
1.40
0.99
5.17
4.67
4.33
4.17
4.17
17
21
19
20
23
Sample Number
S.D.
Average


Flavour
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Score
0.72
1.01
1.32
1.38
0.75
5.25
4.75
4.58
4.58
4.33
17
21
19
20
23
Sample Number
SD
Average

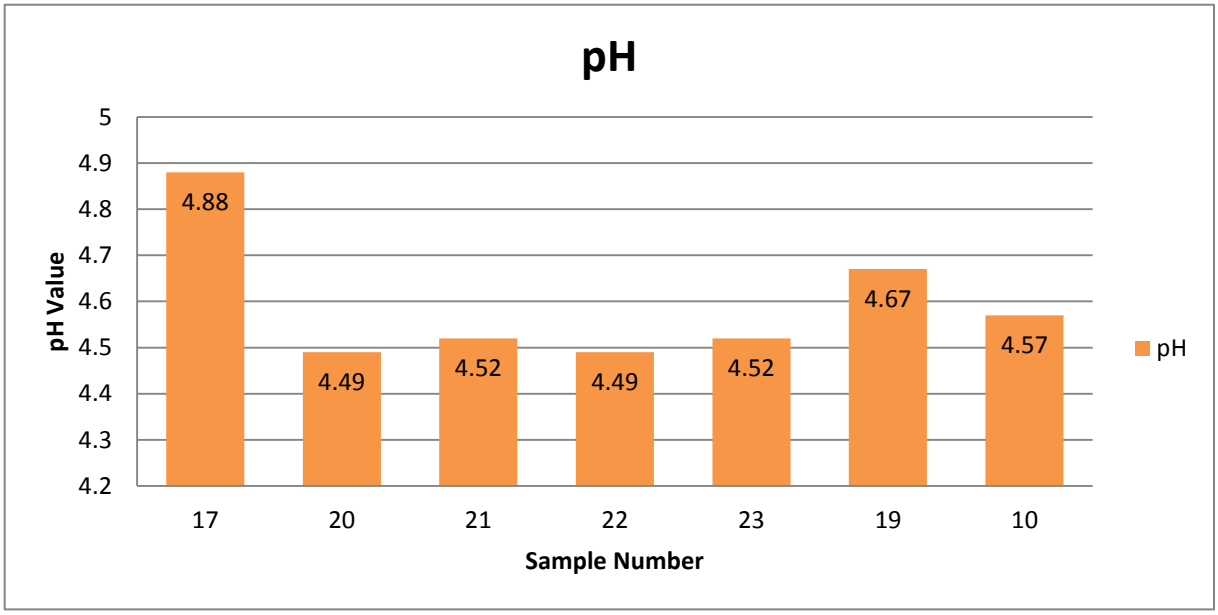

Colour
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Score
0.75
0.94
0.99
1.16
1.75
5.33
5.33
4.83
4.75
4.42
17
21
23
19
15
Sample Number
SD
Average


Taste
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Score
0.72
1.16
1.09
1.16
1.04
5.25
4.75
4.75
4.75
4.42
17
19
20
21
10
Sample Number
SD
Average

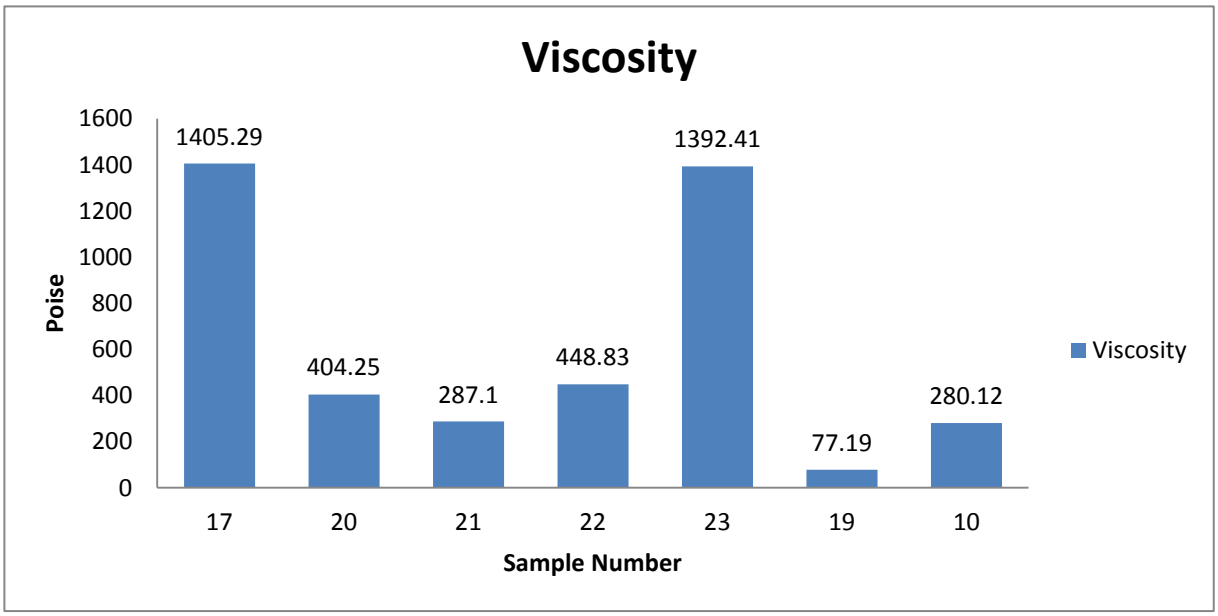

Chewing Ability
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Score
0.82
1.32
1.66
1.00
1.01
5.00
4.42
4.08
4.00
3.75
17
20
10
23
22
Sample Number
SD
Average


Texture
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Score
0.86
1.37
1.53
1.11
1.34
5.08
4.67
4.00
3.92
3.83
17
10
20
23
19
Sample Number
SD
Average

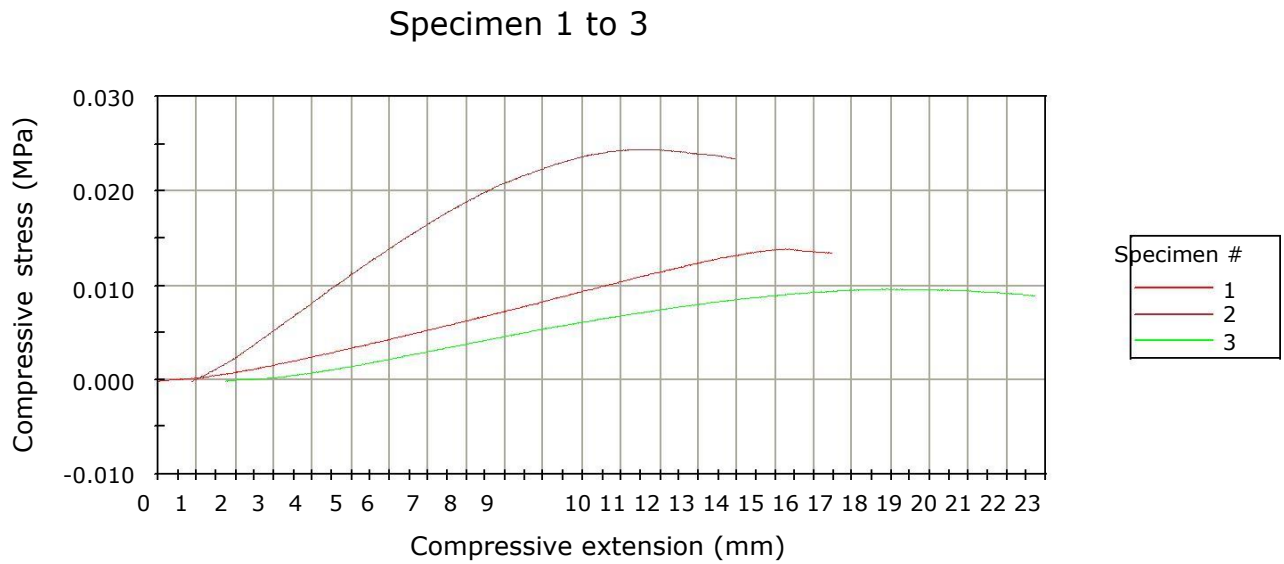
PH COMPARISON



VISCOSITY COMPARISON



COMPRESSION TESTING GRAPH

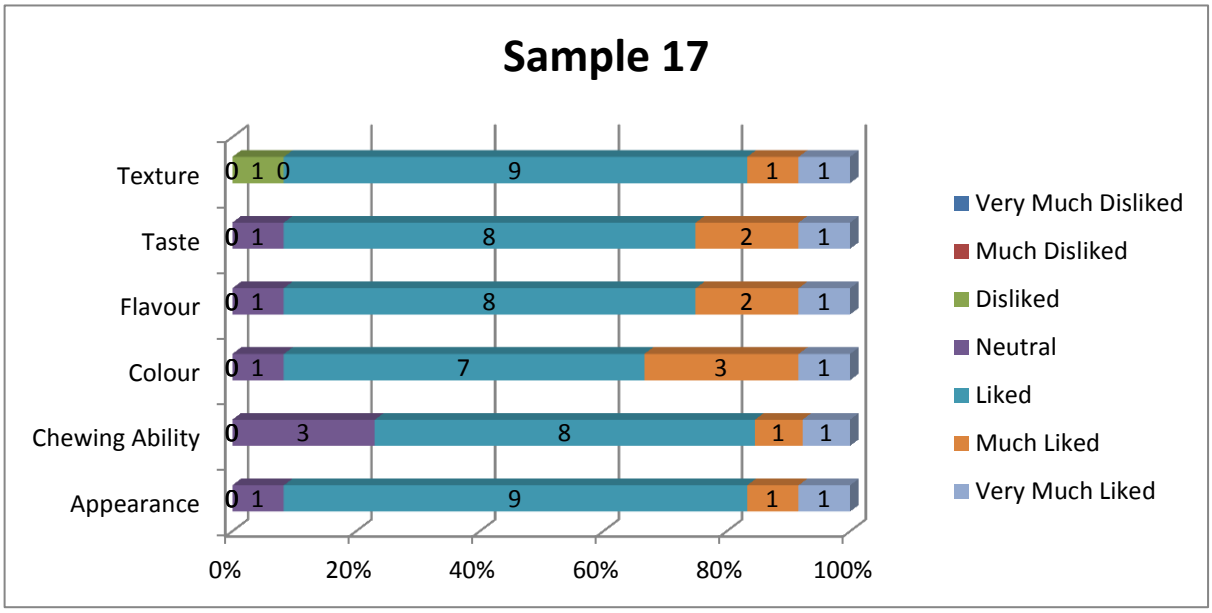


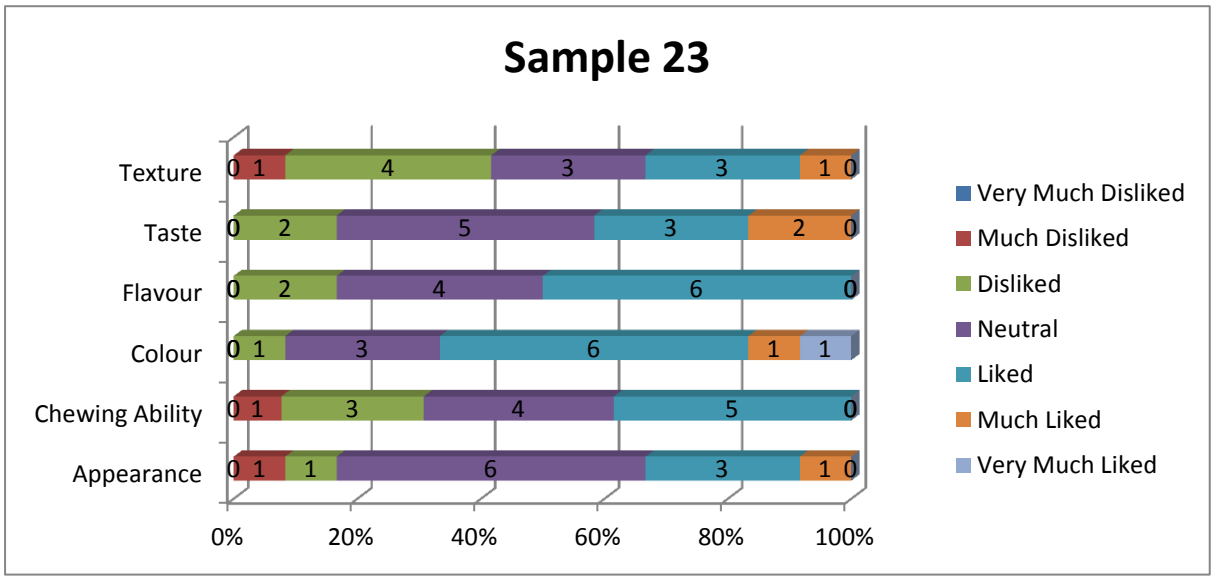
	Maximum Compressive load (N)	Compressive stress at Maximum Compressive load (MPa)	Compressive extension at Maximum Compressive load (mm)
1	27.97	0.01391	16.24170
2	44.91	0.02441	11.96676
3	22.42	0.00966	17.50831
Mean	31.77	0.01599	15.23892
Standard Deviation	11.71691	0.00759	2.90368

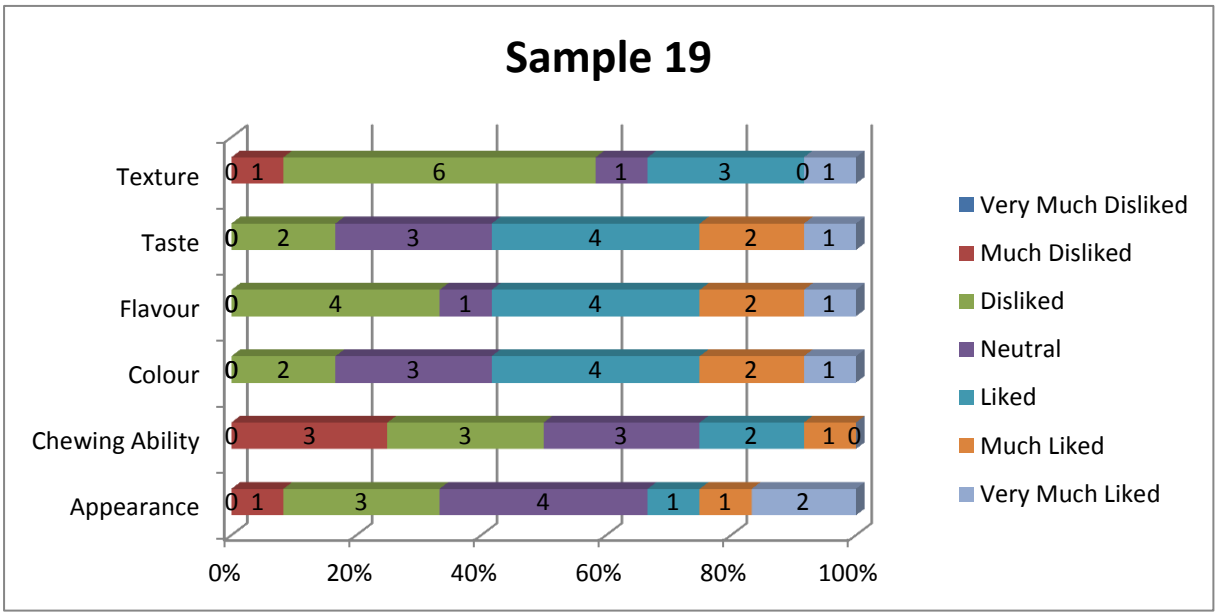
	Diameter (mm)	Anvil height (mm)
1	50.60000	40.20000
2	48.40000	43.50000
3	54.35000	51.88000
Mean	51.11667	45.19333
Standard Deviation	3.00846	6.02131

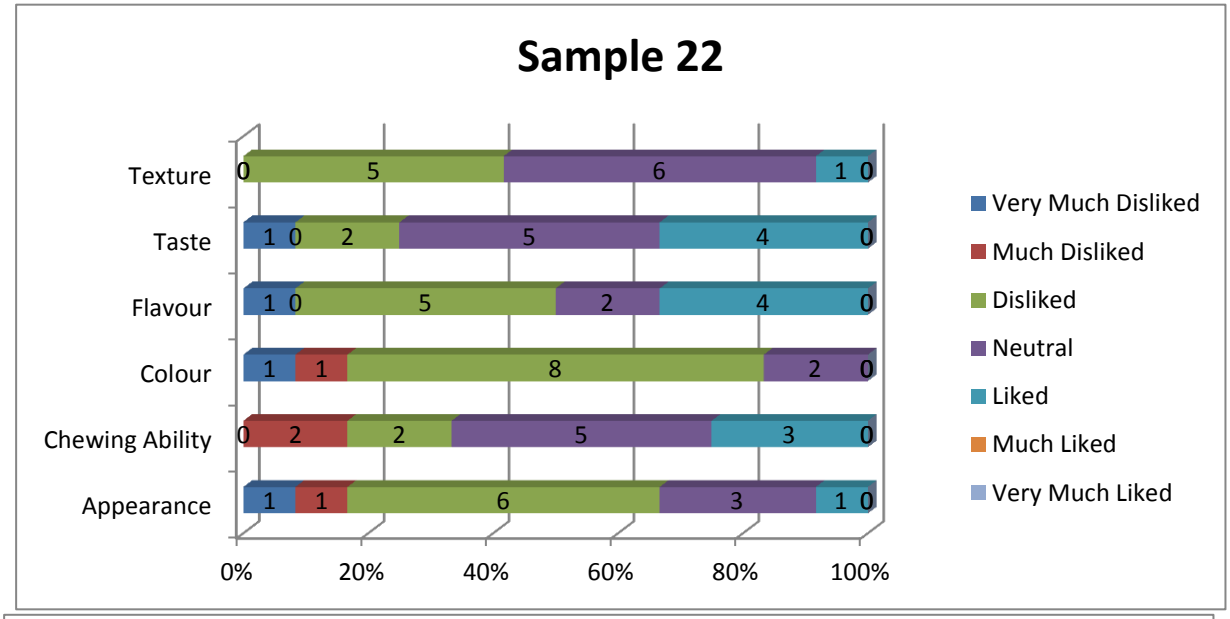
Where,
Specimen 1= Sample 17
Specimen 2= Sample 23
Specimen 3= Sample 10

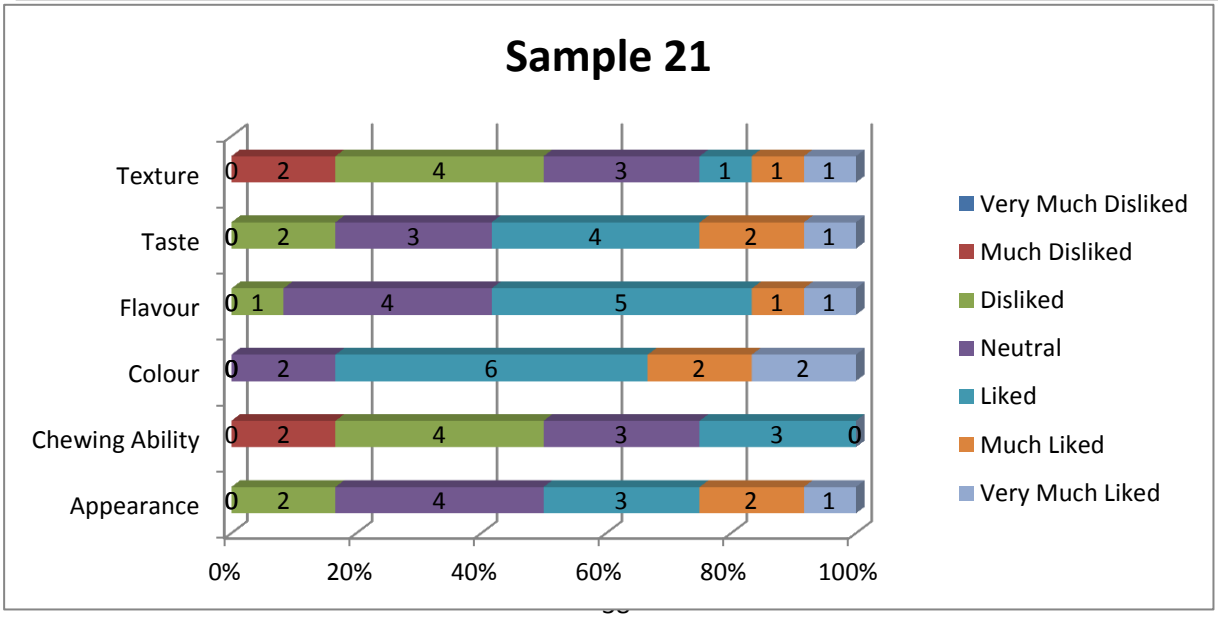
Sample size=12

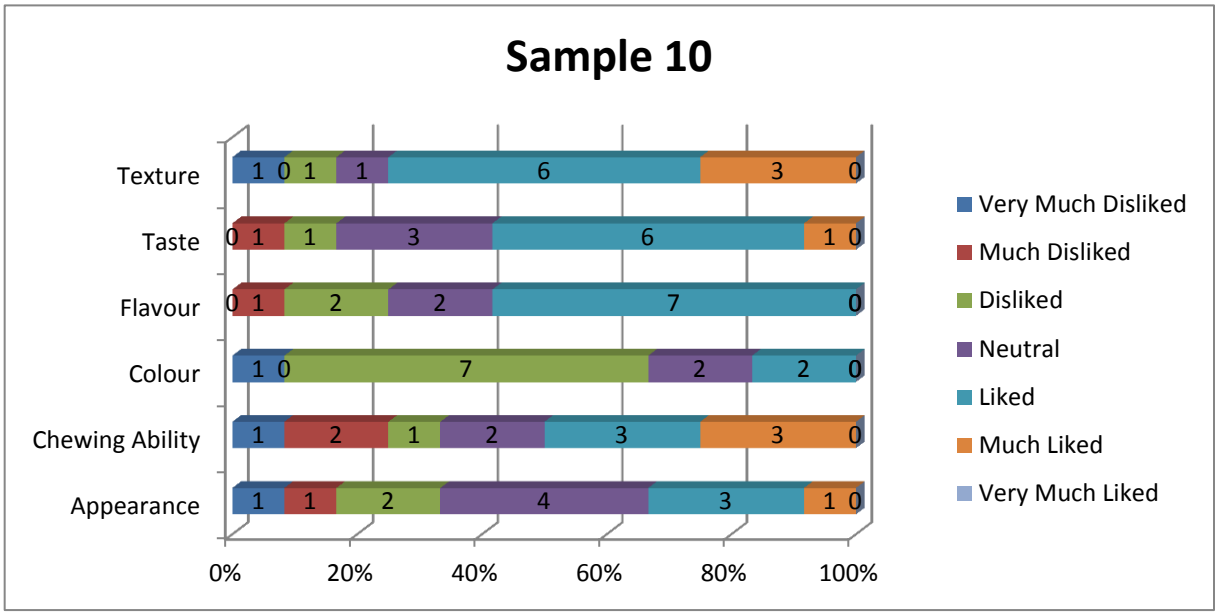


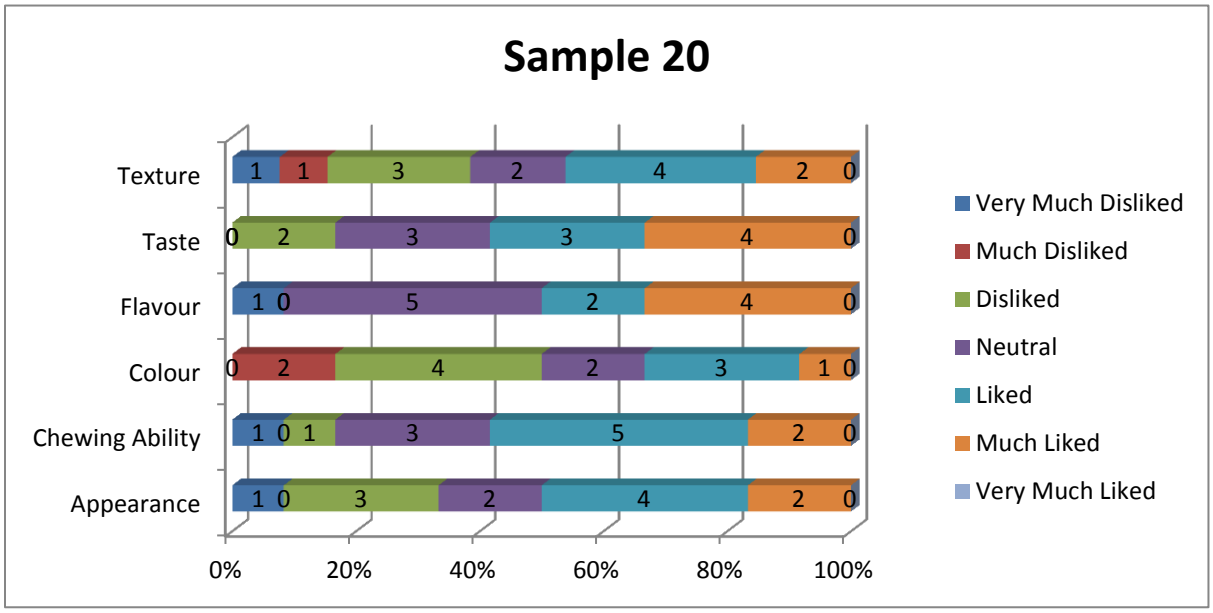



Sample 19
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0% 20% 40% 60% 80% 100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked


Sample 22
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0% 20% 40% 60% 80% 100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked


Sample 21
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0% 20% 40% 60% 80% 100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked


Sample 10
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
1 0 1 1 6 3 0
0 1 1 3 6 1 0
0 1 2 2 7 0
1 0 7 2 2 0
1 2 1 2 3 3 0
1 1 2 4 3 1 0
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked


Sample 20
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
1 1 3 2 4 2 0
0 2 3 3 4 0
1 0 5 2 4 0
0 2 4 2 3 1 0
1 0 1 3 5 2 0
1 0 3 2 4 2 0
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked

CHAPTER 8
THE FUTURE OF THE IDLI

The Future of Eating

Our population is expanding, while standards of living are also changing and our environment is increasingly strained. How will future food production meet the growing demand? Will our diets have to change? Can technology provide the answers? New trends in biotechnology, health science, processing, and cooking technologies, as well as issues like climate change, will all affect what we eat.

Exactly which foods will become fashionable in the future is impossible to predict. Most likely, some exist now, but are underutilized; some have yet to be found or invented; and some will be so radically different we would hardly recognize them today as food. (History)

While analyzing the general future of food we understand the following are the most trending—

- Healthy
- Sustainability
- Cooking Technology

IDLI AS A HEALTH SOURCE

The Idli being a versatile food has great scope to grow on a nutritional platform as a health product which is food specific and customer oriented. By combining various properties of an Idli discussed in this study, we can set parameters to include new and healthier ingredients while achieving the original properties of texture.

For example Whole grains are most preferred for diabetics. Thus, instead of utilizing a whole rice component it can be broken down into combination of proportionate amounts of rice grain with another whole grain like whole wheat or corn, peas or oats and then further mixing it with black gram can create a "diabetic" Idli.

Formulation	Amylose Proportion of Starch	SME Hp./lb.	Resiliency
Oat starch (ConAgra)	23%	0.243	very high
Corn starch (Amazo 100)	28%	0.256	medium
Corn starch (Amazo 5)	50%	0.236	high
Corn starch (Amazo 7)	70%	0.235	very high
Bean starch	35%	0.264	very high
Pea starch	38%	____	_____
Wheat starch	28%	____	_____
Potato starch	20%	____	_____
Rice starch long grain	32%	____	_____
Rice starch short grain	23%	____	_____

SUSTAINABILITY

All over the tropics, forests are being converted to pastures and farmland: 80 percent of all new tropical farmland is created by replacing forests, with huge environmental costs. But we could produce 50 percent more food without new farmland by increasing yields, shifting diets, and using water and fertilizer more efficiently.

Nitrogen fixed by legumes is the main nitrogen source in organic farming systems. The design of crop rotation is strongly depending on the knowledge of how much nitrogen is fixed by legumes. Also for farm scale budgeting of Nitrogen it is essential to know the amount of Nitrogen fixed by the single leguminous crop. According to the literature, the determination of Nitrogen fixation is expensive, time consuming and bears a lot of methodological problems (Larve and Patterson, 1991).
In all agricultural systems, nitrogen is essential for developing healthy plant growth. It plays a central role in amino acid (protein) synthesis, enzyme activity and plant defence (production of secondary metabolites). Most nitrogen is supplied to the plant from either the soil, rainfall or through the process of nitrogen fixation (Adam Wilson, 2005).

Black Gram is a legume that contributes to nitrogen fixing in soil.

Types of manures used	**Nitrogenase activity (nomol g-1 FW)**
Control	1.56
Sea weed	4.3
Cow dung	3.9
Vermicompost	3.2
Coir waste	4.7

Nitrogenase activities in black gram

From the table above the nitrogenase activity of black gram treated is with different organic manures. The nitrogenase activity was analyzed from the root nodules of black gram by GC-MS. Nitrogenase activity was found to be higher in coir waste treated plants in fertile soil. Many studies suggested a significant interaction between organic manures and nodules. This was supported by Sangakkara (2001) who reported that varietal difference together with variation in nutrient uptake in organic manure treated plants influenced nodulation. Nodulation of black gram is one of the determinant factors for the yield of black gram.

By using appropriate crop rotation techniques Black gram can be cultivated after highly fertilized crops like rice or maize as it is a non-fertilized crop. Black Gram is also a restorative crop that should be followed by exhaustive or non-restorative crops.eg. Sesame.

Crops with the same symbiotic / associated microbes should be followed by common host crops, such as,
Rhizobium melilote - lucerna, sweet clover, fenugreek
R. trifolli - berseem, Persian clover
R. leguminosorum - peas, lentil, Lathyrus

R. phaseoli - beans, green gram, pillipesara, **black gram**
R. lupine - Lupines
R. japonicum - cowpea, pigeonpea, guar, sunhemp, Bengal gram, soybean, kudzu

- The rotational use of crop varieties and cultural practices in addition to rotational cropping provides more and assured benefits than that of adopting only crops or land rotation.

Hence we can say that the growth of ingredients required for Idli (Rice and Black gram) are self-sustaining and promote long term sustainability.

COOKING TECHNOLOGY

With the advancement of technology and speeding up of the world today the Idli making procedure would seem too long. Development of various technologies to reduce fermentation time can solve this problem.

Proposals for an accelerated wine maker have been circulating on the internet being introduced as the "miracle maker". The same concept could be used for Idli batter fermentation. The fermentation chamber could use an array of electrical sensors, transducers, heaters and pumps to provide a controlled environment for the primary and, as needed, secondary fermentation stages. These sensors could control fermentation time, acidity of the batter, viscosity etc., for appropriate batter fermentation. Custom-designed ceramic air-diffuser pumps can filter air under a regulated micro-oxygenated environment so as to attract wild yeasts and bacteria required for fermentation.

Yogurt makers are incubators with regulated temperature controlling. Through modification of this model creating an Idli maker with several monitoring properties and sensors that can automate soaking, grinding and fermentation, the idli can be put on an all-new platform making it a global food.

CHAPTER 9
CONCLUSION

A 20gram idli with its meagre 39 calories, less than 16gms of saturated fat, 2gm protein, 2 grams dietary fibre and 8 grams carbohydrates laden with 1 milligram of iron, and trace amounts of calcium, folate, potassium and vitamin A is truly an ideal source of nourishment for all ages. Its wide acceptability has drawn it from the Murugan Idli Shop in Chennai popularizing it around the world through various Indian restaurant chains like Sarvana Bhavan.

The Idli is made from two important food sources that are extensively consumed in India—Black Gram Lentil and Rice. Every household has numerous ingredients that may be added to enhance the taste and texture of the Idli. For this study we considered six main ingredients:

- Parboiled Rice
- Raw Rice
- Brown Rice
- Spilt Black
- Whole Black Gram
- Fenugreek

By combining these various products in different proportions (2:1 and 3:1; the higher factor always being rice grains) or elimination/adding fenugreek notes were made of the changes of the following properties:

- pH
- Viscosity
- Amylose
- Compression Testing

Simultaneously a sensory evaluation was conducted to decipher perceptive tastes and expectations by a sample size of 12 people over a varying age group. The variables used in this project as descriptives were—

- Appearance
- Taste
- Texture
- Flavour
- Chewing Ability
- Colour

Samples 17, 21, 19, 23, 10 and 22 ranked among top five in the variable categories with sample 17 unanimously ranking first for all the descriptors. Among the top samples the parboiled rice was the most common rice grain. Parboiled rice has an amylose content of about 20-25% contributing to a firm (not hard, neither crumbly) soft textured Idli.

Black gram and fenugreek varied with the proportion of the batter and whole or split black gram. Whole black gram did not contain fenugreek whereas the split black gram Idlis preferred fenugreek. 3:1 ratios with rice and whole black gram did not require fenugreek, neither did 3:1 of rice and split gram.

The Black Gram is vital part of fermentation. It is observed that the 2:1 batters ferment better that the 3:1 batters when the same gram is used (either split or whole) Black Gram brings in wild bacteria and yeast to begin the fermentation process. Whole grams ferment more and become more viscous due to untainted micro-organisms present in the gram whereas, split black gram batter with higher proportions of rice is noticeably thinner. The heat of the decortation process in lentils kills most micro-organisms and some nutrients. Black gram also helps in stabilization of the batter which is very important with respect to idli texture. The polysaccharide in black gram stabilizes the soft porous texture of idli. An important way to stabilize the foam is through the formation of a rigid system by means of crystallization, denaturation or gelatinization of the continuous phase. Black gram starch and mucilage combined results in an enhanced foam stability during and after fermentation, due to increased viscosity caused by synergistic interactions between these polysaccharides.

All the ranking samples were within a range of 4.49-4.88 on the pH meter implying that fermentation of those samples (ingredients) occurred for the right period of time, in the right temperature and humidity.

Sample Number 17 was the most preferred sample. It comprised of two parts parboiled rice and one part split black gram without fenugreek.

- No fenugreek
- Amylose= 22%
- pH= 4.88
- Viscosity= 1405.29 centipoise
- It was most preferred for its texture and appearance
- Least preferred for its colour, due to the lack of fenugreek.

In conclusion we can identify a good Idli with the following properties:

- Two parts rice : one part lentils
- Amylose content of no more that 22%, no less than 20%
- pH value of the fermented batter ranging from 4.49-4.88
- viscosity ranging from 1300-1400 centipoise

By using the parameters above there is future scope to develop a model to create different Idlis based on the pre-scripted characteristics to retain the qualities of texture while simultaneously developing tastes and flavor profiles.

From a nutritional perspective, although the idli does contain numerous benefits it does use Rice, which has a high glycemic index. Thus by either substitution rice with another grain or lentil, or by including another variety with lower glycemic index we would be able to cook an Idli with multi-grains/lentils that would be able to satisfy the diabetic population.

Infertility is a massive problem for women and men and can be caused due to lack Zinc and Iron in the body. These can be replenished by the consumption of sunflower and pumpkin seeds and vitamin B-6 rich foods which can be incorporated in the production of an Idli.

Similarly, a proportionate amount of Kidney Beans can be also added for nutritional benefit. These legumes are an excellent source of thiamin and riboflavin. Both vitamins help the body use energy efficiently. Swedish researchers found that if you eat barley—a key ingredient in whole-grain cereals—for breakfast, the fibrous grain cuts blood sugar response by 44 percent at lunch and 14 percent at dinner.

Like the above examples there are numerous other nutritional problems which can be looked after by right consumption. So why not through the most versatile breakfast food?

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ANNEXTURES

RECIPES REFERRED TO:

Regional Indian Recipes by Rachel Muthachen

3 Cups	Parboiled Rice
1 1/2 Cups	Urad Dal
1 Tsp	Salt
1/2 tsp	Methi
3/4 to 1 Cup	Water

Wash & grind separately (Urad+Methi)
Mix together and *beat well* with Wooden spoon
Ferment 6-8 hours
Steam 15-20 minutes

The Essential Andhra Cookbook by Bilkees I Latif

1/2 cup	Husked black gram
3/4 cup	Fine semolina
3/4 cup	Par boiled rice
1tsp	Baking Powder
	Salt

Soak separately. Gring Urad & Semolina together.
Ferment separately.
Mix together; add baking pwd and salt.
Whip in liquidizer

The Indian Cuisine by Krishna Gopal Dubery

Rice	200gm
Urad Dal	100gm

Soak together; Grind together; ferment

Indian Light Cooking by Ruth Law

I cup	Basmati Rice or and other long grained rice
1/2 cup	Split Urad Dal
1 Cup	Warm Water
1/4 tsp	Salt
1/4 tsp	Baking Soda

Grind Separately, Ferment Together.
Stir in gently Baking soda & salt

CALORIES PER SERVING	36
Protein	1gm
Fat	0gm
Carbs	7gm
Sodium	33 mg
Cholestrol	0 mg

Inspired by a recipe from K. Natarajan, Executive chef, The taj Coromandel, Madras

Indian Food Sense (a health and nutrition guide to traditional recipes) by Ruth N Davidar

480g	Uncooked parboiled rice
180g	Black gram (without husk)
450ml	Water
Salt	To taste

Soak separately for 6 hours
Grind separately. Mix add salt & ferment

Per Idli

Kilo calories	97
Protein	3gm
Fat	Trace
Carb	20g
Calcium	13mg
Phosphorous	58mg
Iron	0.5mg
Vitamin C	Nil
Vitamin A (as Carotene)	3 mcg
Fibre	Trace
1mcg	1000mg

Idlis ideally demonstrate how cereals and pulses can be conbined to make up for the inherent imbalance of essential amino acids that is a feature of each group separately. In combination however, this is more than amply compensated for.

Idlis are perfect for little children and for the sickas they are low in fat and easily digested. Their bland flavour is especially appealing.

THOUGH parboiled rice is preferred, raw rice may also be used. To soften idlis add, 1 handful of puffed rice or 1 handful cooked rice when the rice is being ground.

Aharam (Traditional Cuisine of Tamil Nadu) by Sabita Radhakrishna

2cups	Parboiled rice
2 cups	Raw Rice
1 cup	Black Gram Dal
1/2 cup	Cooked rice
Salt	
Baking Soda	Pinch

Soak the two kinds of rice together with water. Soak black gram separately. Grind separately.
Ferment.
Stir in soda

Delicious Recipe from Andhra by Karuna

Raw Rice or	1 1/2 cup
Idli semolina	1 1/2 cup
Broken Black Gram	1 cup

Idli semolina softer idlis than with raw rice

A taste of Goa (Ilustrated guide to goan cooking) Suchitra Kaul Misra

SAANAS

Rice	1 1/4 cup
Toddy	1 cup
Coconut	1 no.
Sugar	4 tbsp
Salt	1/2 Tbsp

The Exquisite world of Indian Cuisine by Uma Aggarwal

Rice long grain	4 cups
Urad Dal	1 cup
Cooked Rice	1 cup
Salt	4 tsp

Cook one cup of cream of wheat in 1 tbsp of oil until light brown cool and mix with 1/4 tsp of salt and baking soda and 1 1/2 cup of yogurt. Add some water if too thick

Indian Spa Cuisine by Manjit Singh Gill

Vegetable idli

Lentil (masoor dal)	100gm
Semolina	300gm
Salt	
Turmeric	1 tsp
Carrots	25gm
Cabbage	25gm
Green Peas	25gm

Dakshin Bharat Dishes Cookbook by Jaya V. Shenoy

Black gram dal	1 pav
Raw rice	2pav
OR 1 pav boiled + 1 pav raw rice	

Soak + Grind Separately
Mix together with HAND add salt ferment overnight
Next day, beat the batter well

Delights from GOA Aroona Reejhsinghani

Rice Flour	500gm
Coconut Milk	2 cups
Toddy	1/3 cup
Salt/Sugar	

Mixtogether . steam

The Art of South Indian Cooking by Aroona Reejhsingh

DAL IDLI

1 cup	Mung Dal
1 cup	Urad Dal
1/2	Grated coconut
	Salt

Soak together; Grind together; Ferment

HOME-MAKER RECIPES

"A"
3:1 Brown Rice + Urad Dal
+ Cooked Rice while grinding

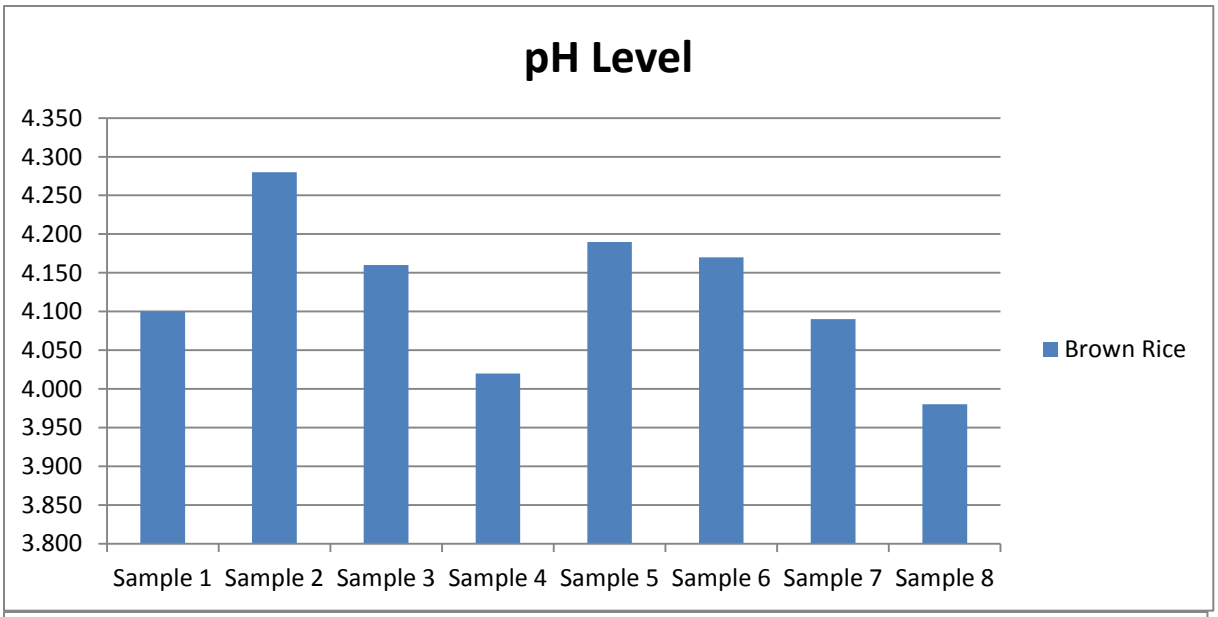
"B"
3:1 Raw Rice Rice : Split Urad dal
+ 3-4 Pellets yeast
+ Cooked rice while grinding

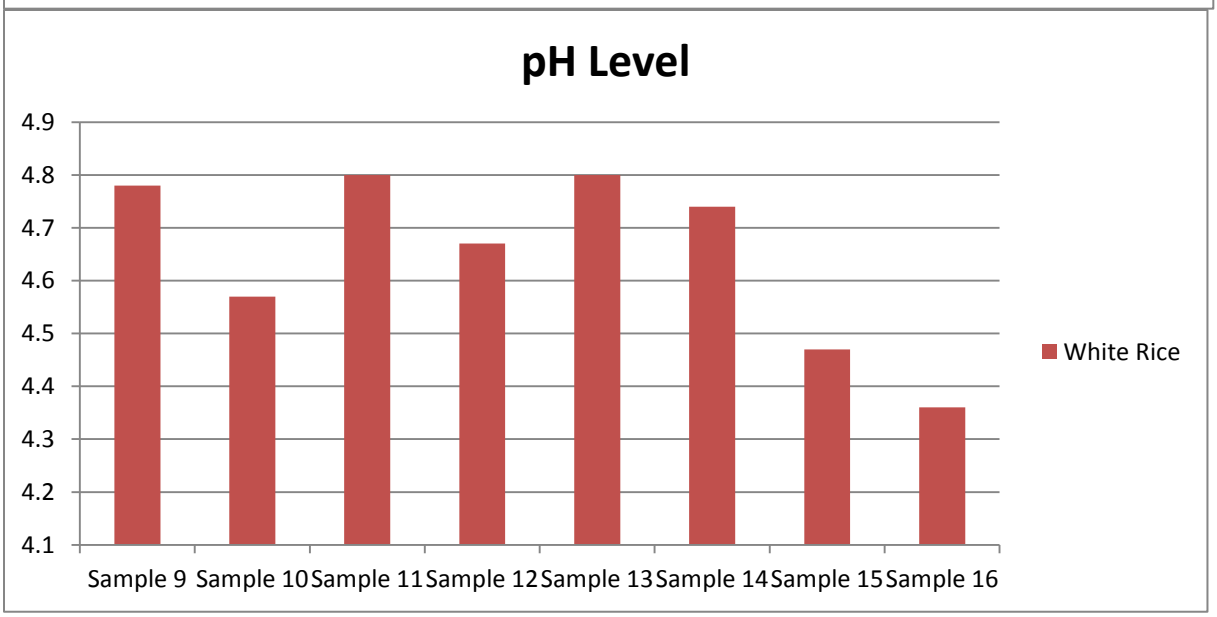
"C"
2:1
Idli Rice: Whole Urad
+ Onion
+ Soaked Flattened rice while grinding

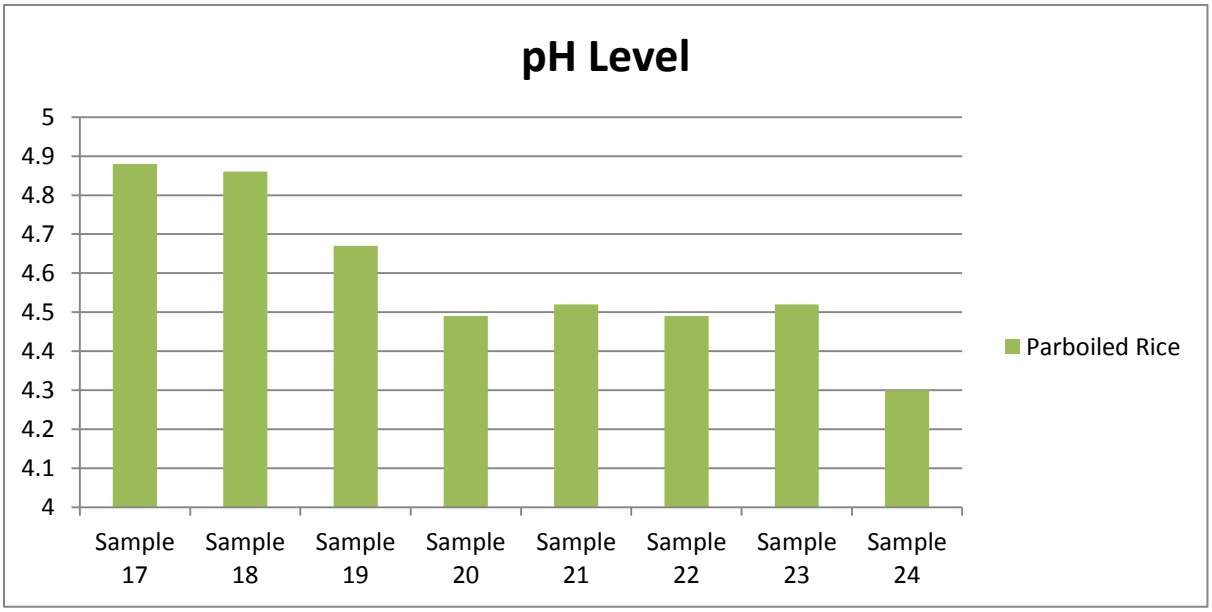
"D"
2:1
Rice:Split Urad
+ Onion

"E"
2:1
Raw Rice: Split Urad
+ Coconut while grinding

"F"
2:1
Raw Rice: Split Urad
+ Toddy while grinding instead of water


pH Level
4.350
4.300
4.250
4.200
4.150
4.100
4.050
4.000
3.950
3.900
3.850
3.800
Sample 1
Sample 2
Sample 3
Sample 4
Sample 5
Sample 6
Sample 7
Sample 8
Brown Rice


pH Level
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
Sample 9
Sample 10
Sample 11
Sample 12
Sample 13
Sample 14
Sample 15
Sample 16
White Rice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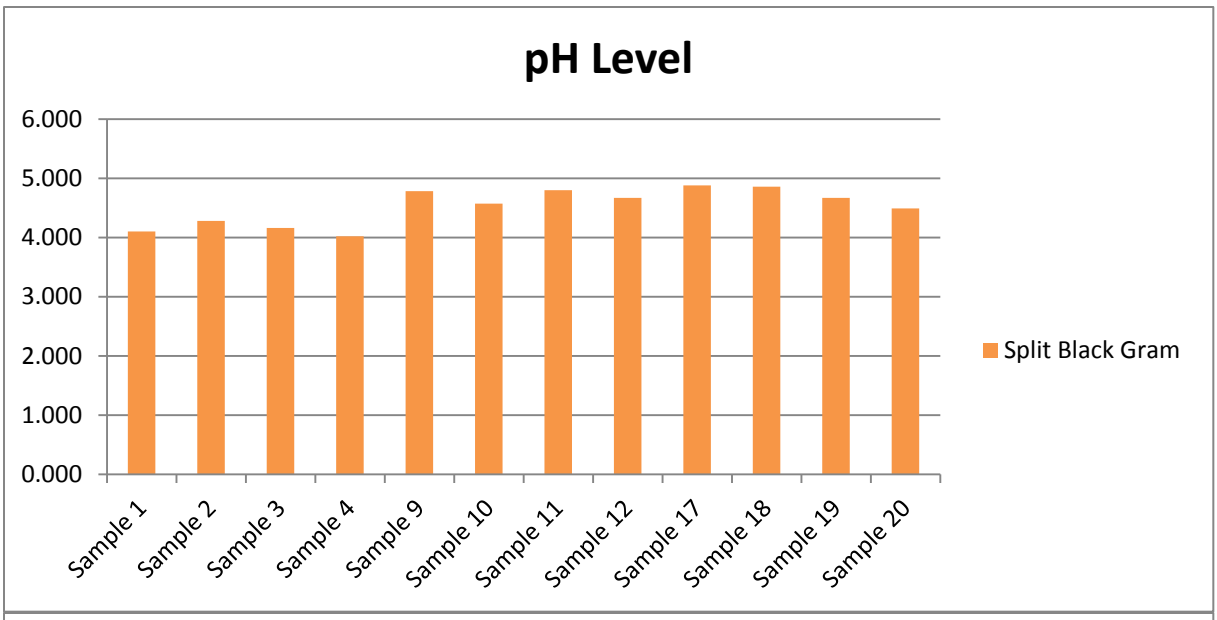
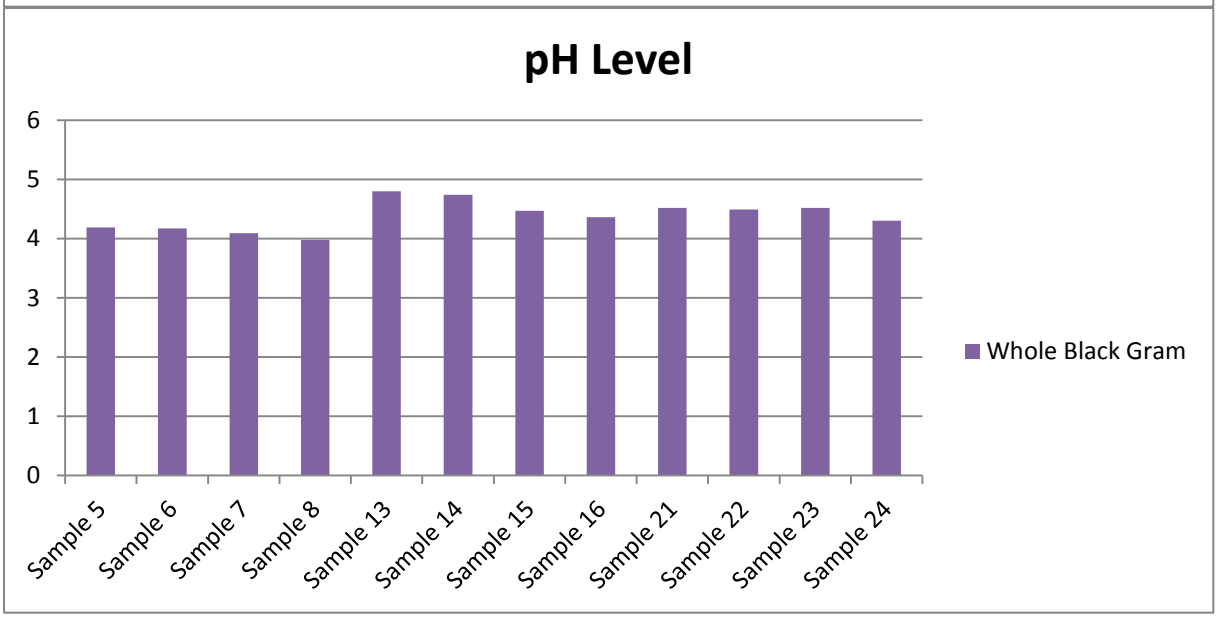
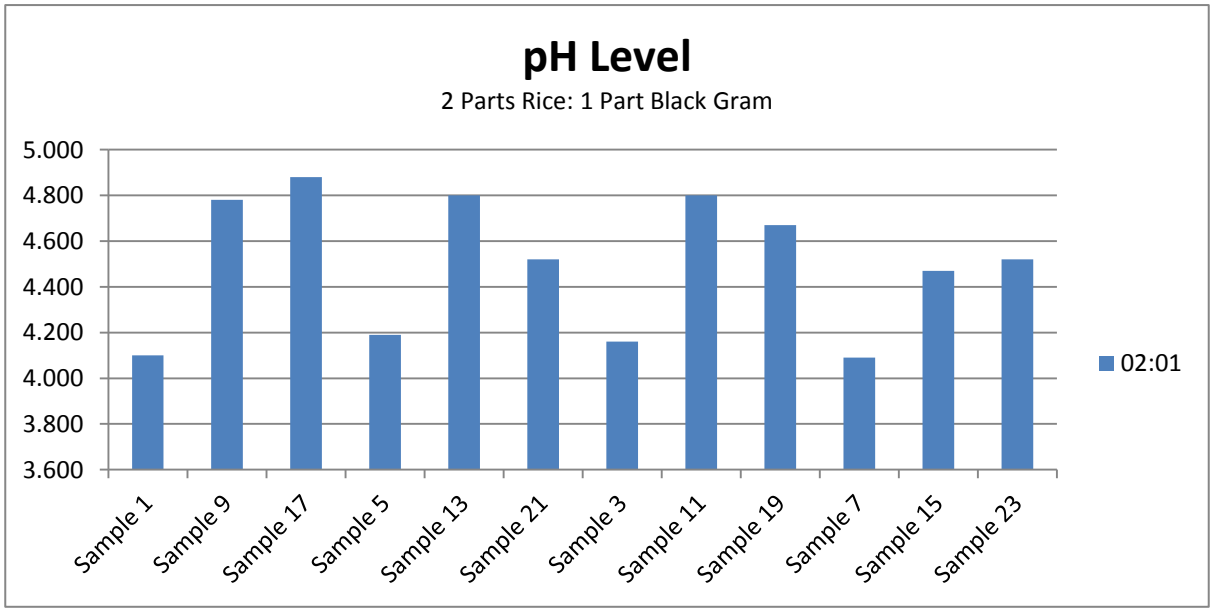
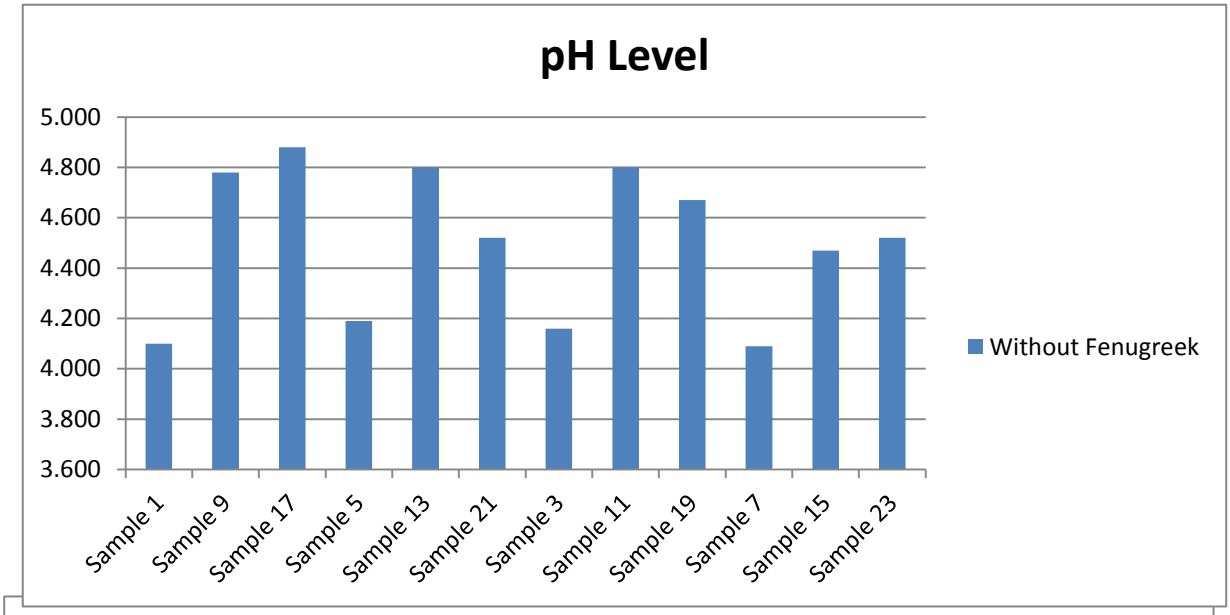
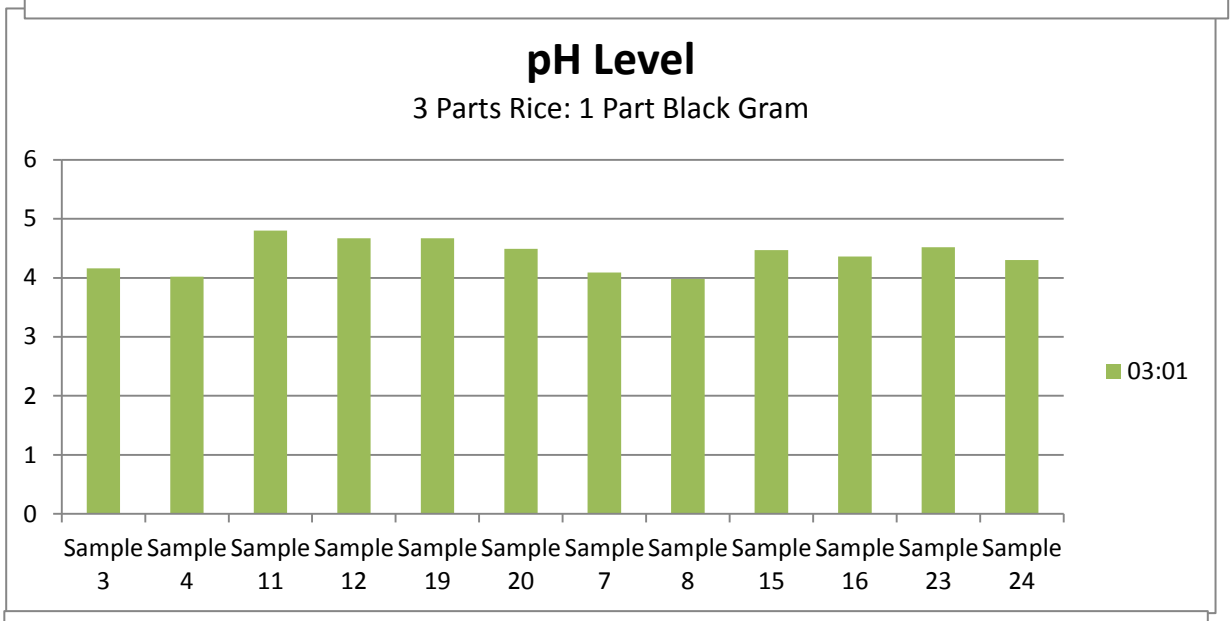
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
Sample 17
Sample 18
Sample 19
Sample 20
Sample 21
Sample 22
Sample 23
Sample 24
Parboiled Rice

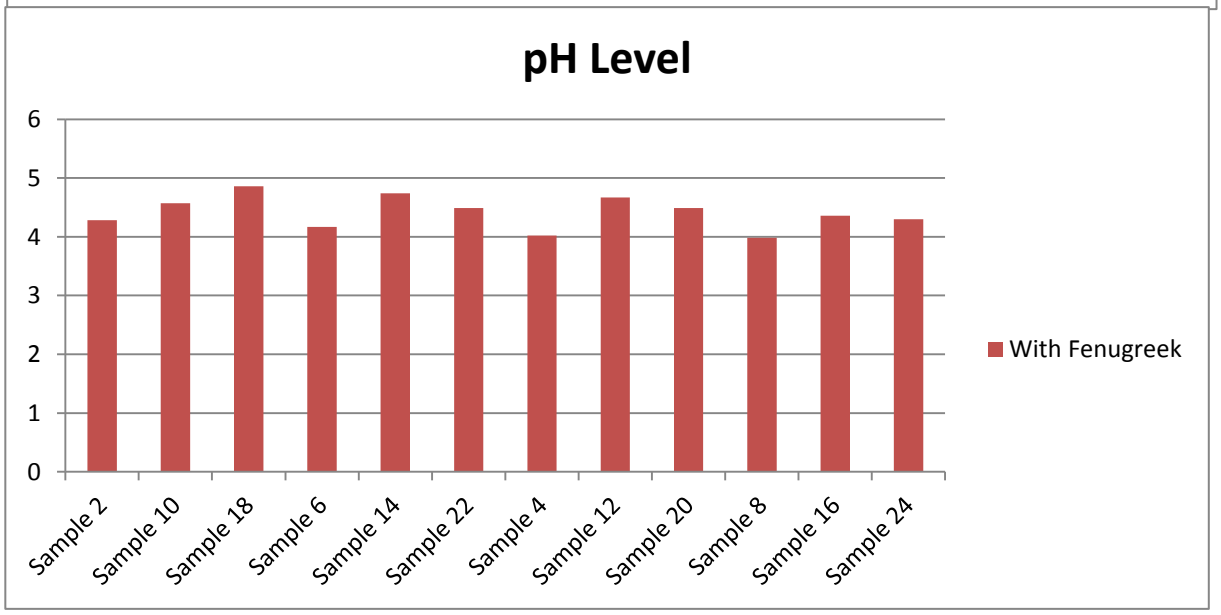

pH Level
6.000
5.000
4.000
3.000
2.000
1.000
0.000
Sample 1
Sample 2
Sample 3
Sample 4
Sample 9
Sample 10
Sample 11
Sample 12
Sample 17
Sample 18
Sample 19
Sample 20
Split Black Gram


pH Level
6
5
4
3
2
1
0
Sample 5
Sample 6
Sample 7
Sample 8
Sample 13
Sample 14
Sample 15
Sample 16
Sample 21
Sample 22
Sample 23
Sample 24
Whole Black Gram

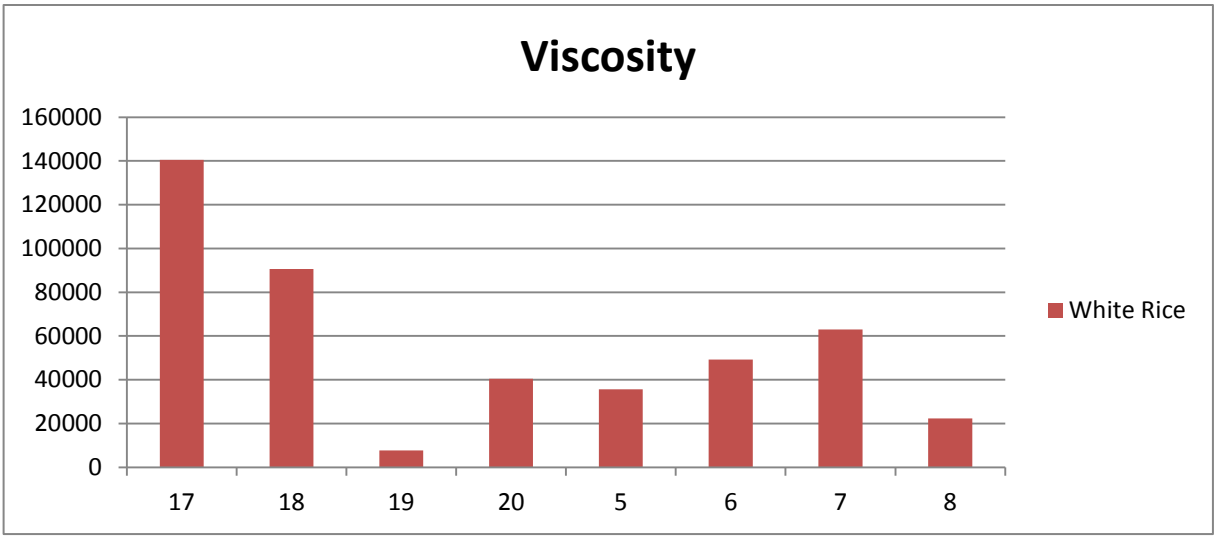

pH Level
2 Parts Rice: 1 Part Black Gram
5.000
4.800
4.600
4.400
4.200
4.000
3.800
3.600
Sample 1
Sample 9
Sample 17
Sample 5
Sample 13
Sample 21
Sample 3
Sample 11
Sample 19
Sample 7
Sample 15
Sample 23
02:01

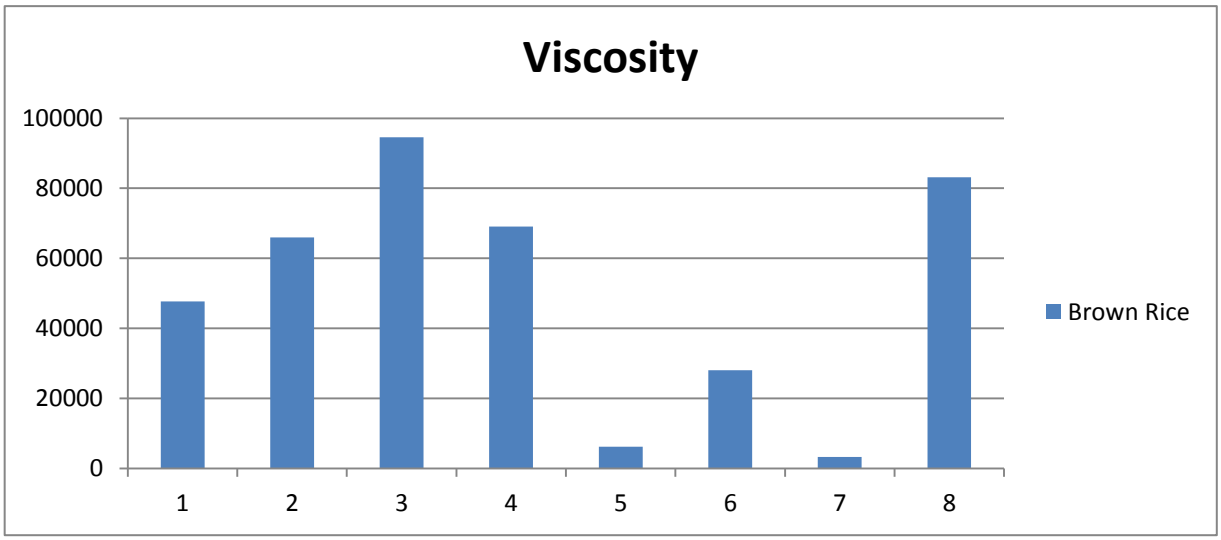

pH Level
5.000
4.800
4.600
4.400
4.200
4.000
3.800
3.600
Sample 1
Sample 9
Sample 17
Sample 5
Sample 13
Sample 21
Sample 3
Sample 11
Sample 19
Sample 7
Sample 15
Sample 23
Without Fenugreek

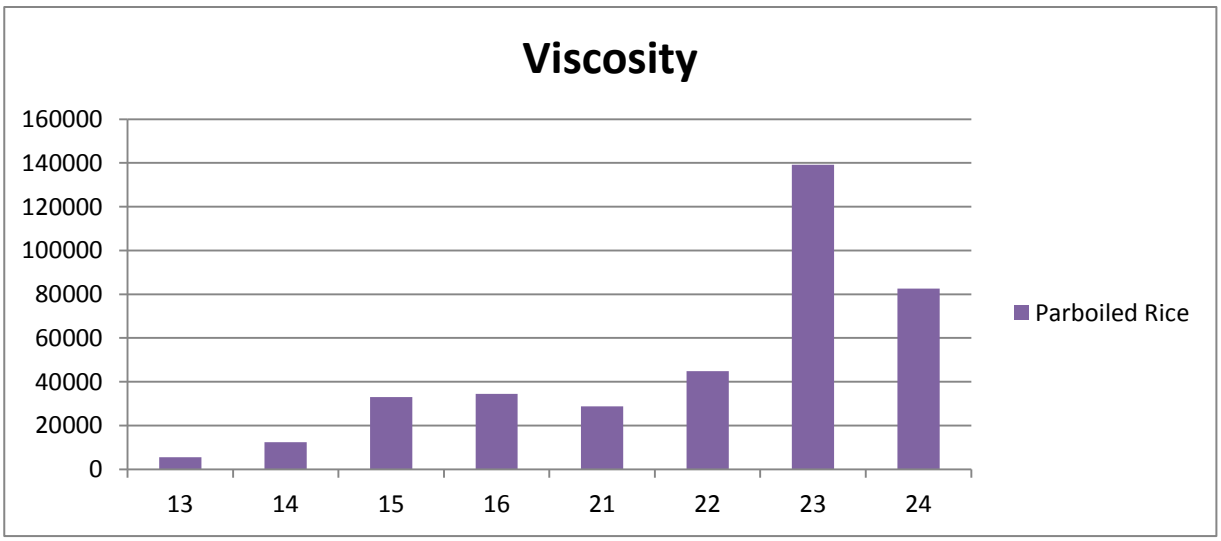

pH Level
3 Parts Rice: 1 Part Black Gram
6
5
4
3
2
1
0
Sample 3
Sample 4
Sample 11
Sample 12
Sample 19
Sample 20
Sample 7
Sample 8
Sample 15
Sample 16
Sample 23
Sample 24
03:01

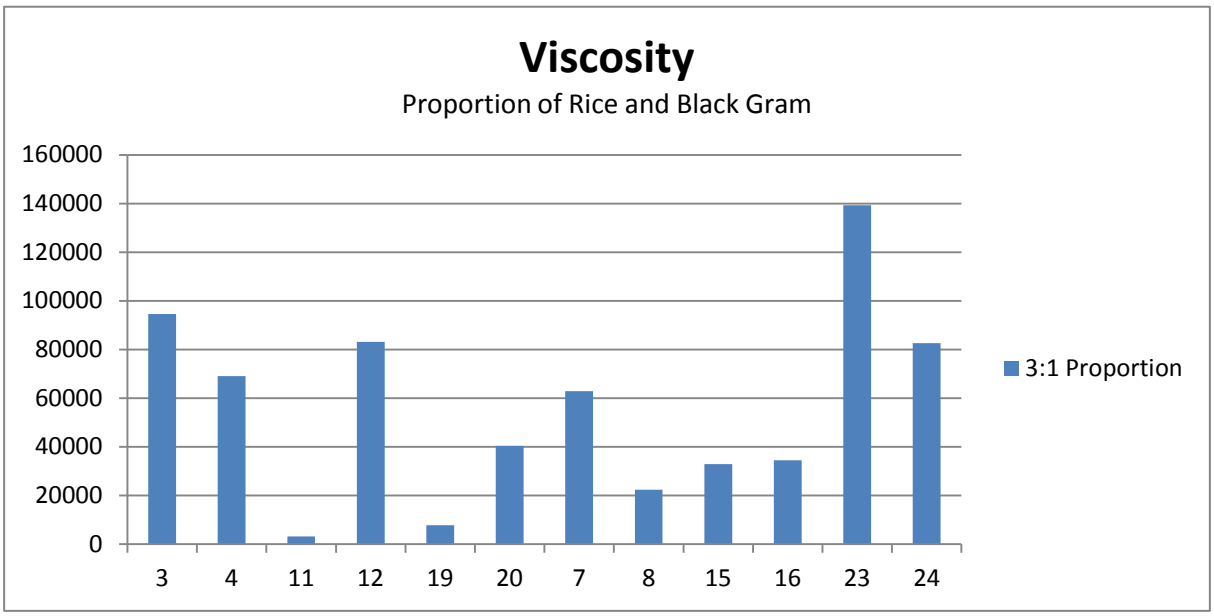

pH Level
6
5
4
3
2
1
0
Sample 2
Sample 10
Sample 18
Sample 6
Sample 14
Sample 22
Sample 4
Sample 12
Sample 20
Sample 8
Sample 16
Sample 24
With Fenugreek

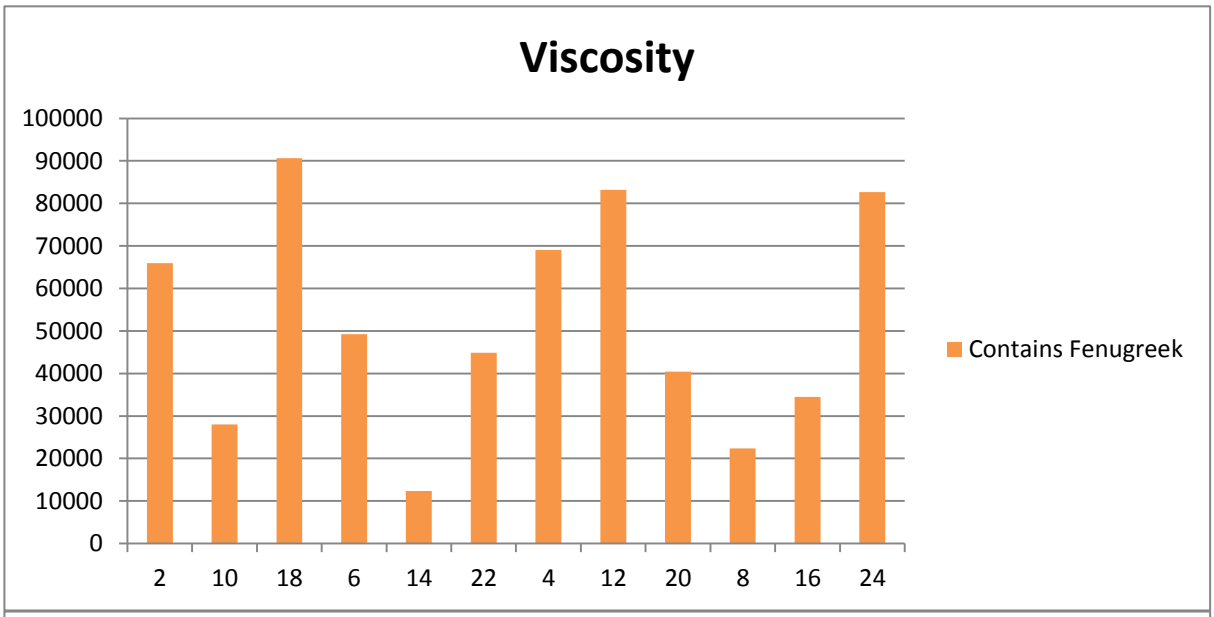
VISCOSITY

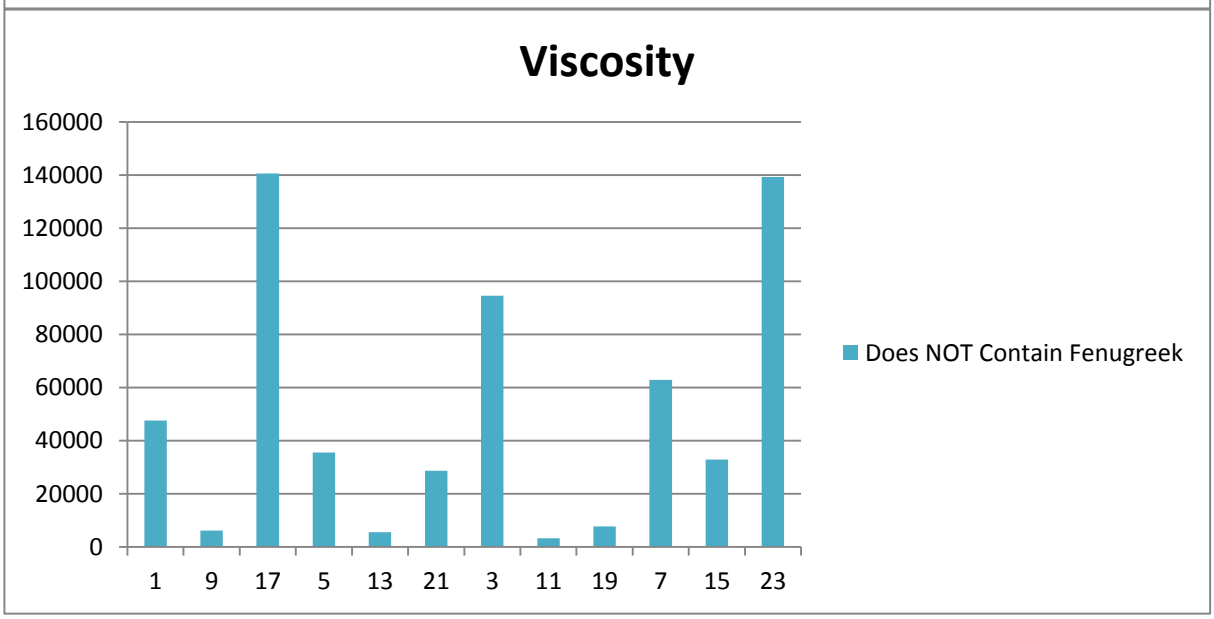

Viscosity
160000
140000
120000
100000
80000
60000
40000
20000
0
17
18
19
20
5
6
7
8
White Rice

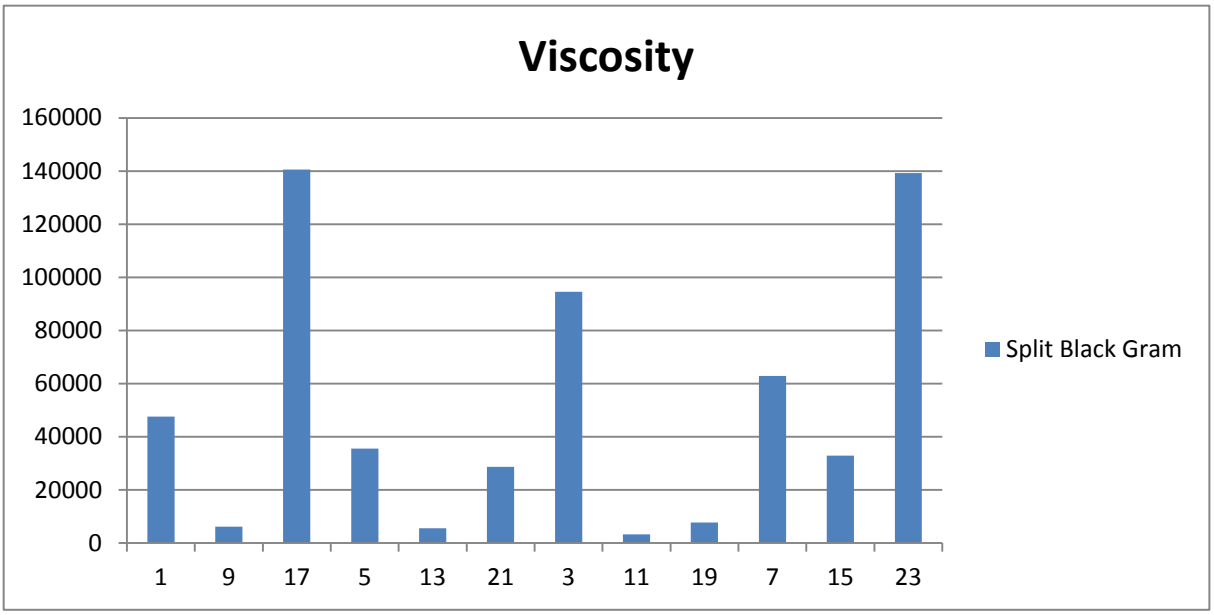

Viscosity
100000
80000
60000
40000
20000
0
1
2
3
4
5
6
7
8
Brown Rice

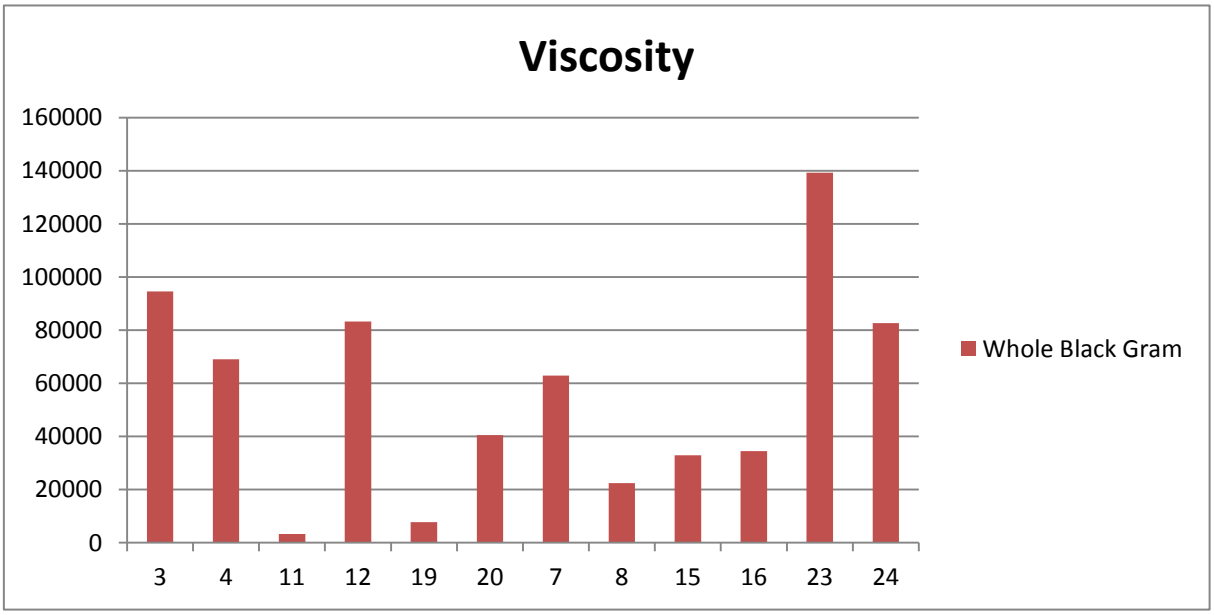

Viscosity
160000
140000
120000
100000
80000
60000
40000
20000
0
13
14
15
16
21
22
23
24
Parboiled Rice

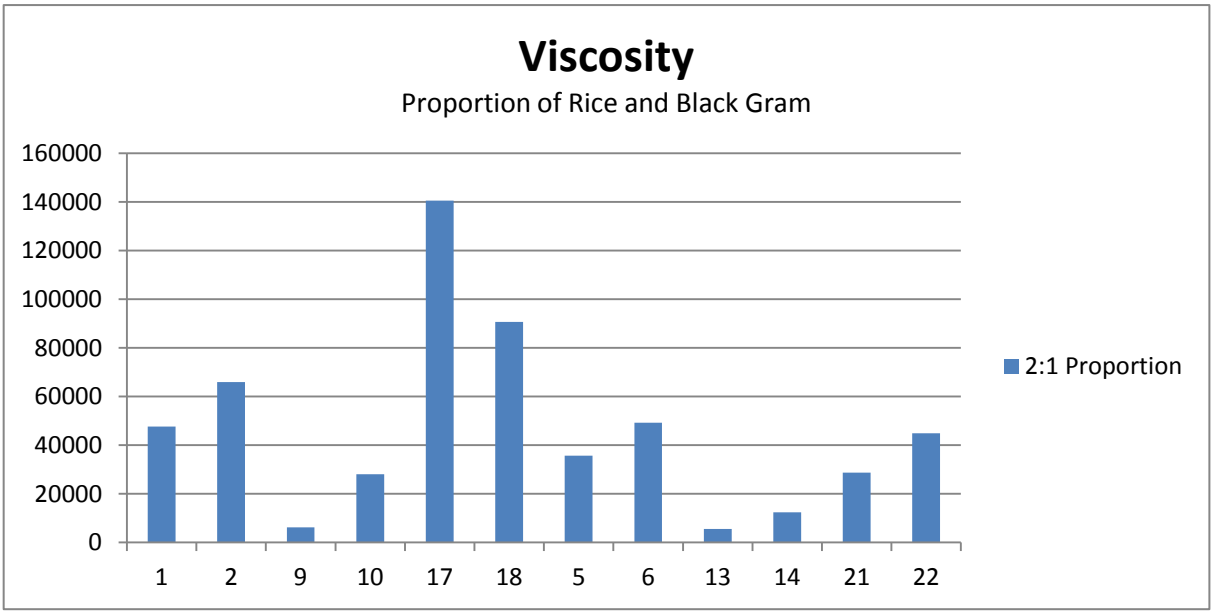

Viscosity
Proportion of Rice and Black Gram
160000
140000
120000
100000
80000
60000
40000
20000
0
3
4
11
12
19
20
7
8
15
16
23
24
3:1 Proportion

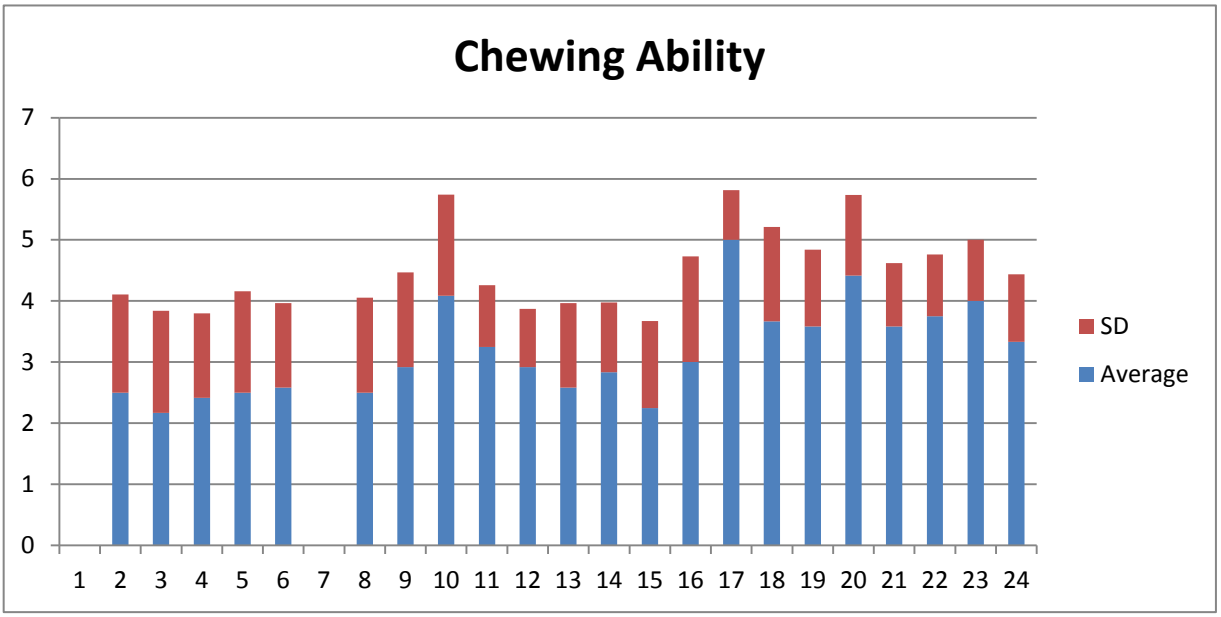

Viscosity
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
2
10
18
6
14
22
4
12
20
8
16
24
Contains Fenugreek

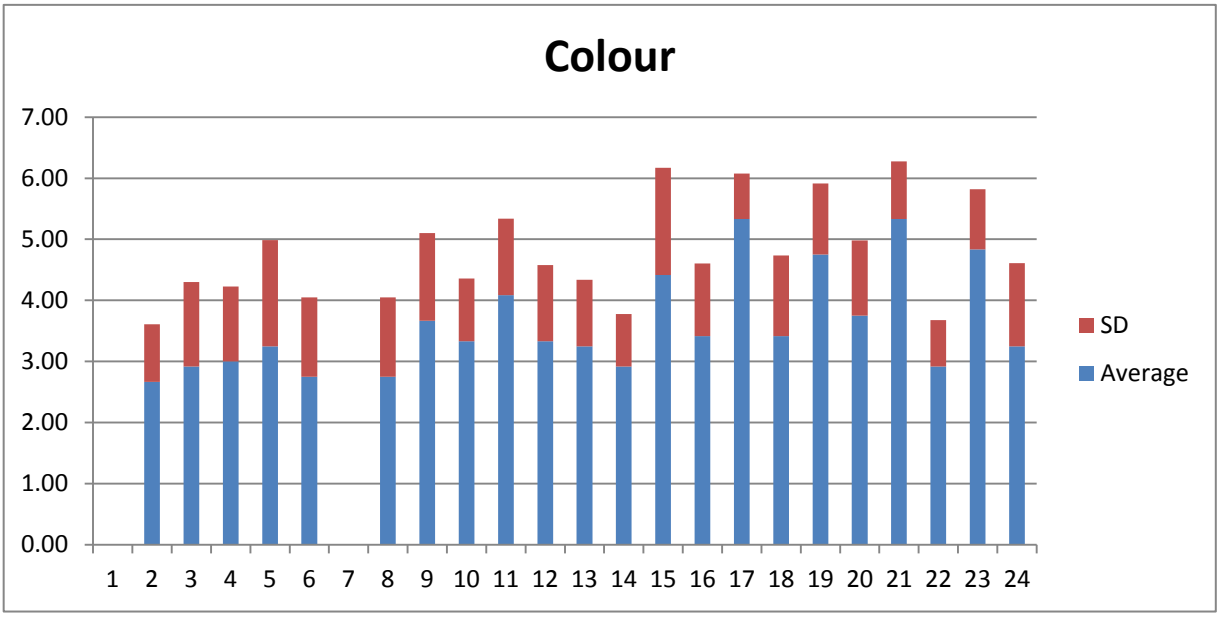

Viscosity
160000
140000
120000
100000
80000
60000
40000
20000
0
1
9
17
5
13
21
3
11
19
7
15
23
Does NOT Contain Fenugreek

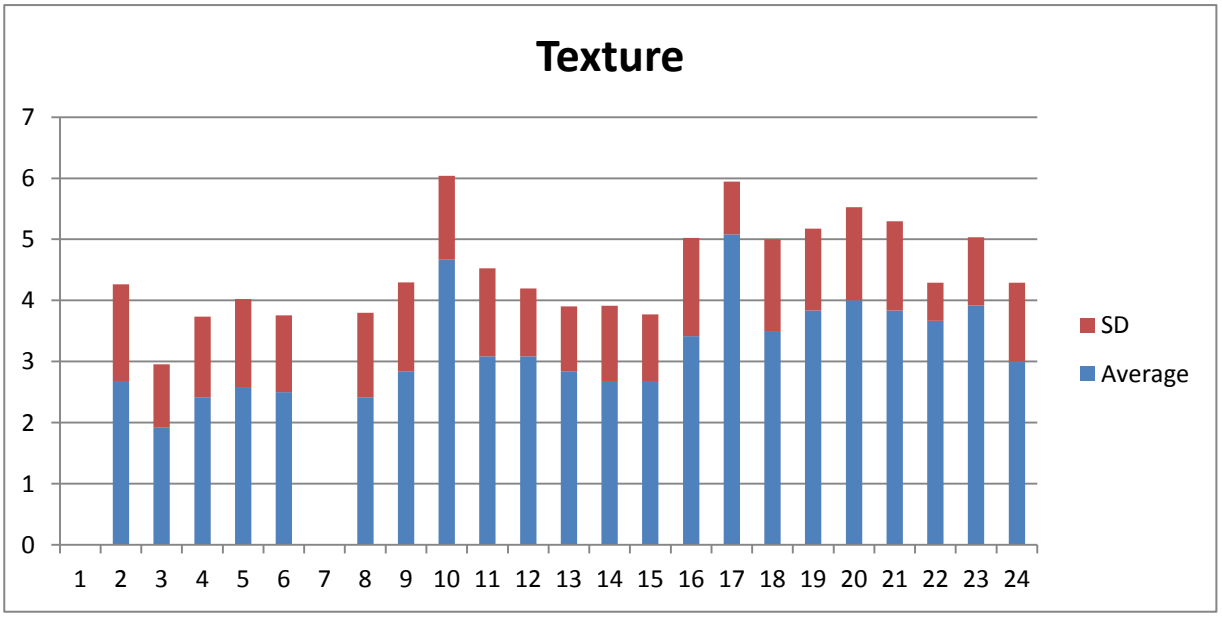

Viscosity
160000
140000
120000
100000
80000
60000
40000
20000
0
1
9
17
5
13
21
3
11
19
7
15
23
Split Black Gram

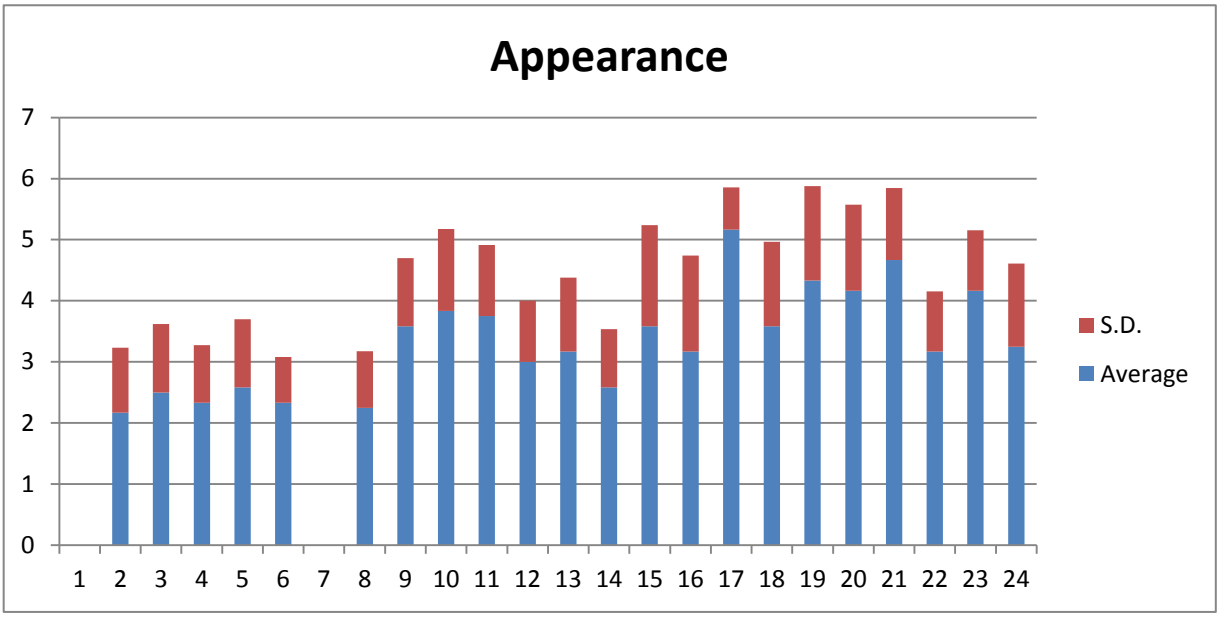

Viscosity
160000
140000
120000
100000
80000
60000
40000
20000
0
3
4
11
12
19
20
7
8
15
16
23
24
Whole Black Gram

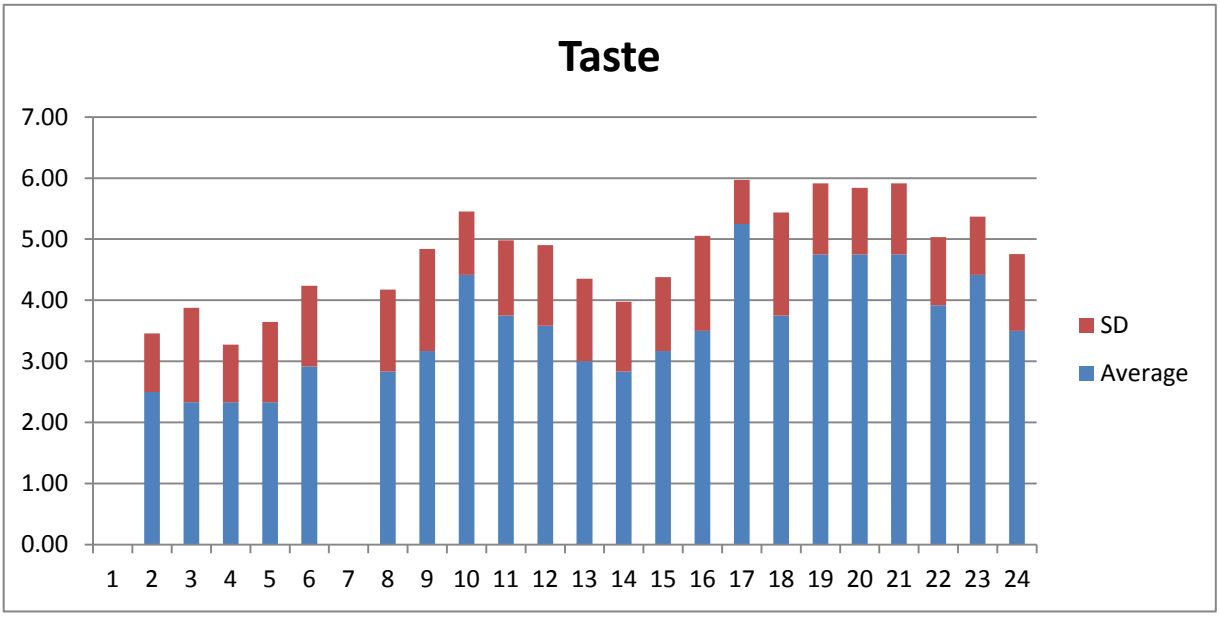

Viscosity
Proportion of Rice and Black Gram
160000
140000
120000
100000
80000
60000
40000
20000
0
1
2
9
10
17
18
5
6
13
14
21
22
2:1 Proportion

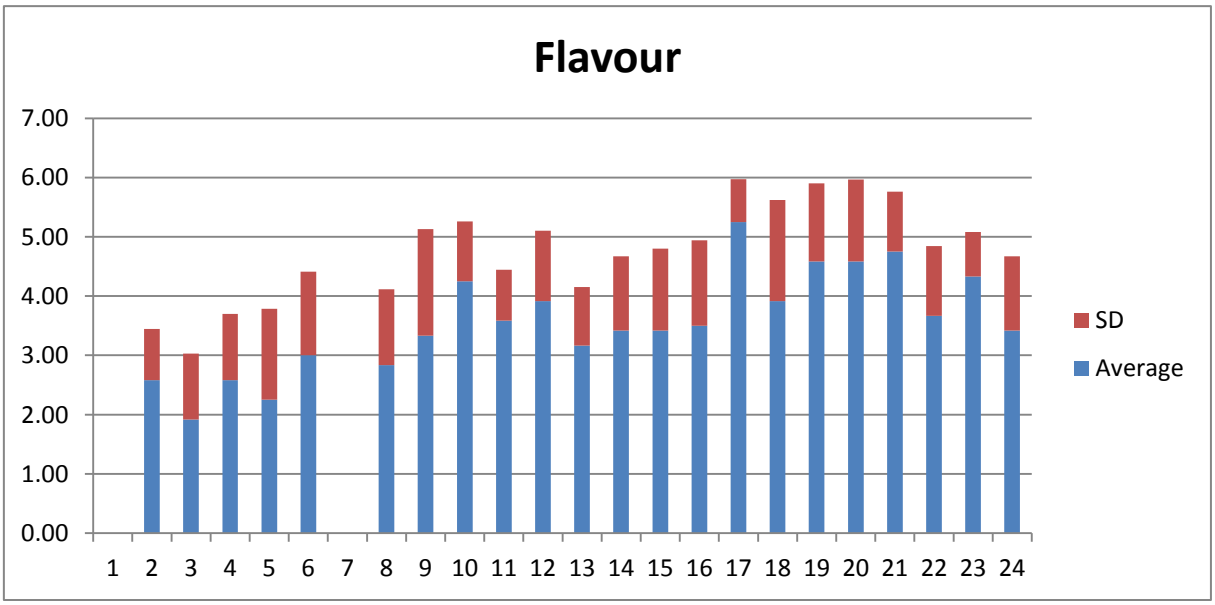

Chewing Ability
7
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
SD
Average

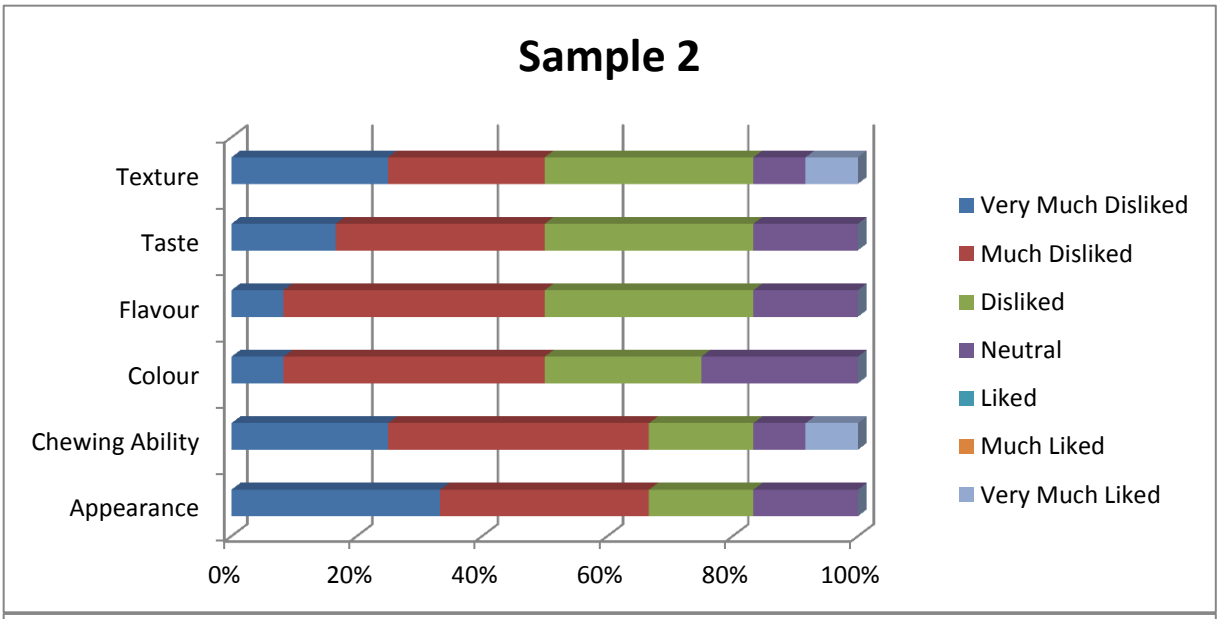

Colour
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
SD
Average

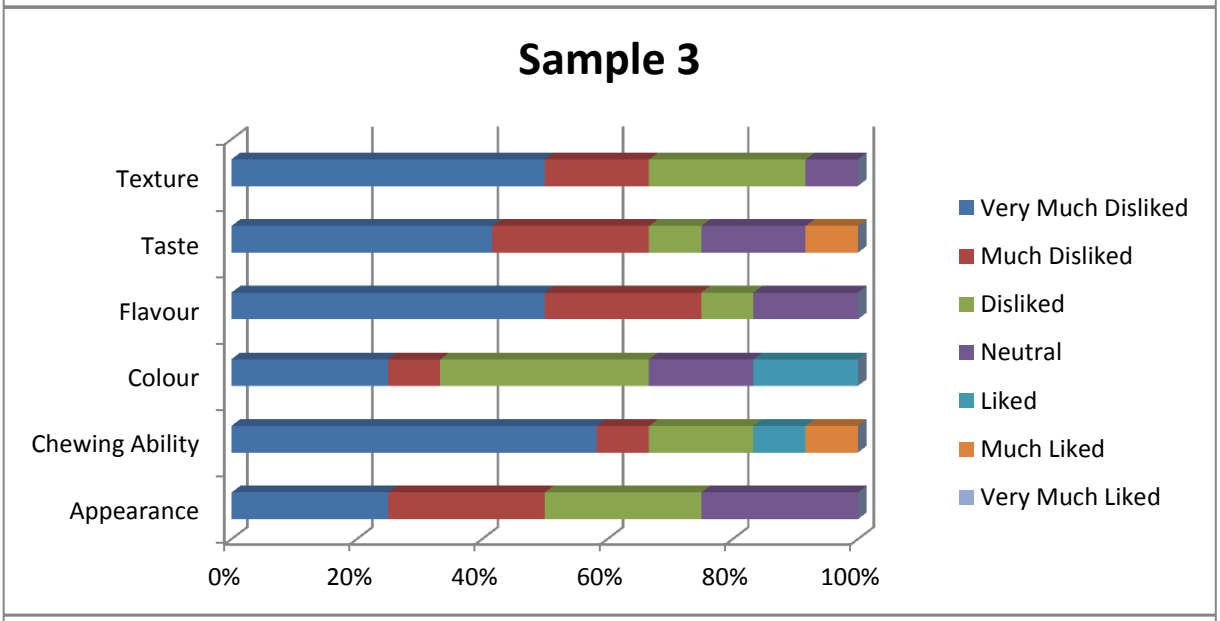

Texture
7
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
SD
Average

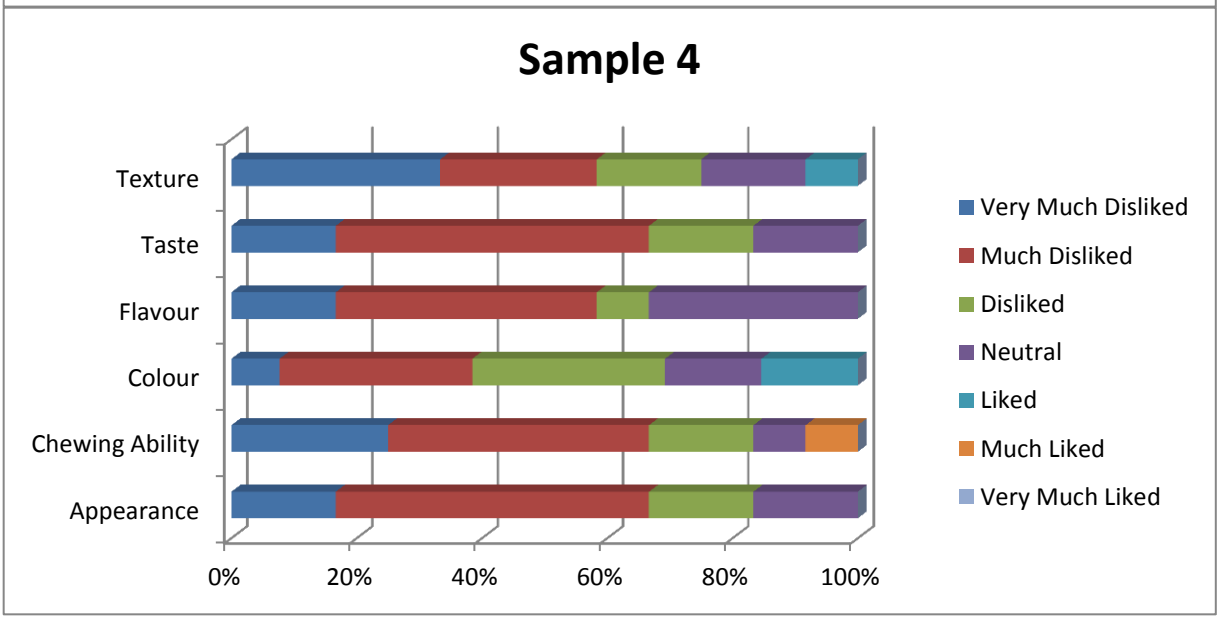

Appearance
7
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
S.D.
Average

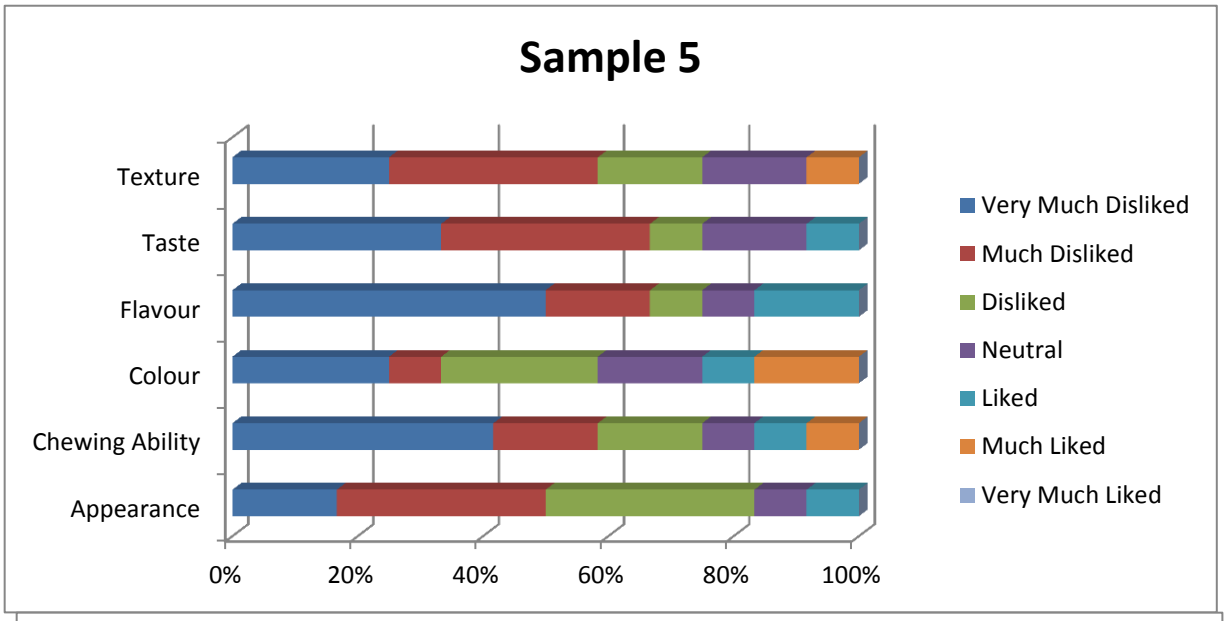

Taste
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
SD
Average

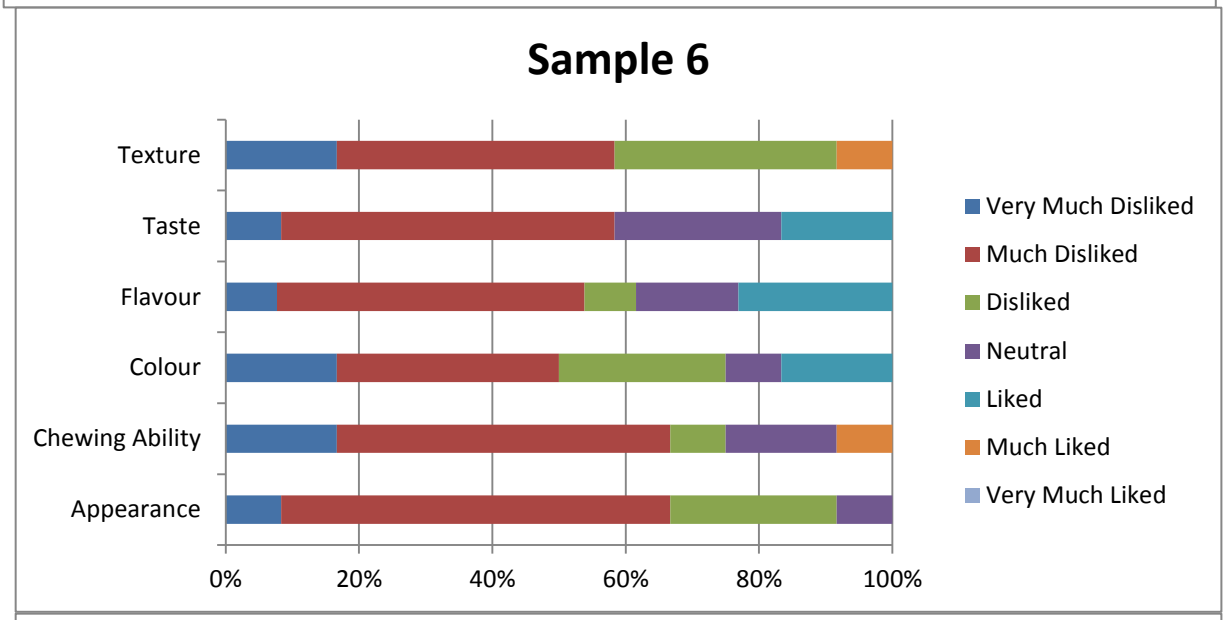

Flavour
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
SD
Average

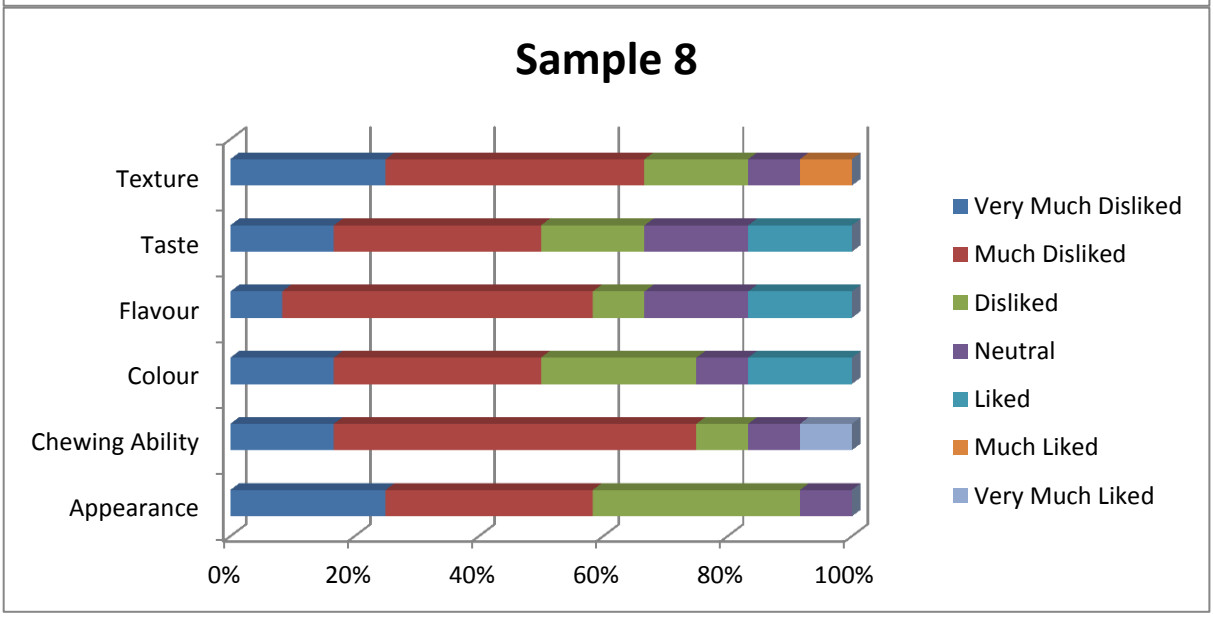

Sample 2
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked

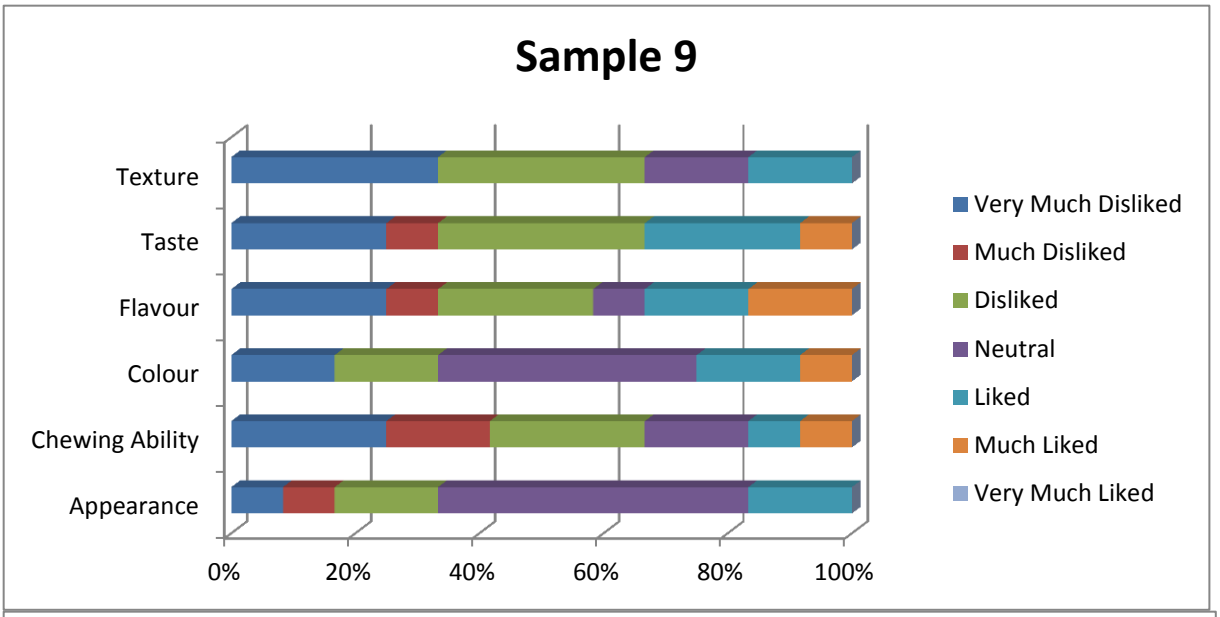

Sample 3
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked

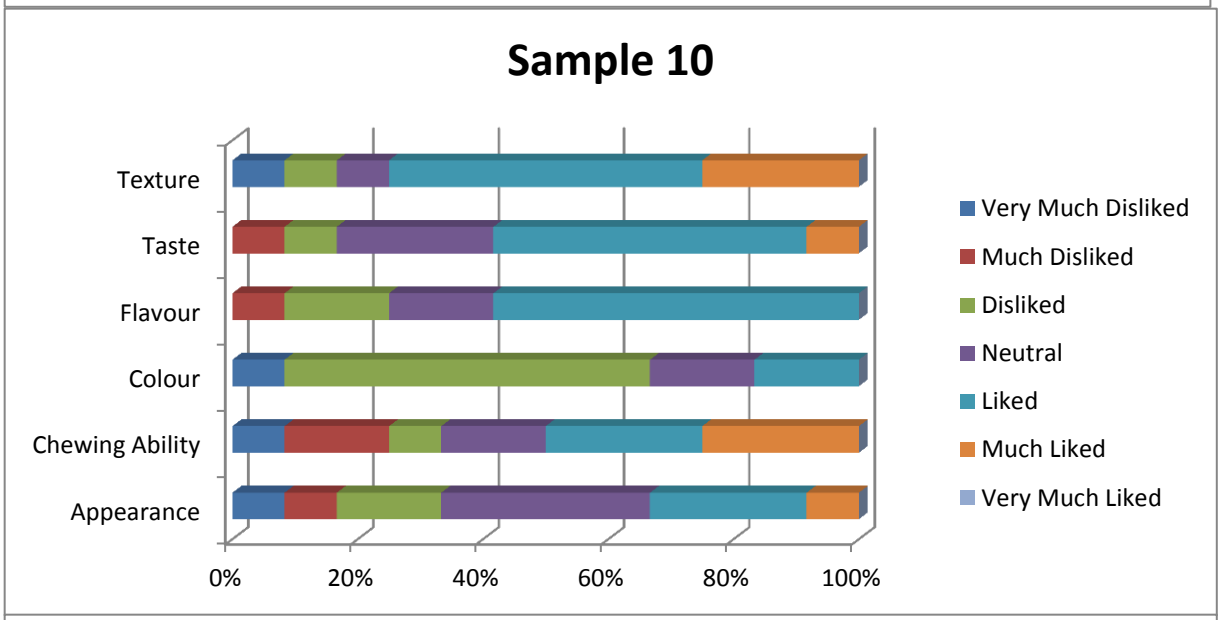

Sample 4
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked

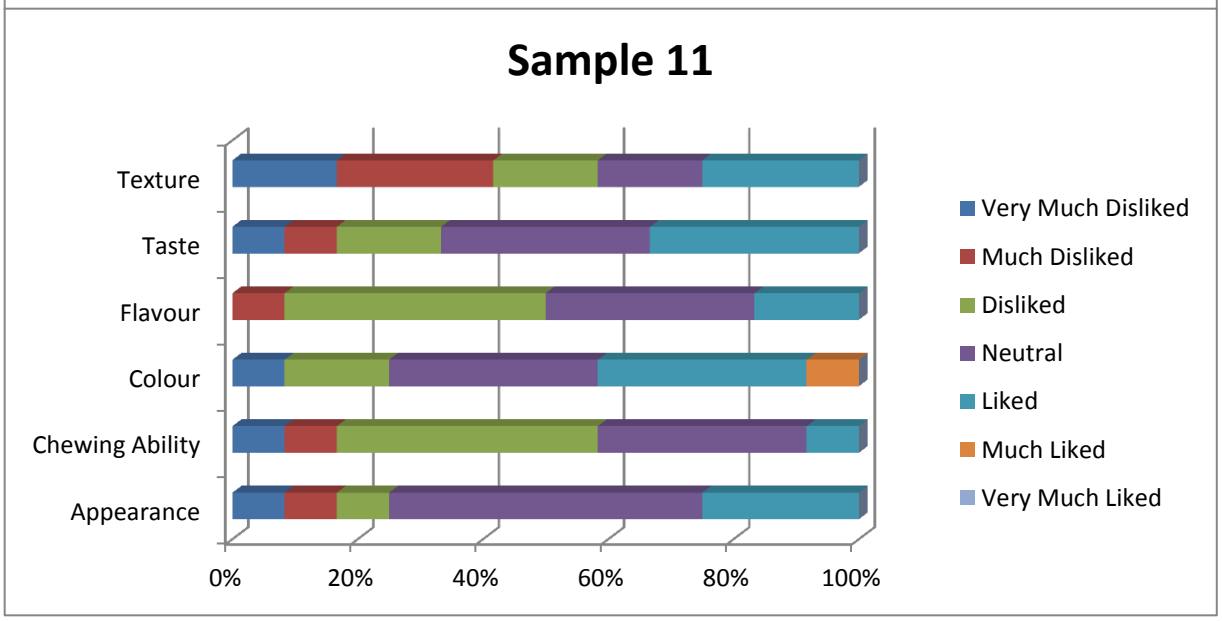

Sample 5
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked

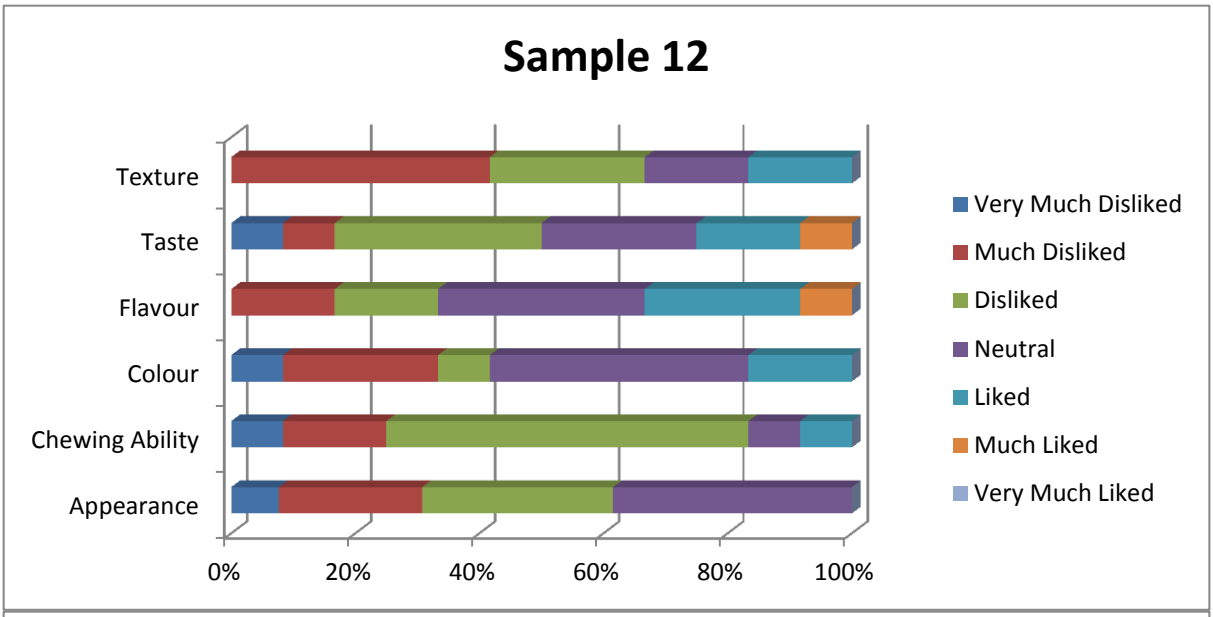

Sample 6
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked

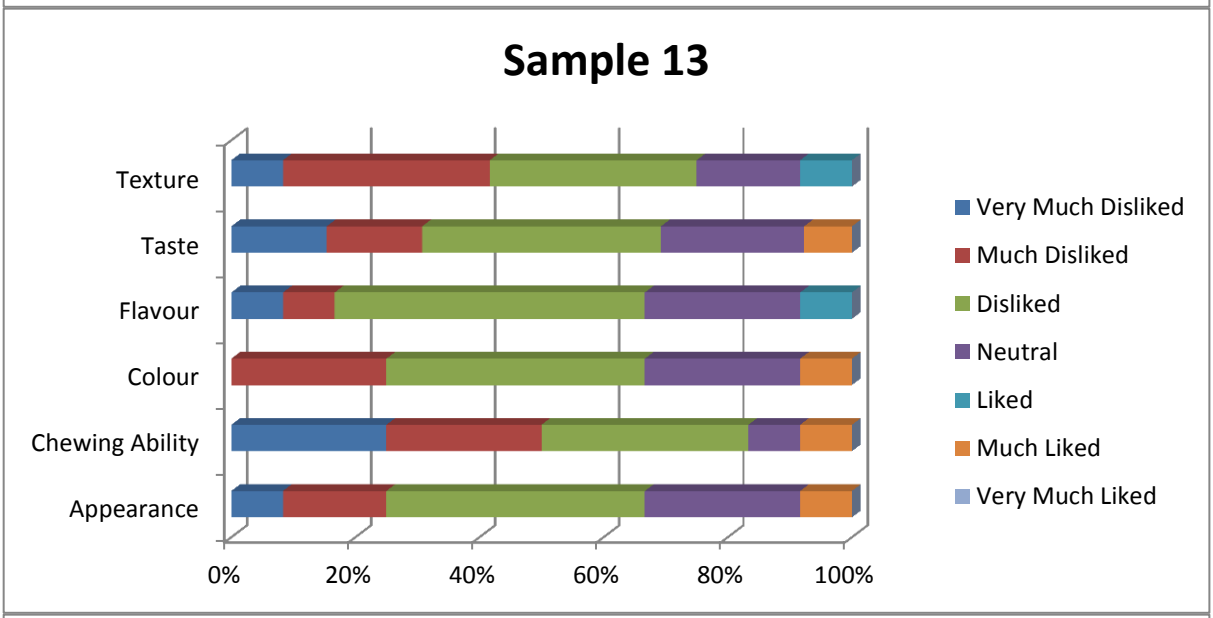

Sample 8
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked

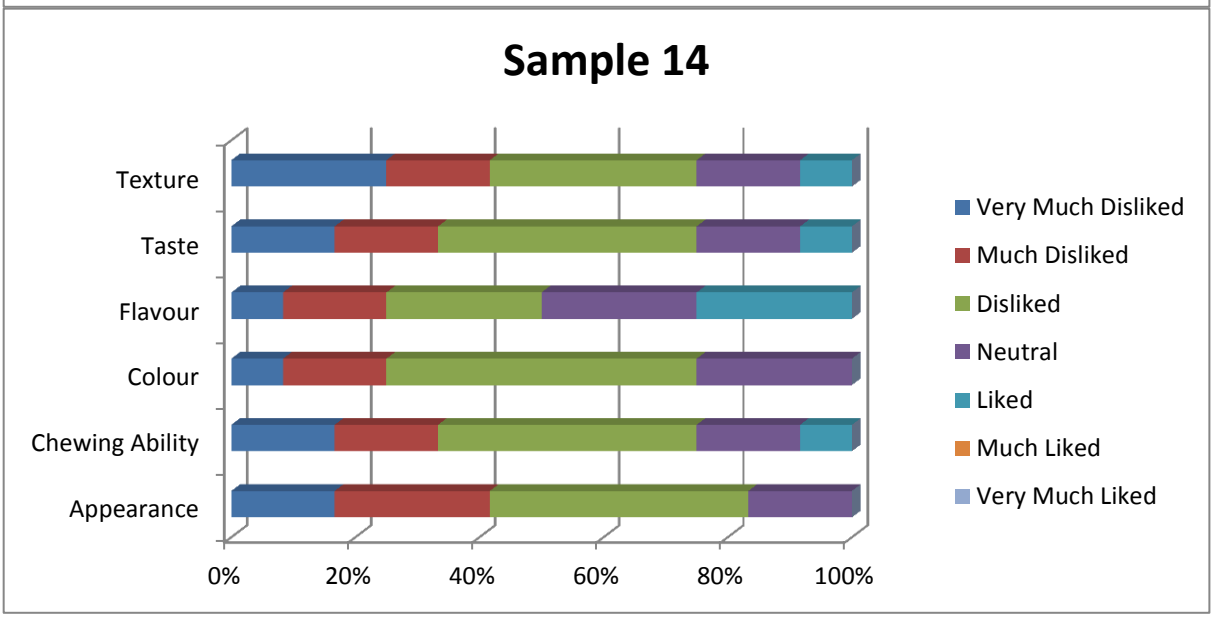

Sample 9
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked

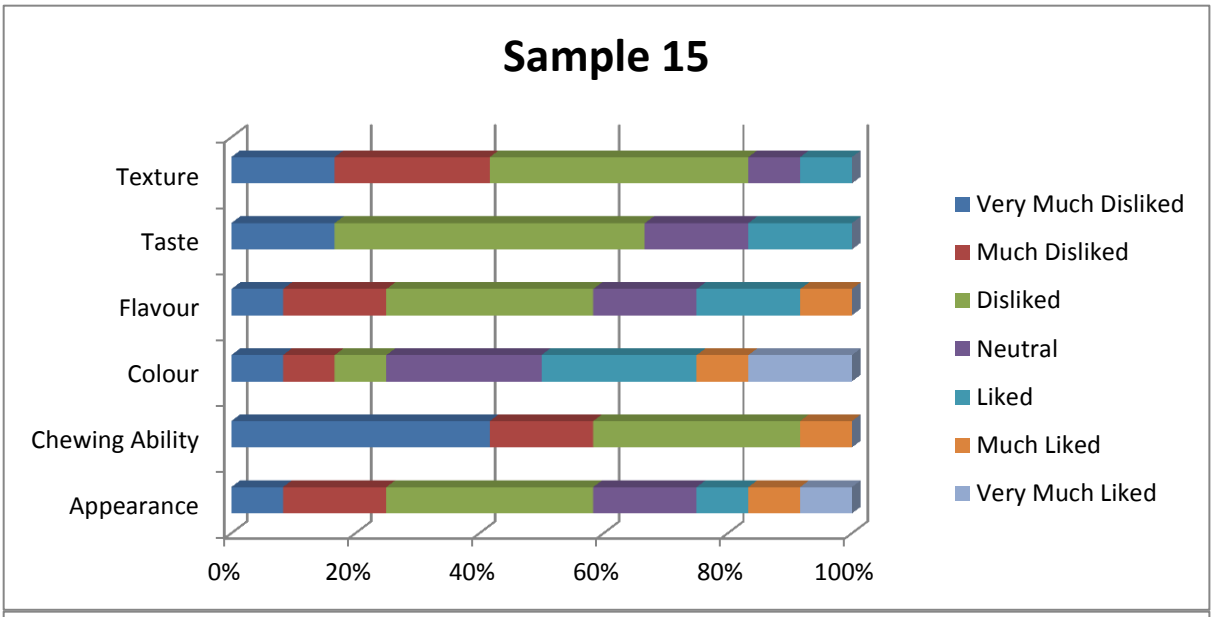

Sample 10
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked

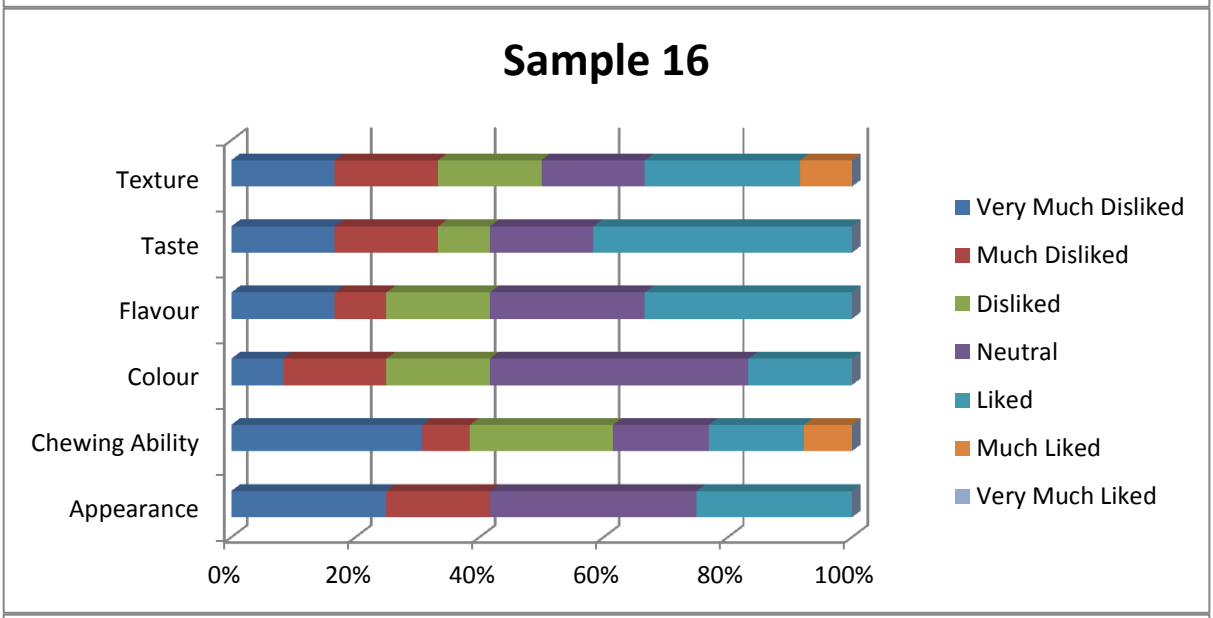

Sample 11
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked

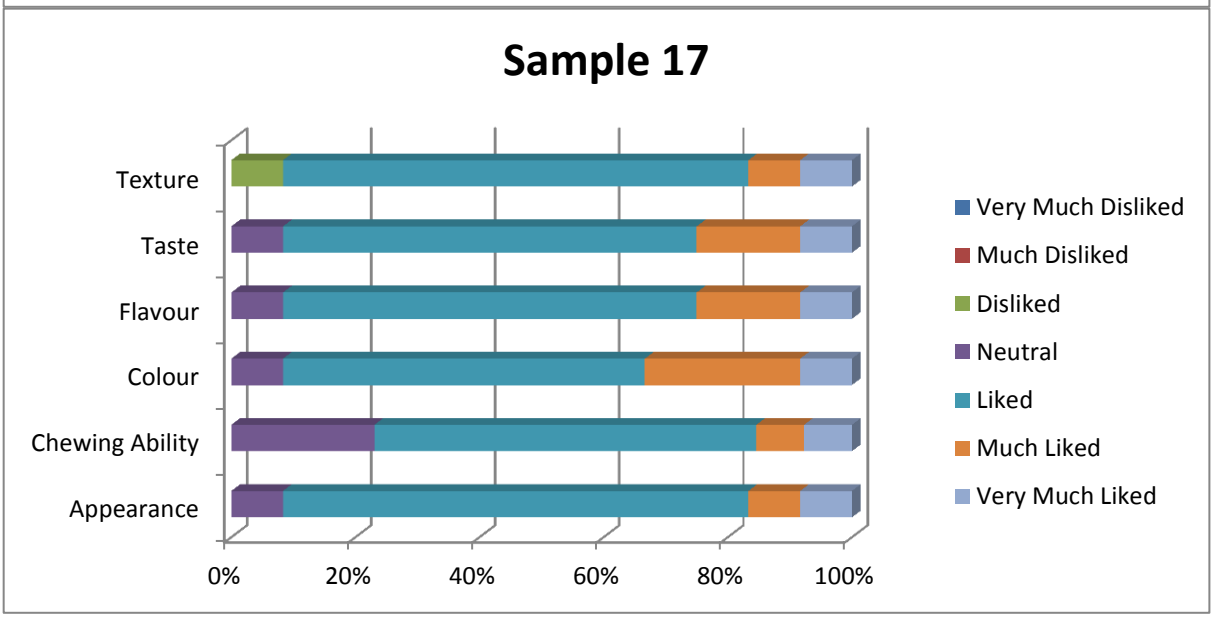

Sample 12
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked

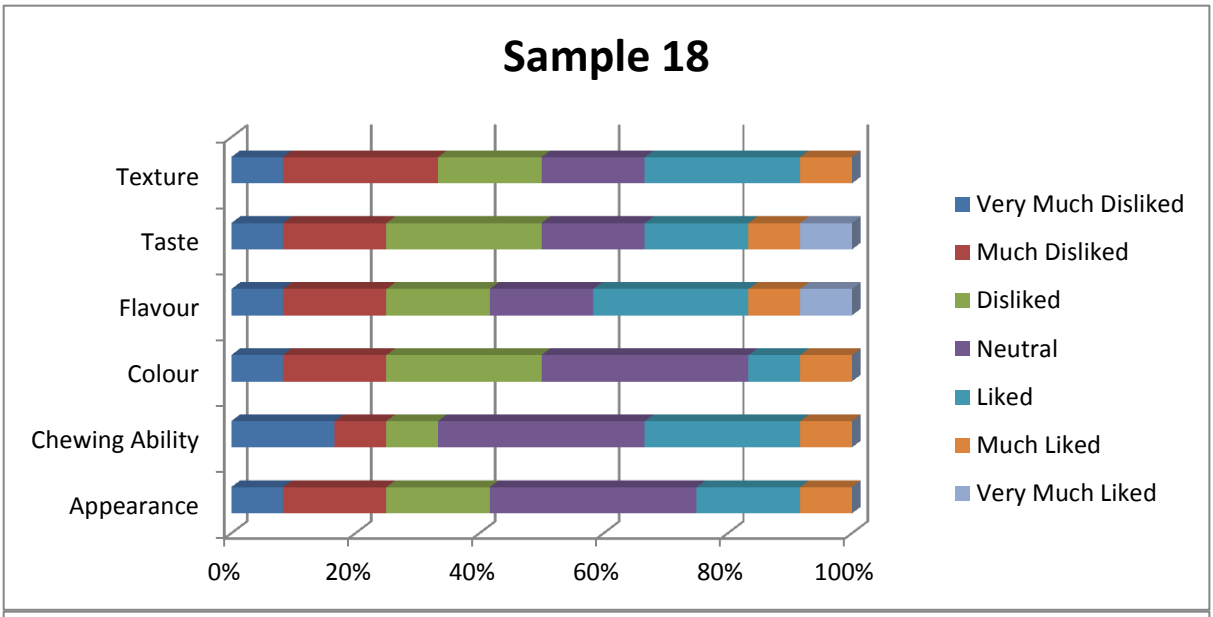

Sample 13
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked

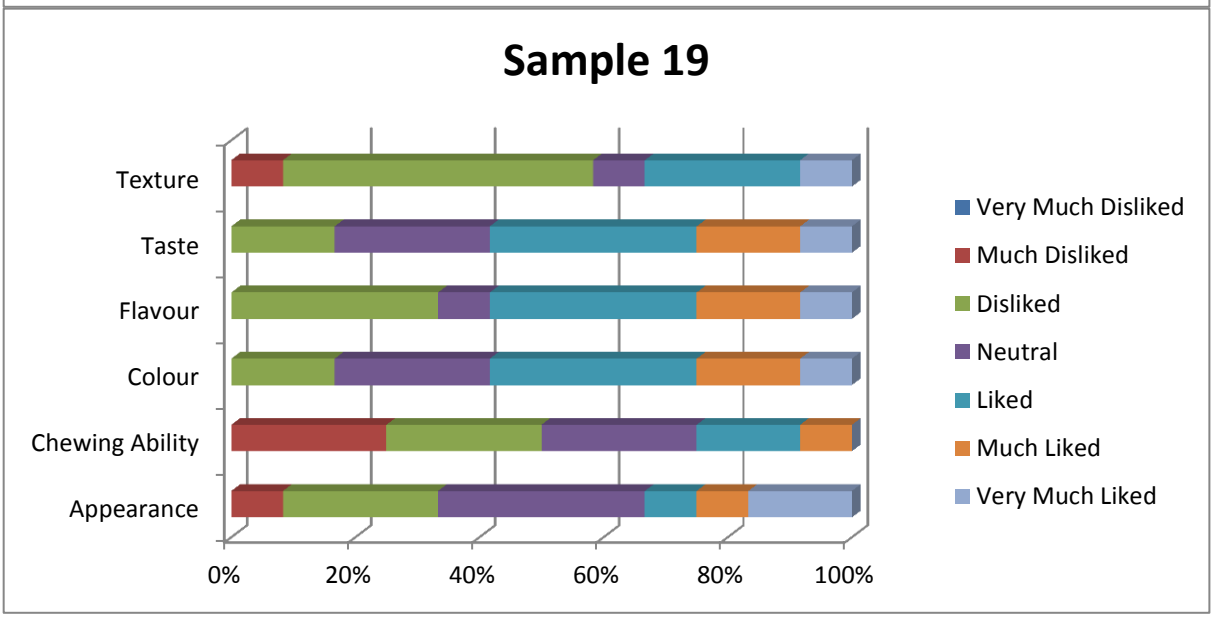

Sample 14
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked

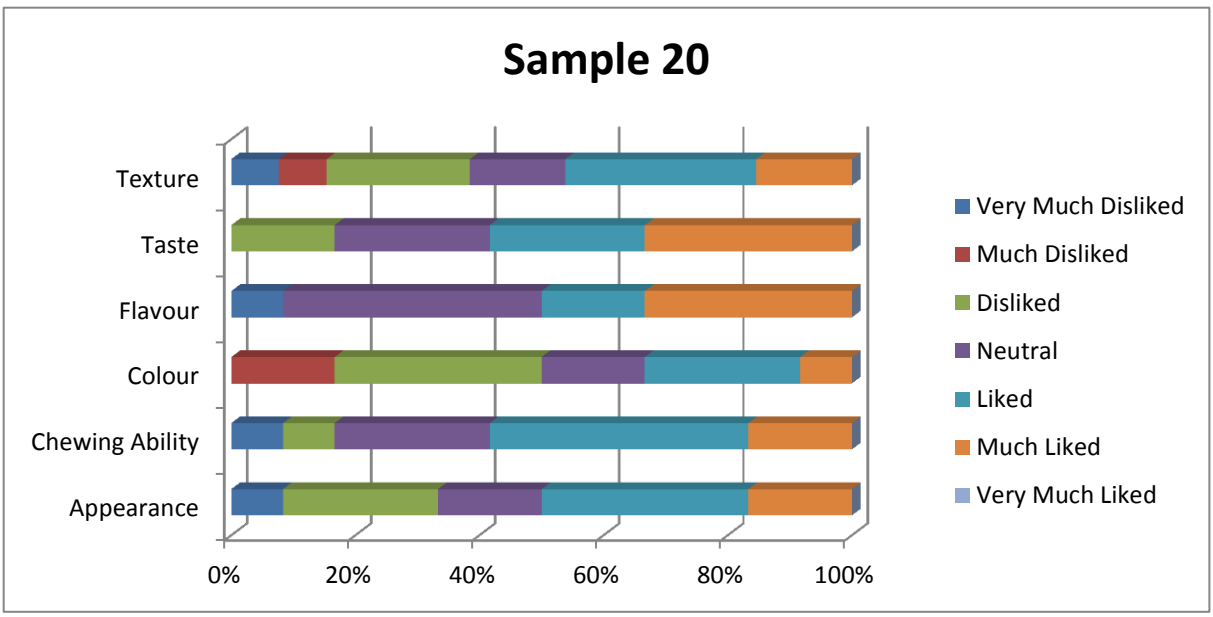

Sample 15
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked

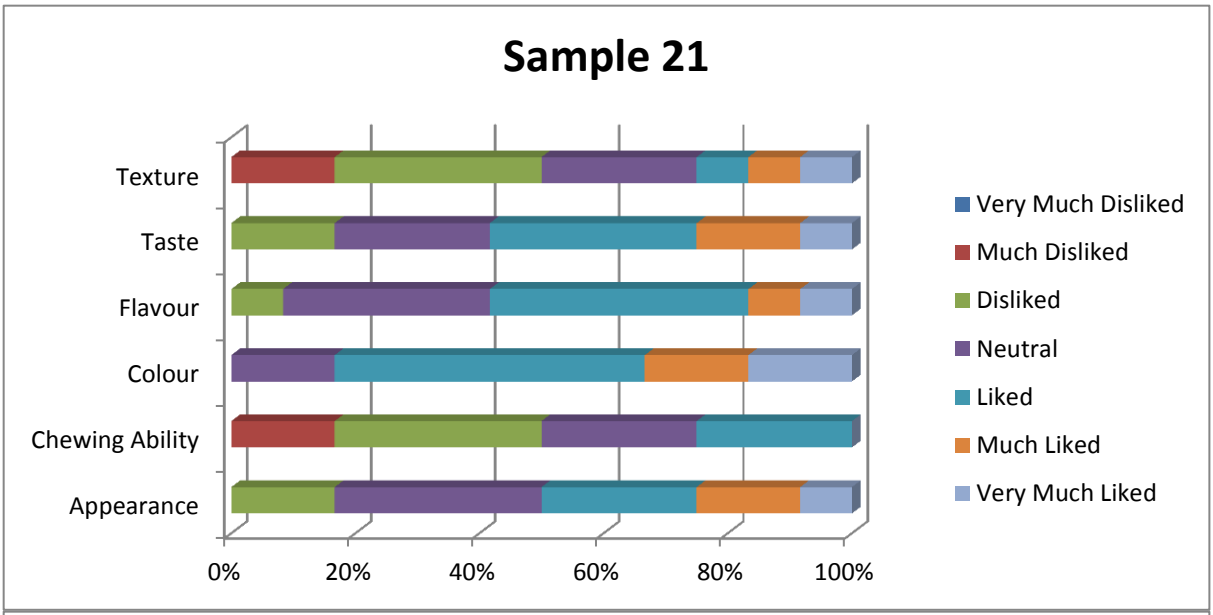

Sample 16
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked

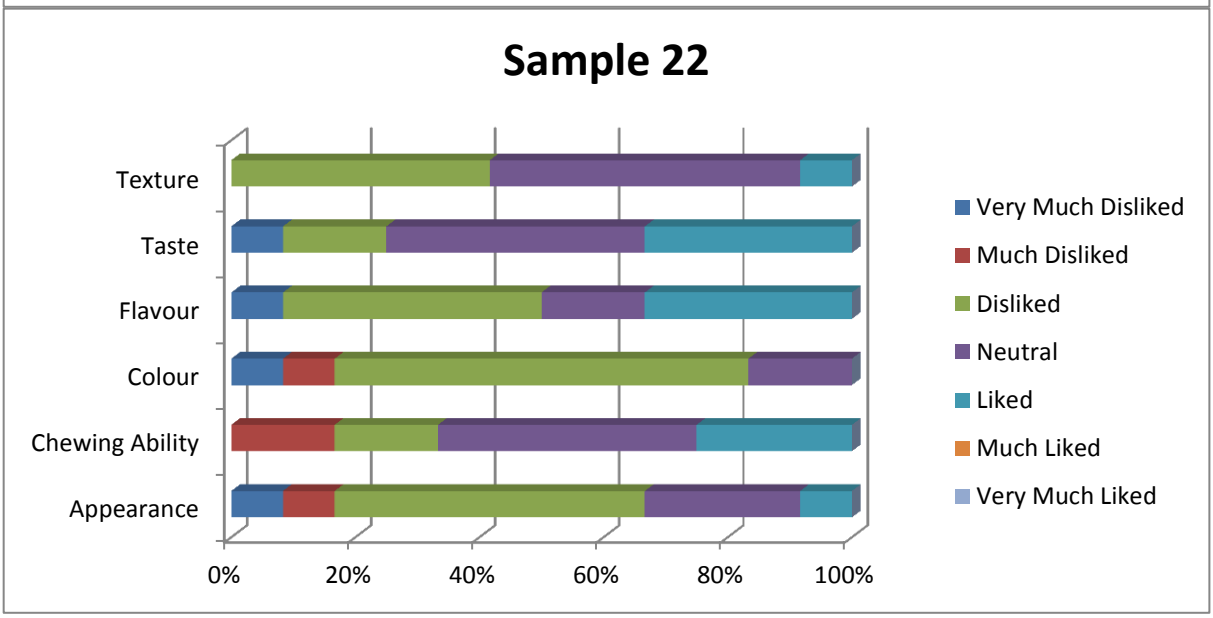

Sample 17
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked

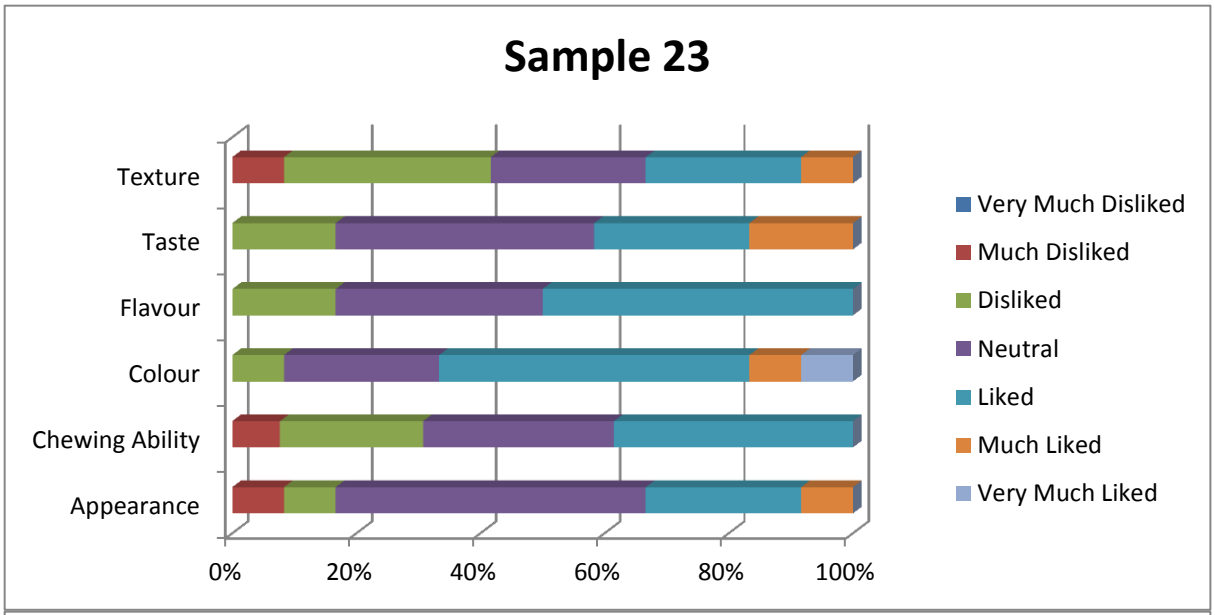

Sample 18
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked

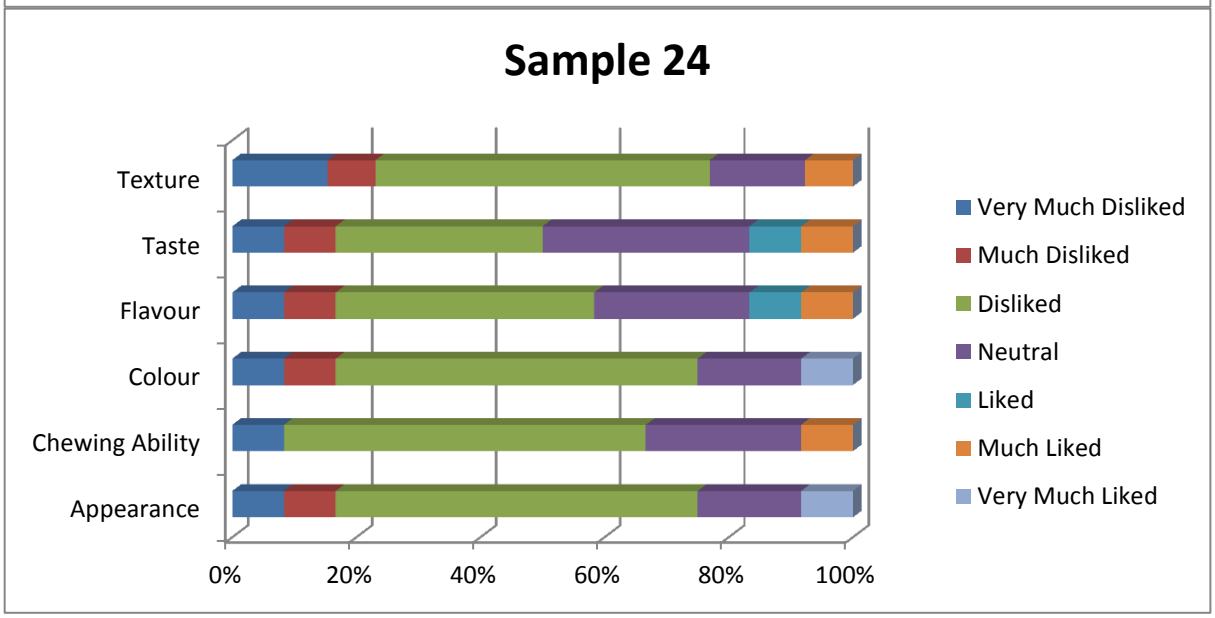

Sample 19
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked


Sample 20
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked


Sample 21
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked


Sample 22
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked


Sample 23
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked


Sample 24
Texture
Taste
Flavour
Colour
Chewing Ability
Appearance
0%
20%
40%
60%
80%
100%
Very Much Disliked
Much Disliked
Disliked
Neutral
Liked
Much Liked
Very Much Liked