UNIVERSIDADE
EDUARDO
MONDLANE

Faculty of Engineering
Department of Chemical Engineering

Development of rehydratable peanut sauce:

Quantification of Polyphenols

Maputo, August 2016

Author:

Yula Américo Ugembe

Development of rehydratable peanut sauce: Quantification of Polyphenols

Dissertation presented to the Faculty of Engineering,
-Chemical Engineering Department
as a requirement for obtaining the degree of
Master of Science in Food Technology

Supervisors:

Prof. José da Cruz Francisco,

Prof. Björn Bergenståhl and Prof. Ingegerd Sjöholm

Maputo, August 2016

Declaration of originality statement.

I hereby declare that this dissertation has never been presented in any other University to obtain any degree it is the result of my own hard and humble work. This dissertation is presented in partial fulfillment for obtaining the master degree in Food Technology at Eduardo Mondlane University.

Maputo, August, 2016

(Yula Américo Ugembe)

Acknowledgement

In order for any research work has quality, it is necessary the collaboration of various stakeholders. Therefore, the present research could not have exception. First of all, I would like to thanks, Prof. José da Cruz Francisco for the opportunity given to conduct my experiments in Sweden, without forgetting the monitoring given, dedication, and encouragement in the choice of the research topic, as well as the supervision of my work. The Swedish supervisors at Lund University, especially Profs Björn Bergenståhl, and Ingegerd Sjöholm for monitoring and encouragement in carrying out the work. I cannot forget Doctor Telma Magaia who was like a mother to me in the Swedish environment "Kanimambo". To Doctor, Borges Chambal goes my humble thanks for the practical and theoretical lessons in Sweden. My thanks are extended to Doctor Lucas Tivana especial and all the lectures of the faculty of engineering especially department of chemical engineering who tirelessly teach with love, respect and affection. To Eng. Virginia, by the practical lessons of using laboratory equipment, and dr Candida Mavie for the greater contribution in the practical part of my research work.

To my Director Prof. Doctor Simião Balane for the encouragement of keeping my studies on, to my boyfriend Fernando Chivale for understanding and giving me the motivation to keep going even in critical circumstances.

I would like to thank God for the gift of life and watching my back always, finally my parents Graça Ugembe and Américo Ugembe for the tirelessly teaching that have been giving me since my childhood, there goes my humble thank you. To my brothers Ferdino Ugembe and Renato Ugembe, it goes my thank you for understanding my studying time, lastly to everyone who directly and indirectly contribute to my dream of becoming master in Technology of food becomes a reality.

At last, thanks to all my fellow classmates of master's degree for to fellowship we developed during the journey of our studies, in especially to João Sambo and Graça Muaga.

Contents

Resumo

O caldo de amendoim faz parte das tradições culinárias de Moçambique principalmente na região sul de Moçambique (Maputo, Gaza e Inhambane). Normalmente, a sua preparação leva muito tempo (mais de 2horas) e para aquilo que são as características das cidades no caso concreto de Maputo, é inconveniente prepara-lo durante a semana. Com o propósito de reduzir o tempo de preparação do caldo desenvolveu se um caldo reconstituível á base de amendoim. A obtenção do caldo desidratado consistiu em usar as amostras de grãos de amendoim, trituradas para a obtenção da farinha. Foram pesadas 100g de farinha para 3 litros de água (temperatura ambiente) a seguir procedeu se a cozedura a 100^0C e 80^0C respectivamente durante 150 min e 512 min. A pasta de amendoim obtida foi submetida secagem a 50^0C (T1) e 100^0C (T2) respectivamente, com velocidade do ar constante (3m/s) para os dois tipos de secagem. Determinara-se os compostos fenólicos foram resultantes com base no plano factorial de 2^n sendo $n\neq0$. O conteúdo de polifenóis foi analisado, usando espectrofotometria e os resultados para a cozedura a 100^0C foram de 78.09mg/L aos 0 min e o valor máximo de 140,8mg/L aos 128min, para a cozedura a 80^0C os resultados foram de 82.82mg/L e de 141.3mg/L aos 0 e 512 minutos de cozedura respectivamente. Quanto maior a temperatura maior foi concentração de compostos fenólicos observada. A análise sensorial demonstrou que quanto maior for a temperatura e o tempo de cozedura menor será o sabor adstringente. Quanto às características físicas do caldo desidratado, a cor demonstrou para valor de Chroma de 20.56 e Hue^0 78.68^0 para a T1,e para o valore a T2 o chroma foi de 24.01 e Hue^0 66.83^0, estes valores significam que verificou-se uma cor castanho-escuro para a amostras submetidas a T2 e quanto ao Hue^0 a secagem a T1 apresentou uma cor castanho-clara, a temperatura tem um efeito na qualidade do produto quanto mais alta for maior será a intensidade da cor do alimento. O pH apresentou 6,71 e 6.47 para T1 e T2 respectivamente, estes valores encontram-se próximo a um pH neutro. A humidade e actividade da água foram de 2.30%, 0.36 paraT1 e 1.36%, 0.35 para T2. Estes valores demonstram que no caldo de amendoim não existem condições para o crescimento de microrganismos patogénicos, podendo este ser considerado um alimento seguro. A re-hidratação do caldo da amostra a T1 (50g para 600ml de água durante 15min) foi a que apresentou melhores resultados no que concerne a estabilidade da proteína e a formação ou expansão da espuma a 100^0C de cozedura.

Palavras-chaves: caldo de amendoim hidratável, polifenóis, sabor adstringente.

Abstract

The peanut sauce is one of the Mozambican traditional cookery, which is most common cooked in the south part of Mozambique (Maputo, Gaza, and Inhambane). To prepare the peanut sauce it takes long time (more than 2hours), therefore, for the characteristics of urban cities e.g. Maputo, it is not convenient during the week. In order to a rehydratable sauce using peanut was developed. To obtain the dehydrated 100g of peanut flour in 3L of water (room temperature) were used, followed by cooking at 100^0Cand 80^0C respectively during 150 minutes and 512 minutes, and the peanut sauce obtained submitted to drying at 50^0C (T1) and 100^0C (T2) respectively, at a constant air speed of 3m/s. Phenolic compounds content was determined based in the factorial plan of 2^n ($n\neq0$), using Folin reagent, using spectrophotometric method. The results of phenolic compounds at 100^oc were 78.09 mg/L for 0 minute and the maximum value of 140.8mg/L for 128 minutes. For cooking at 80^0C the results were 82.82mg/L and 141.3 mg/L for 0 and 512 minutes of cooking, respectively. The higher the cooking temperature, the higher the content of polyphenol compounds obtained. The sensory analysis showed that the higher the temperature or cooking time, the lower is the astringent taste. The physical characteristics of the dehydrated sauce, the colour demonstrated for the Chroma value of 20.56 and Hue^0 78.680 to T1 and T2 the value was 24.01 chroma and Hue^0 66,830, these values mean that there was a dark-brown colour for samples submitted and Hue^0 showed for T1 a clear brown colour, temperature has an effect on product quality the higher the greater the intensity of colour food. The pH values were 6.71 and 6.47 for T1 and T2 respectively that are near the neutral pH. The humidity and water activity were 2.30%, 0.36 for T1 and 1.36%, 0.35 for T2. These results show that in the peanut sauce, there are no conditions for the growing of pathogenic microorganisms; therefore it can be considered a safe food. The rehydration of the sample sauce of T1 (50g for 600ml of water during 15minuts) has shown the best results concerning the protein stability and formation or foam expansion at 100^0C.

Keywords: rehydrate peanut sauce, polyphenols, astringency, flavour.

Abbreviations

AOAC- Association of Official Analytical

5AV- 5-avenasterol

a_w-Water activity

BMI- Body mass index

CA- campesterol

CAE- Caffeic acid equivalents

CHD- coronary heart disease

CI- Confidence interval

CV- Coefficient of variation

DM -diabetes mellitus

FCP- Free-Choice Profiling

HDL- high density lipoprotein

HPLC- High-performance liquid chromatography

LDL- low density lipoprotein

PPO- polyphenol oxidase

rpm- Rotations per minute

RVP- Relative Vapour Pressure

SD- Standard deviation

ST- stigmasterol

T1- drying temperature at 50^0C

T2- drying temperature at 100^0C

TPC-Total phenolic compounds

USAID- United States Agency for Internacional Development

wt/wt- weight / weigh.

List of tables

List of Figures

1.0 Introduction

Groundnut, or peanut, is commonly called the poor man's nut. However, it is an important oilseed and food crop. This plant is native to South America and has never been found uncultivated. The botanical name for groundnut, *Arachis hypogaea Linn,* is derived from two Greek words, *Arachis* meaning a legume and *hypogaea* meaning below ground, referring to the formation of pods in the soil. Groundnut is an upright or prostrate annual plant. It is generally distributed in the tropical, sub-tropical and warm temperate zones. Groundnuts especially those produced in the developing countries have been used traditionally since the origin of humanity. It is rich in oil and protein and has a high-energy value. Developing countries account for nearly 95 percent of world production (Nautiyal, 2002).

The edible parts of peanuts consist of the kernel and protective skin. The skin has a pink-red colour and astringent taste, and is typically removed before peanut consumption or inclusion in confectionary and snack products. However, peanut skin is rich in phenolic and potentially other health promoting compounds (Miller & Rice-Evans, 1995; Renaud & de Lorgeril, 1992).

The consumption of nuts has been shown to be beneficial to health. This is primarily due to their desirable lipid profile, which is higher in unsaturated fatty acids than in saturated fatty. In addition to their nutrient composition, peanuts contain certain bioactive compounds that may also play a role in the reduction of the risk for the development of chronic diseases.

Polyphenols occur in nature in free or bound forms; thus, some processing methods such as boiling or heating have been shown to increase the polyphenolic content of foods (Chukwumah *et al*., 2007).

Soluble carbohydrate profile indicates peanut flour is low raffinose content (0.14%) and stachyose (0.71%) compared than commercial soy flour, two poorly digestible sugars soy flour from commercial production contains about seven times this level. These sugars are considered difficult to digest and those responsible for flatulence in humans, which is an important factor in the formulation of infant and dietetic foods (Ayres *et al.,* 1974).

It is important to development product related with our cultural and tradition, therefore important to development a rehydratable peanut sauce and to know the amount of polyphenol compounds and, what happens with the compounds during the cooking

process. Peanut sauce is a typical dish of the Mozambican culinary, particularly the south of the country, including Maputo, Gaza and Inhambane provinces. It can be prepared with chicken, bovine meat, with vegetables and dried shrimp. The ingredients include dried and pounded raw peanuts, salt, onion, coconut milk (especially in the Inhambane province) and tomato, etc. (https://pt.wikipedia.org/wiki/Caril_de_amendoim).

The development of the peanut sauce, aims also to contribute to the addition of technologically processed foods, rich in nutrients that preserve the characteristic of the unprocessed food, and the reduction of meals preparation time. The ingredients for a peanut sauce are diverse accounting with their availability. For the proposed study we are going to concentrate in a template that can later be modified according to the will and ingredient availability.

2.0 Objectives

2.1 General

The general objective of the present work is to develop a rehydratable dried peanut sauce.

2.1.1 Specific

Specifically it is intended to

- Elaborate a formulation that preserves the functional properties of dehydrate peanut sauce;
- Quantify polyphenols in peanut sauce;
- Verify sensory quality of the peanut sauce and compare it with the home made sauce consumed by the Mozambican population;
- Determine the physical compos characteristics of rehydratable peanut sauce.

3.0 Justification

In this work the focus of interest is the peanut which is classified within the family of legumes; it has more protein than meat and eggs, and is also rich in energy, minerals and vitamins. It is also an important food for children, pregnant and nursing women. The peanut has many uses: it can be eaten raw, boiled, roasted, and toasted and as flour and even as milk. The peanut is of great economic importance, especially in the food industry. Some varieties have a large amount of lipid and have been used for the manufacture of cooking oil (give 45 to 50% of oil). In parts of Africa, peanuts are ground to cook several dishes of the local cuisine, which are so rich in lipids and proteins (USAID, 2010).

Even today, there are populations in the world with food shortages for protein products, especially where animal protein is not easily accessible. Great efforts have been made to increase the availability of this nutrient in food, using new richest plant sources of protein. The diversification of food, from the inclusion of other legumes like peanuts, either fresh or in the form of derivatives, can help minimize this need, besides enriching the diet (Santos *et al.,* 2006).

Epidemiological and intervention studies have shown that the frequent consumption of peanuts promotes cardiovascular health by lowering serum low density lipoprotein (LDL)-cholesterol levels and reduces the risk of development of type II diabetes (Fraser *et al.,* 1992 & Jiang *et al.,* 2002). It has also been shown to promote weight management when consumed as part of a moderate fat diet as a result of its satiating effect (Higgs, 2005)

In addition to look up what is the reality of Mozambique, most restaurants don't prepare meals based on peanut maybe because of its time consuming. We believe that with a rehydratable peanut sauce the situation may change as a technologically developed food can reduce the time to prepare this type of food, and can also contribute to diversify the diet.

In Addition, rehydratable peanut sauce is a technologically product obtained that will make it easier for consumer prepare at home and/or enhance the peanut products availability in their culinary practices.

4.0 The Problem

Mozambique is a country in a full development, that has registered higher urban growth, accompanied by a characteristic lifestyle of big cities, e.g. Maputo city, where the inhabitants have not much time to stay in their homes., thus, they are subject to forget their eating habits, which are part of their tradition and ending even not consuming some typical and healthy dishes of their culture. In the southern region of Mozambique the consumption of peanut sauce is part of the culinary traditions of individual. To the peanut flour are incorporated different types of meats, crushed cassava leaves, cowpeas leaves, pumpkin leaves among others, but all these dishes take a long time in preparation, more than 2 hours (depending on how each one prepares). Why consumers take a long time when cooking, which scientific aspects are connected to this delay, what scientific bases are connected in the perception of peanut sauce; all these aspects are the focus to understand scientifically the meals of our culture and culinary tradition.

5.0 Hypotheses

- H0: The presence of polyphenols in peanut grain contributes to the delay of peanut sauce cooking;
- H1: The presence of polyphenols in peanut grain does not contribute in delaying peanut sauce cooking**.**

6.0 Literature review

6.1 Production of peanuts in Mozambique

Mozambique has 49 million hectares of arable land with agricultural potential however only 5 million hectares are being used. The agriculture and fisheries have a 31% weight in GDP (Gross Domestic Product) and involve approximately 80% of the population. Unfortunately still 98% of agriculture is based on rudimentary production techniques and only the remaining 2% on commercial agriculture. The limited diversity of production leads to poor levels of nutrition with serious implications for public health of the poorest people. This is reflected in the data presented by the health ministry, where just under half of the population has chronic malnutrition. Peanuts are one of the main oilseeds in Mozambique, grown mainly by small holder farmers. Farmers use little or no technology, and aims to meet production mainly unprocessed product consumption. Peanut adapts to dry climates, having the ability to enrich the soil through nitrogen fixation, a particularity of legumes. The chain value in peanut Mozambique has limited development, mainly because of lack of product quality control, especially as it relates to aflatoxin. Aflatoxin is a highly toxic metabolite produced by the fungi *aspergillus flavus* and *parasiticus*. In Mozambique the peanut has a very important role in the diet of both the rural and urban populations. It is also important in generating income for women in ruralities, being sold for consumption in roasted peanut, fresh or groundnut to cook traditional dishes; the following is Table 1 about peanut production in the country (Jasse, 2013).

Table 1: Production of peanut in Mozambique (Jesse, 2013)

Element	unit	2005	2006	2007	2008	2009	2010
Area harvested	ha	293.000	295.000	295.000	295.000	295.000	295.000
Production	ton	93.000	85.977	102.932	94.454	68.000	70.000
Productivity	Kg/ha	317	291	348	320	230	237

The peanut market in Mozambique is increasingly competitive and should mainly to the decrease in supply and demand of southern Mozambique and South Africa. South Africa has a limited and variable production due to less favourable weather for the culture of this

product. The Exports to Europe also already is a reality although there is tight control on the import of European countries due to aflatoxin (Jasse, 2013).

6.2 Consumption of peanuts and peanut products

As a major peanut uses, may refer to use of the seeds directly on to food and oil extraction. But the peanut has other uses. Are mature seeds that have more use, and can be eaten raw, boiled or roasted. May also made into peanut butter or used for making soup, appetizers and cakes. And the sauces that accompany the meat or rice in Africa often have peanuts in their composition. In Nigeria, peanut meal is used in the making of one of the main dishes. Peanuts may also be fermented and used to produce an alcoholic beverage, such as in South America. Around half peanut produced worldwide is intended for the oil extraction industry, which is then used in the food industry but also in the cosmetics industry, and others. The resulting paste of oil extraction is rich in protein. In Indonesia, this folder is fermented and fried for human consumption. It can be processed into flour for food but can also be targeted to the industry for manufacture of glues, fabrics or other products (Ntare, 2006).

Among the peanut eating people of the world, roasting and salting is the most preferred way of eating. Of the various ready-to-eat (RTE) foods of peanuts, roasted nuts are the most popular ones. About 60% of the peanuts harvested outside the United States are crushed and used for oil extraction while 70% of the United States crop is used for food purposes (Lusas, 1979).

Some important food uses of peanuts in different regions of the world are listed in Table 2. In the United States, nearly 52% of the domestic edible peanut crop is used for peanut butter spreads, 23% for salted peanuts and 21% for confectionery (Evans, 1982). Peanuts are sold fresh as a vegetable, canned frozen, roasted in the shell, toasted and salted, used in more than 50% confections are bakery products and are ground into butter for use in more than 100 recipes (Woodroof, 1983). Extruded products of peanut meal and legume flour are also becoming popular as human foods in some African countries (Singh, 1985).

Table 2: Some important major food uses of peanut (Singh & Singh, 1991).

Food uses	Regions
1. Raw dry nuts	South and Central Asia, Africa
2. Fresh boil and salted	Southeast Asia, Africa
3. Fried and mixed with sugar syrup	Asia, particularly in India, Pakistan and Bangladesh
4. Fried and mixed with chick pea flour	South Asia and Mediterranean regions
5. Nuts fermented and fried	Southeast Asia, particularly Indonesia, Philippines and Thailand
6. Roasted and salted	Asia, Africa, Central and South America
7. Peanut butter	Europe, North, Central and South America
8. Candies and confections	North and central America, some European, Asian and Africa countries

6.3 Recipes of peanut sauce in Mozambique

The peanut sauce is one of the typical dishes of Mozambique, especially the southern part (Maputo, Gaza and Inhambane). For Mozambicans sauce is liquid, which is added the rice or maize porridge (htt://www.portugal-linha.pt/sabores/mocamb/ca001.html).

The dish is very popular for its slightly sharp taste, although it can be nauseating when it exaggerates the amount of peanuts (for being fatty) or coconut. The peanut sauce is a good dish, like all African dishes to accompany with chilli and a good drop (http://www.portugal-linha.pt/sabores/mocamb/ca001.html).

In some regions of Mozambique has the habit of adding coconut milk to the sauce, which makes that there are no standards of recipes in the country. The following are presented (Table 3) some recipes that illustrate how the population preparing this type of dish.

Table 3: Ingredients of the Recipes of peanut sauce (http://lifestyle.sapo.pt/sabores/receitas/caril-de-amendoim)

Recipe 1: Peanut sauce (murhu wa marhumana)	Recipe 2: Peanut Sauce Tastes // Tastes
Ingredients: dry and raw peanuts, onion, Salt; Cow meat; grated coconut optional tomatoes (fresh or pulp).	Kitchen: Mozambican Difficulty: Easy Time: Quick Ingredients Olive oil and enough chilli , 1 clove garlic, 2 tomatoes,1 onion, peanut pilado200 g, 1 chicken, enough salt

6.3.1 Recipe 1

Origin: Mozambique

Traditionally, in Africa, there are no measurements for the food preparation. Who cooks, counts with someone else. It is, therefore, difficult to say exactly the amounts of ingredients, given the number of people who will be part of the meal. For the first recipe, just have half a kilo of peanuts, a big onion, and half a kilo of meat and enough salt. Triturate peanut (for those who have pestle), and then is milled together with tomato in an earthen bowl. In modern ways, the resort is the magic wand. One time milled, the peanuts are placed in a sufficiently large container, where sets and hot water. In a pan, cut the onion into rings. If you want to add the grated coconut, also put it in a container (or even where he put crushed peanuts) and pour it hot water. The peanut is passed through a colander; extracting her milk (the rest is discarded). Do the same with coconut. Add the peanuts and coconut milk in the pan with the onion and put in the fire along with the meat, previously cut the meat into pieces. Start stir with a ladle, in continuous movement from top to bottom (taking a liquid ladle and turning it to the pan then). Do this until the liquid boils, which can take more than 30 minutes. Add salt to your taste. It is accompanied with rice or maize porridge (http://www.portugal-linha.pt/sabores/mocamb/ca001.html).

Warning: If you leave the stir will happen one of two - or water separates from the peanut and does not cook or when it starts to boil, peanut milk will tend to shed the pot (http://www.portugal-linha.pt/sabores/mocamb/ca001.html).

6.3.2 Recipe 2

The crushed peanut poured into a container with one liter of cold water. Mix everything well and leach themselves. The water will on the cooker and boil about 30 minutes. Garlic, onion, tomatoes (cut in pieces), sauté in olive oil is heated. The stew should be quick and joins then the chicken was cut into small pieces. Also joins the chilli, salt and water peanut. The sauce should thicken (http://lifestyle.sapo.pt/sabores/receitas/caril-de-amendoim).

Figure 1: Peanut sauce (https://pt.wikipedia.org/wiki/Caril_de_amendoim)

6.4 Chemical composition of peanuts

Legumes and nuts in general are important sources of protein, lipids and fatty acids necessary for human nutrition (Gaydou *et al.*, 1983). The chemical composition varies depending on the kind, cultivation, location, year and physiological maturity of the seed (Grosso *et al.*, 2000);

Peanut grain is formed by peeling or pericarp (28 to corresponding30% of) the perisperm or tegument that is the thin skin surrounding the endosperm (from 1.45 to 3.22%), the embryo (1.8 – 2 to corresponding6%) and kernel (67.70 to 71.88%). The average content of water is 5.4%, carbohydrates 11.7%, fibre 2.5% and ash 2.3% (Peixoto, 1992).

Groundnut consists mainly of protein 22–30% (Pancholy *et al.*, 1978) and oils 44–56% providing high energy source 5.64 cal/g (Cobb & Johnson, 1973). Peanut oil mainly composed of unsaturated fatty acids and is consequently susceptible to lipid oxidation (Ahmed &Young, 1982). The ratio of polyunsaturated fatty acids to saturated fatty acids of peanuts has been reported as 1.8 compared to 2.9 for soybean oil, 4.3 for corn oil and 8.7 for safflower oil (Carpenter *et al.*, 1974). Peanut oil mainly contains less linoleic acid (a relatively unstable fatty acid) than other seed oils. Oleic, linoleic, and palmitic acids account for 90% of the fatty acid profile of peanuts, although five other fatty acids are present in at least 1% proportions (Ahmed & Young, 1982).

The seeds also have satisfactory values for some vitamins (E and B complex) and various mineral elements. Potassium, magnesium, phosphorus and calcium are minerals found in the main grain and more required in the cultivation; their lack in the field results in delayed flowering and pods and malformed seeds, besides conferring the right rancid taste of grains (Bortoli *et al.*, 2005). In 100 g of peanuts there are92 mg of calcium, 168 mg magnesium, 376 mg of Phosphorus, 4.6 mg of iron and 3.3 mg of zinc. The energy value of 100 g *arachis* is 567 kcal (Ntare, 2006).

The proteins present in peanuts are classified as albumin and globulins (Andersen, 2001). Protease inhibitors and alpha-amylase inhibitors act as anti-nutritional factors, as inactivate the enzymatic activity of trypsin, chymotrypsin and amylase, hindering the digestion and absorption of protein and carbohydrates (Silva & Da Silva, 2000). Protease inhibitors and alpha-amylase inhibitors act as anti-nutritional factors, as inactivate the enzymatic activity of trypsin, chymotrypsin and amylase, hindering the digestion and absorption of protein and carbohydrates (Irshad & Sharma, 1981).

The peanut is rich in essential amino acids phenylalanine, histidine, conditionally essential amino acids and arginine, aspartic acid and glutamic acid. However, despite the high protein content, it presents lysine, threonine, isoleucine and methionine, as limiting amino acids as these are essential and which are present in small amounts (Conkerton & Ory, 1976)

The nutritional significance of peanuts, as well as nutrients and density profile of fatty acids, also is related to the presence of bioactive compounds with antioxidant properties as alpha-tocopherol, sterols and phytochemicals such as isoflavones, flavonoids and polyphenols that contribute to sequestering activity of free radicals and inhibiting the effects of lipid peroxidation and protein glycation (De Almeida *et al.*, 2011).

6.5 Polyphenols

Phenolic compounds, or polyphenols, constitute one of the most numerous and widely-distributed groups of substances in the plant kingdom, with more than 8,000 phenolic structures currently known. Polyphenols are products of the secondary metabolism of plants. The expression "phenolic compounds" embraces a considerable range of substances that possess an aromatic ring bearing one or more hydroxyl substituents. Most of the

major classes of plant polyphenol are listed in Table 4, according to the number of carbon atoms of the basic skeleton. The structure of natural polyphenols varies from simple molecules, such as phenolic acids, to highly polymerized compounds, such as condensed tannins (Bell & Charlwood, 1980).

The term ‘polyphenols’ defining those with more than one phenolic ring, which fulfil a very broad range of physiological roles in plants (Harbone, 1989). Although the bulk of these compounds play cell wall structural roles, plant tissues synthesize a vast array of non-structural constituents that have various roles in plant growth and survival. Thus, the expression “plant phenolics” embraces a highly diverse group with an extremely large structural diversity (Quideau *et al.*, 2011).

Polyphenols are the most abundant antioxidants in the diet. Their total dietary intake could be as high as 1g/d, which is much higher than that of all other classes of phytochemicals and know dietary antioxidants. Their main dietary sources are fruits and plant derived beverages such as fruit juices, tea coffee, and red wine. Vegetables, cereals, chocolate, and dry legumes also contribute to the total polyphenols intake (Scalbert *et al.*, 2005).

Flavonoids represent the most common and widely distributed group of plant phenolics. Their common structure is that of diphenylpropanes (C6-C3-C6) and consists of two aromatic rings linked through three carbons that usually form an oxygenated heterocyclic (Bell & Charlwood, 1980). Figure 2 shows the basic structure and the system used for the carbon numbering of the flavonoid nucleus. Structural variations within the rings subdivide the flavonoids into several families: flavonols, flavones, isoflavones, antocyanidins and others. These flavonoids often occur as glycosides, glycosylation rendering the molecule more water-soluble and less reactive toward free radicals. The sugar most commonly involved in glycoside formation is glucose, although galactose, rhamnose, xylose and arabinose also occur, as well as disaccharides such as rutinose. The flavonoid variants are all related by a common biosynthetic pathway, incorporating precursors from both the shikimate and the acetate-malonate pathways (Crozier *et al.*, 2000). Further modification occurs at various stages, resulting in an alteration in the extent of hydroxylation, methylation, isoprenylation, dimerization and glycosylation (producing O- or C-glycosides). Phenolic compounds act as antioxidants with mechanisms involving both free radical scavenging and metal chelation. They have ideal structural chemistry for free

radical-scavenging activities, and have been shown to be more effective antioxidants *in vitro* than vitamins E and C on a molar basis (Rice- Evans *et al*., 1997).

Table 4: The major classes of phenolic compounds in plants (Bell & Charlwood, 1980).

Number of carbon atoms	Basic skeleton	Class	Examples
6	C6	Simple phenols	Catechol, hydroquinone
		Benzoquinones	2,6-Dimethoxybenzoquinone
7	C6-C1	Phenolic acids	Gallic, salicylic
8	C6-C2	Acetophenones	3-Acetyl-6-methoxybenzaldehyde
		Tyrosine derivatives	Tyrosol
			p-Hydroxyphenylacetic
		Phenylacetic acids	
9	C6-C3	Hydroxycinnamic acids	Caffeic, ferulic
		Phenylpropenes	Myristicin, eugenol
		Coumarins	Umbelliferone, aesculetin
		Isocoumarins	Bergenon
		Chromones	Eugenin
10	C6-C4	Naphthoquinones	Juglone, plumbagin
13	C6-C1-C6	Xanthones	Mangiferin
14	C6-C2-C6	Stilbenes	Resveratrol
		Anthraquinones	Emodin
15	C6-C3-C6	Flavonoids	Quercetin, cyanidin
		Isoflavonoids	Genistein
18	(C6-C3)2	Lignans	Pinoresinol
		Neolignans	Eusiderin
30	(C6-C3-C6)2	Biflavonoids	Amentoflavone
n	(C6-C3)n	Lignins	
	(C6)n	Catechol melanins	
	(C6-C3-C6)n	Flavolans (Condensed Tannins)	

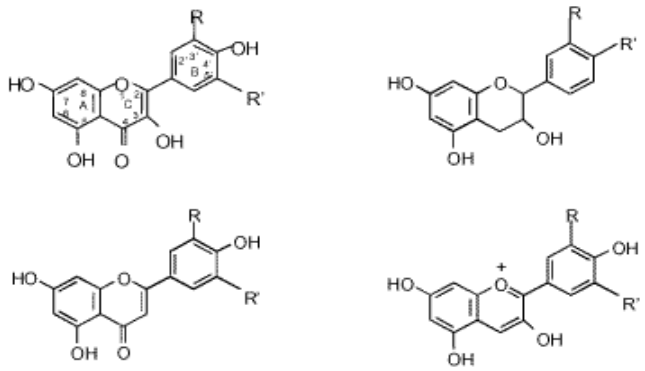


Figure 2: Flavonoids (C6-C3-C6) Basic structure and system used for carbon numbering of the flavonoid nucleus. Structural variations within the rings subdivide the flavonoids into several families (Crozier *et al.*, 2000).

These secondary (polyphenols) plant metabolites are distributed ubiquitously within plant foods (vegetables, cereal, legumes, fruits, nut and so on) and beverages (tea, wine, cocoa, and so on). Their levels vary greatly even between cultivars of same species. Environmental factors such as light, germination, degree of ripeness, variety, processing and storage, and genetic factors (see table 4) can influence the levels. Currently there is no accurate information available on dietary intake of polyphenols; only a few estimates are available which are 1g/day (US), 23mg day (Dutch) and 28 mg/day (Denmark) (Bravo, 1998).

Table 5: Polyphenolic content of different from plant food and beverages (Bravo, 1998)

Food	mg/100g dry matter
Cereals	22-102.60
Legumes	34-1710
Nuts	0.004
Vegetables	6-2025 (mg/ fresh matter)
Fruit	2-1200(mg/ fresh matter)
Beverages	
Tea	150-210 (mg/200ml)
Red wine	1000-4000 (mg/L)
White wine	200-300 (mg/L)

6.5.1 Biosynthesis of Polyphenols

The phenolic compounds, phenolic acids such as gallic acid and cinnamic acid are considered to be metabolites of the shikimate pathway. Biosynthesis of complex polyphenols such as flavonoids is linked to primary metabolism through plastid and mitochondrial derived intermediates, each requiring export to the cytoplasm where they are incorporated into separate parts of the molecule. The aromatic ring B and the chromane ring are considered to originate from the amino acid phenylalanine, itself a product of the shikimate pathway, whereas Ring A from three units of malonyl-CoA(Fatland, 2002; Tsao, 2009). These three malonyl-CoA units are added through sequential decarboxylation condensation reactions, which initiate flavonoid biosynthesis.

Phenylalanine ammonia lyase (PAL) is a key enzyme of the phenylpropanoid pathway which catalyzes the conversion of phenylalanine to cinnamate, which then leads to the C6–C3 structures. The final intermediate 4-coumaroyl-CoA and three molecules of malonyl-CoA are then condensed to yield the first flavonoid structure naringeninchalcone by the enzyme chalcone synthase (CHS). Chalcone is isomerized by chalcone flavanone isomerase (CHI) to a flavanone. This flavanone intermediate is pivotal because it is essentially from where all classes of flavonoids-including their subgroups-branch out. Chalcone is also where isoflavones and coumestrols branch out from through different enzymes including CHI and isoflavone synthase (IFS). For example, the intermediate (2S)-flavanones are catalyzed by flavanone 3-hydroxylase (F3H) to dihydroflavonols, which are then reduced by dihydroflavonol reductase (DFR) to flavan-3,4-diols (leucoanthocyanins), which are converted to anthocyanidins by anthocyanidin synthase (ANS). Glucosylation of flavonoids is catalyzed by glucosyltransferase (Bohm, 1998; Tsao, & McCallum, 2009). Understanding the biosynthetic pathways of polyphenols can help the breeding program for designer foods with enhanced polyphenol content and health benefits (Tsao *et al*., 2006).

6.5.2 Polyphenol in meals

Total polyphenol intake in a complete diet, including both extractable and non-extractable polyphenols has been investigated. To utilize their biological properties, polyphenols have to be available to some extent in the gastrointestinal tract. Consequently, the biological

properties of dietary polyphenols may depend on their absorption in the gut and their biovality (Saura-Calisto *et al*., 2000). To exert their biological properties, polyphenols have to be available to some extent in the target tissue. Therefore, the biological properties of dietary polyphenols may depend on their absorption in the gut and their bioavailability.

Bioaccessibility is defined as the amount of a food constituent that is present in the gut, as a consequence of the release of this constituent from the solid food matrix, and may be able to pass through the intestinal barrier. Only polyphenols released from the food matrix by the action of digestive enzymes (small intestine) and bacterial microflora (large intestine) are bioaccessible in the gut and therefore potentially bio available. The amount of bioaccessible food polyphenols may differ quantitatively and qualitatively from polyphenols included in food databases. The bio accessibility is not taken into account in studies regarding the bioavailability of polyphenols. Moreover, most studies on polyphenol bioavailability use mainly pure single molecules (isolated from food or chemically synthesized) although their bioavailability from whole foods may be substantially different. Some beverages and single foods have also been used in these studies, but the significance of the results for health may be limited because a specific food may contribute little to the total polyphenol intake in the diet (Williamson & Manach, 2005).

6.6 Drying processes in general

Drying is an important unit operation used in numerous industries and well known as a dominant industrial consumer of fossil fuel-derived energy in developed countries. Drying is one of the most cost-effective ways of preserving foods of all variety which involves removal of water by application of heat. A variety of food sub-types are pre-served using drying, these include: marine products, meat products as well as all fruits and vegetables (Chen & Mujumdar, 2008)

Drying is a complex operation involving transient transfer of heat and mass along with several rate processes, such as physical or chemical transformations, which, in turn, may cause changes in product quality as well as the mechanisms of heat and mass trans-fer. Physical changes that may occur include: shrinkage, puffing, crystallization, glass transitions. In some cases, desirable or undesirable chemical or biochemical reactions may occur leading to changes in colour, texture, odour or other properties of the solid product (Mujumdar & Zhonghua, 2008).

6.6.1 The principles of drying

In the most basic terms, drying is the removal of water from foods. Usually foods are dried using hot air to remove the water. In some instances, such as when gari is being made from cassava, a hot metal pan is used which comes into contact with the food and causes the moisture to evaporate. This technical brief, concentrates on drying using hot air.

For effective drying, the air should be hot, dry and moving. These factors are inter-related and it is important that each factor is correct (for example, cold moving air or hot, wet moving air is both unsatisfactory). The dryness of air is referred to as the humidity - the lower the humidity, the dryer the air. There are two ways of expressing humidity; the most useful is a ratio of the water vapour in air to air which is fully saturated with water. This is known as the relative humidity (RH). Air that is completely dry has a RH of 0% and air that is fully saturated with water vapour has a RH of 100% (Azam- Ali, 2008).

6.6.2 Artificial drying

Artificial drying uses equipment in which the food is placed, and the dehydration process occurs for a given period of time. This process is classified as batch. However, wet food can be continuously loaded in the machine and dry food continually removed, being rated continuous process. In most artificial drying process, hot air at a velocity of 0.5m/s to 3m/s and low humidity is used for the transfer of heat by convection to the food, but the conduction and radiation heat transfer mechanisms also occur. Drying is advantageous to increase the lifetime of the product, be economic in the home or semi-industrial production, and have low cost of storage and easy transport. Despite the advantages of drying, it causes chemical and physical changes that affect the quality of the dehydrated product (Gava, 2000).

6.6.3 Dryer type tunnel

There are several types of dryers used to dry food, in the present thesis convection oven (tunnel dryer was used, Figure 3).

In the tunnel dryer, the solids are placed on trays that are supported on water mobile base, which enables the movement inside the drying tunnel. The air circulation in the drier and also made by a inlet air fan which circulates counter current to the trays. The evaporation

rate is much higher compared to the process by dryer tray. The trays are loaded from a tunnel side with wet food and dry food discharged from another (Geankoplis, 1993).

Figure 3: Convection oven (Tunnel dryer)

6.7 Health benefits of peanut consumption

A large body of evidence consistently shows that consumption of tree nuts and peanuts is associated with a reduced risk of coronary heart disease (CHD) (Griel *et al*., 2004).

Numerous clinical studies have demonstrated that tree nuts and peanuts beneficially affect plasma lipids and lipoproteins (reduced total cholesterol (TC), low density lipoprotein cholesterol (LDL-C) and triglycerides without reducing high density lipoprotein (HDL) cholesterol (Kris-Etherton, 2001).

The health benefits associated with nuts are thought to reflect their nutritional profile including their nutrient density, fatty acid profile and presence of bioactive compounds. Peanuts are a rich source of B-vitamins, vitamin E, magnesium, copper and phosphorus. In addition, they are a source of plant protein (including arginine), dietary fibre, and unsaturated fatty acids. Numerous bioactive substances (i.e., flavonoids, resveratrol and plant sterols) also are present in peanuts. Resveratrol and β-sitosterol found in peanuts have been associated with decreased risk of CHD and reduced cancer risk .Thus, it stands to reason that tree nut and peanut consumption would be associated with a favourable nutrient intake (Awad *et al.,* 2000).

There is a qualified health claim stating consumption of most nuts may reduce the risk of heart disease. As interest in incorporating nuts into the diet grows, it is important that consumers understand how to include them into a healthy diet without promoting weight gain. They are a high-fat, energy-dense food and are therefore a potential threat for

contributing to positive energy balance. However, evidence is accumulating to question this view and to update recommendations on nut use under conditions of weight loss and maintenance (Mattes *et al*., 2008).

Based on the evidence from epidemiological and controlled clinical studies, nut consumption is not associated with higher body weight. In fact, the epidemiological evidence indicates consistently that nut consumers have a lower BMI than non-consumers (Griel *et al*., 2004).

With respect to clinical studies, the evidence is nearly uniform that their inclusion in the diet leads to little or no weight gain (Hollis & Mattes, 2007). Moreover, adherence to a moderate-fat, weight loss diet vs. a low-fat weight loss diet in free-living subjects is better and the nutrient profile of the moderate-fat diet is superior (McManus *et al*., 2001). Moderate-fat diets that contain nuts elicit a more favorable lipid and lipoprotein profile after maintenance of weight loss as well (Pelkman *et al.*, 2004).

Peanut consumption promotes demonstrably positive impact on the nutritional quality of the diet as it is associated with a higher intake of protein, unsaturated fats (mono and polyunsaturated fatty acids), fibre, vitamin A, vitamin E, folate, calcium, magnesium, zinc, iron, bioactive compounds such as polyphenol, besides reducing the consumption of saturated fat and cholesterol. Several studies have demonstrated the beneficial effect of peanut consumption reduction of blood lipids (total cholesterol and LDL cholesterol and maintenance levels of HDL cholesterol) and reduced risk of cardiovascular disease due to positive effects such as vasodilation, reduction in the formation of reactive oxygen molecules, the reduction of pro-inflammatory substances and the inhibition of platelet aggregation.

The presence of nutrients such as fibre, monounsaturated fatty acids (mainly oleic acid), arginine, folate, tocopherol, magnesium, polyphenols (resveratrol) and sterol (β-sitosterol) are associated with beneficial effects on cardiovascular diseases resulting grain consumption. The peanut is also beneficial in maintaining glucose levels and antioxidant response to stress generated by diabetes mellitus, in addition to higher consumption fatty mono- and polyunsaturated acids. Other nutritional components such as magnesium, selenium, vitamins, minerals and other phenolic compounds appear to assist in positive effect of peanut consumption in DM. The relationship between the consumption of peanuts and overweight/obesity is not observed in the studies. The influence of grain consumption in compensation mechanisms in food intake, lipid metabolism and increased energy

expenditure are resulting from higher consumption of unsaturated fatty acids, fibre, protein and flavonoids and can aid in weight loss when combined with a diet healthy. Resveratrol (Figure 4) a polyphenol present mainly in red grapes and wine red, which is associated with the chemoprevention of cancer, is also present in peanuts. Other compounds such as phytosterols (β -sitosterol, Figure 4) and phytic acid also perform preventive action (De Almeida, *et al.*, 2011).

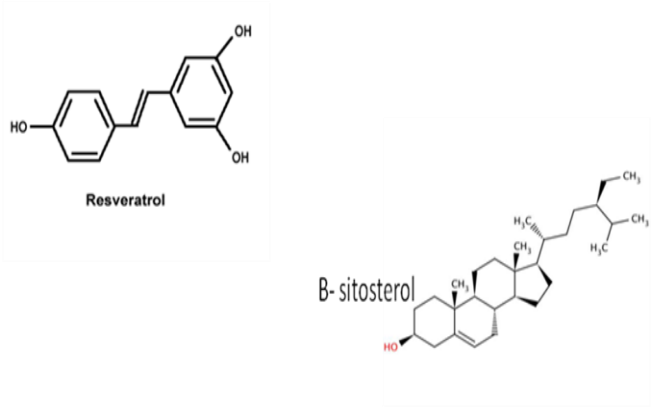


Figure 4: Chemical structure of resveratrol & β -sitosterol (De Almeida, *et al.*, 2011).

The most abundant sterol components present in the sterol fractions of commodity vegetable oils (i.e. coconut, canola, cocoa butter, cottonseed, linseed, olive, palm, peanut. Rice bran, safflower, sesame, soybean, sunflower oils) are campesterol (CA) (2.6-38.6%) and sitosterol (SI) (40.2-92.3%).These are followed by stigmasterol (ST) and 5-avenasterol (5AV) in abundance. The percent compositions of ST and 5AV in these oil, range 0.0-31.0% and 1.5-29.0%, respectively (Abidi, 2001).

7.0 Material and Methods

7.1 Collection and sample preparation

To perform the experiments, samples of peeled grain and dry peanut (*Arachis hypogaea L*) were collected in the formal market in Lund city, (Sweden) between May and June 2015.The peanut flour was obtained by placing 200grams peanut grain in an electric multi-purpose food processor (Electrolux, EBD-40, Sweden) at four speed position for 2 minutes and 30 seconds. The milled peanut was withdrawn and placed in a manual sieve coupled to the bowl and rotated for 5 min. The finest peanut flour was separated and the thickest

recycled into the multi-purpose food processor.The process was repeated until two types of flour, one with finer size and other with coarser size were obtained (Figure 5)

Figure 5: Peanut flour with different sizes**.**

7.2 Preparation of rehydratable peanut sauce

7.2.2Procedure:

The rehydratable peanut sauce was obtained as described below:

***7.2.2.1 Preparation of peanut milk*:** using a stainless steel spoon peanut flour was taken from the container, placed in an aluminium dish and weighed (100g) on a semi-analytical analytical balance. The sample was added to 500ml of water and placed in a blender (Electrolux, power mix silent) ran no more than 3 minutes and allowed to rest for one minute. The process was repeated until peanut milk was obtained. This took approximately 10 minutes. The peanut milk was then put in the stainless steel pot and was added again 2.5 L of potable water at room temperature.

7.2.2.2 Cooking the peanut milk- the peanut milk with water was placed in an electric cooker (Brand-Elektro Helios, Electrolux) for cooking under constant stirring. The boiling took 150 minutes at 100^0C (first experiment) and 8 hours at 80^0C (the second experiment) until a paste was obtained. This was the peanut sauce.

Using again the semi analytical balance, about 100g of peanut paste was placed in aluminium dishes before drying.

7.2.2.3 Peanut sauce drying: the aluminium dishes with 100g sauce were taken to the dryer (Convection oven –Tunnel Dryer). In the dryer the loss of humidity was controlled and measure by the computer coupled to the dryer (Fig 6). The drying lasted no more than 48 hours depending on the thickness of the paste. The drying temperature was 50^0C for the

sauce that was submitted for cooking at 100^0C and 100^0C for sauce submitted to cooking at 80ºC. The air velocity was held constant for both drying (3m/s).

Figure 6: Peanut sauce drying,

7.2.2.4 Milling: the dry peanut paste was placed in a multi-purpose food processing (Electrolux, power mix silent) and grind for 1-2 minutes until a peanut sauce powder was obtained.

7.2.2.5 Packing: the samples were allowed to lower the temperature for a period between 15 min to 30 min. They were removed and weighed in the semi analytical balance and packed using vacuum machines to remove the air in the peanut sauce powder.

7.2.2.6 Storage: the samples packed were stored in shelves at room temperature.

Following (figure 7) is a flowchart of production rehydratable peanut sauce.

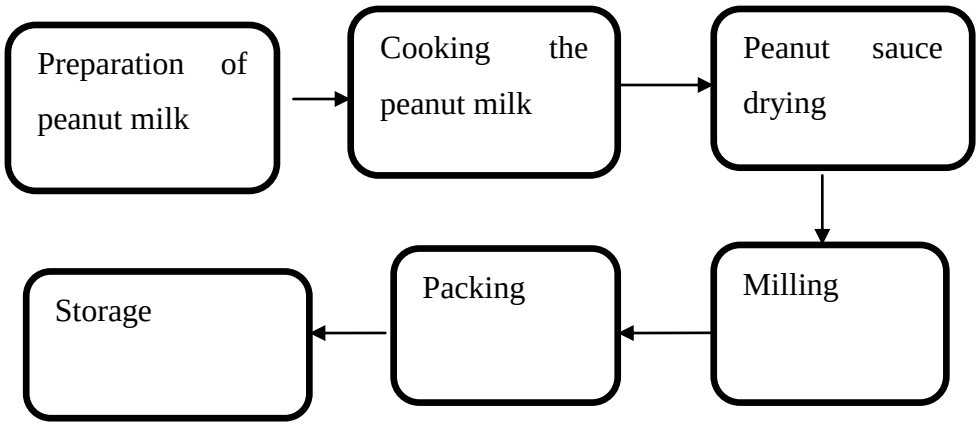


Figure 7: Production flowchart of rehydratable peanut sauce

7.3 Analytical Determinations

7.3.1 Total polyphenolic content

Total Phenolic Compounds (TPH) was determined by the Folin-Ciocalteau reagent which oxidizes the phenolic compounds to phenolates at alkaline pH in a saturated solution of sodium carbonate, resulting in a blue molybdenum-tungsten complex (Singleton & Rossi 1965).

To plot the standard curve it was used a sodium carbonate solution saturated: 35g Na_2CO3, + 100ml distilled water (total volume) but it before in a small quantity of hot water; 100mg of caffeic acid solved in 10 ml of methanol→ concentration= 10g/L and was used 1 ml of standard solution of caffeic acid with methanol, and was diluted with 100 ml of distilled water. The same was diluted with different quantity of distilled water to obtain solution with several concentration of the standard range (caffeic acid) from 0 to 50 mg/L. From each standard solution and sample 2ml was mixed with 100 µL of Folin-Ciocalteu reagent vortex 10 seconds, waited 3 minutes and was added and 400 µL of sodium carbonate solution vortex 10 in and added 7.5 m of distilled water. The samples were mixed and was put each tube in a dark room at ambient temperature, for 1 hour. The absorbance was read at 725 nm, was repeated 3 times for each tube .The results were expressed as caffeic acid equivalents (CAE). Following is a caffeic acid standard curve.

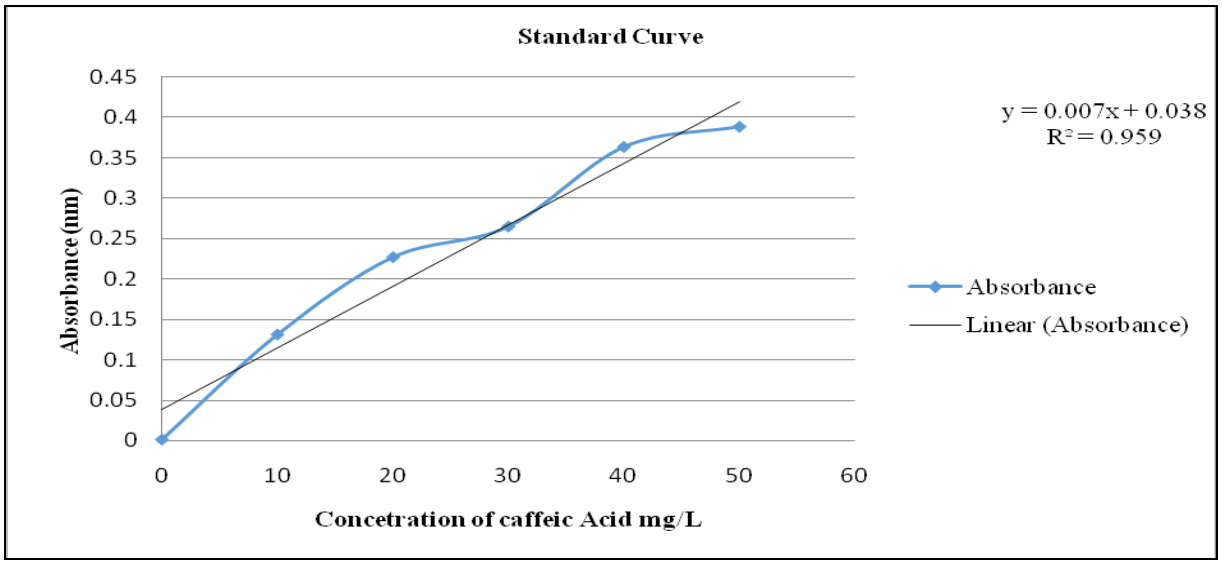


Figure 8: Caffeic acid standard curve to determine phenolic compounds.

7.3.1.1 Sample extraction

Was withdrawn glacier the peanut sauce samples and left 30 min at room temperature, using a pipette withdrew from the test tube to peanut sauce 7ml dilution and added 7ml of distilled water (ratio 1: 1 by volume) 2ml removed and placed in a micro-tube, then placed in a micro-centrifuge (micro-centrifuge with 12 x 1.5 / 2.0 ml rotor, 13400 rpm) at 13000 rpm for ten minutes and with the aid of a pipette was transferred the supernatant was approximately 2ml to another test tube repeated until obtaining a clear solution.

To calculate the concentration of phenolic compounds was utilized a standard curve equation of the straight constructed with caffeic acid.

7.3.2 Moisture

The moisture (or total solids) content of foods is important to food manufacturers for a variety of reasons. Moisture is an important factor in food quality, preservation, and resistance to deterioration. Determination of moisture content also is necessary to calculate the content of other food constituents on a uniform basis (i.e., dry weight basis). The dry matter that remains after moisture analysis is commonly referred to as total solids (Nielsen, 2010a).

Moisture corresponding loss in weight undergone by the product when heated under conditions in which water is removed (Adolfo, 1985).

Data and Calculations

Calculate percentage moisture (wt/wt):

$$\%\text{Moisture (wt/wt)} = \frac{(wt\ of\ wet\ sample - wt\ of\ dry\ sample)}{wt\ of\ wet\ sample} \times 100$$

The moisture content was determined according to the official method of analysis (AOAC, 1995) by drying the weight samples in an air forced oven at 102^0C for 24 h or longer until constant weight was obtained. Analysis was performed in triplicates in peanut sauce powder.

7.3.3 Water activity (aw)

In drying of some materials, which require careful hygienic attention, e.g., food, the availability of water for growth of microorganisms, germination of spores, and participation in several types of chemical reaction becomes an important issue. What is important is the availability of the water to micro-organisms, not its abundance. The

concept of 'water activity' is nowadays universally adopted by food scientists and technologists to quantify availability (Coultate, 2002).Water activity (*aw*) is one of the most critical factors in determining quality and safety of the goods which are consumed every day. Water activity affects the shelf life, safety, texture, flavour, and smell of foods (Jangam *et al.*, 2010).

It is the *availability* of water for microbial, enzymic or chemical activity that determines the shelf life of a food, and this is measured by the water activity (a_w) of a food, also known as the Relative Vapour Pressure (RVP) (Fellows, 2000).

Water activity is defined as 'the ratio of the vapour pressure of water in a food to the saturated vapour pressure of water at the same temperature' (equation below):

$$a_w = \frac{P}{Po}$$

Where P (P_a) → vapour pressure of the food; P_0 (P_a) →vapour pressure of pure water at the same temperature (Fellows, 2000).

Determination of water activity:

The water activity for peanut sauce powder was analysed using a water activity meter (Aqualab series 3and 3TE, Decagon Devises, Pullman,WA). The equipment was calibrated with standard salt solutions 13.41 mol/kg LiCl (0.25 aw) and 8.87mol/kg LiCl. Analyses were performed in triplicate.

Figure 9: Aqualab Standards &Aqualab apparatus.

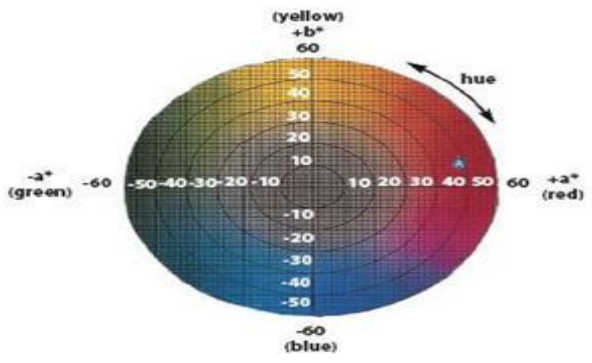
7.3.4 Colour

Colour is one of the important quality attributes for dried food product. Although the optical property is often an assessment of the physical appearance of the product, the colour development is in fact the results of various chemical and biochemical reactions. Browning reaction, in either positive or negative way, is an important phenomena occurring in food during processing and storage. In brief, the major reactions leading to browning can be grouped into enzymatic phenol oxidation and non-enzymatic browning. Enzymatic browning is often catalyzed by the enzymes polyphenol oxidase (PPO), where the phenolics constituents are oxidized to quinones in the enzymatic reaction and then further polymerized to melanoidins (brown pigment) that has high molecular weight. On the other hand, non-enzymatic reactions are referring to Maillard reaction (reaction between carbonyl and amino compounds), caramelization, ascorbic acid browning, lipid browning and pigment destruction (Perera, 2005).

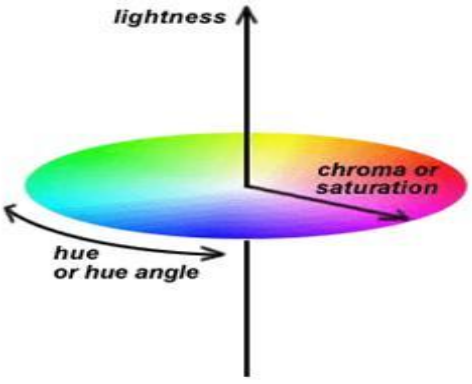
Colour can be defined as the sensation that is experienced by an individual when radiant energy within the visible spectrum (380–770 nm) falls upon the retina of the eye. In food research and quality control, instruments are needed which provide repeatable data that correspond to how the eye sees colour (Nielsen, 2010b).

The Munsell system is a visual system that designates colour in terms of hue, value, and chroma. Each of these dimensions has equivalent visual spacing, which is advantageous.

Colour-order systems have been developed that are more suitable for measuring colour differences. These include the Hunter *Lab* system, the *CIE Lab* system, and the *LCH* system (Nielsen, 2010b).



10



11

Figure 10: a*, b* chromaticity diagram (http://www.photonics.com/EDU/Handbook.aspx?AID=25124)

Figure 11: The geometry of color making attributes in a modern color **space** (www.handprint.com/HP/WCL/color7.html)

In fig 10 the L*a*b* diagram, a spherical color solid, L* indicates lightness, and a* and b* are the chromaticity coordinates. Here the a* and b* indicate colour directions (+a* is the red direction, -a* is the green direction) (www.handprint.com/HP/WCL/color7.html).

In fig 11 the vertical dimension is the *lightness or value* of a colour; by itself, this dimension defines a *gray scale* of values from black to white. The circumference of the horizontal disk, perpendicular to the lightness dimension, is the *hue* of a colour; this defines a *hue circle* that places hues in their spectrum order.

The lateral distance or radius on this disk, measured from the center outward, is the *hue purity* of a colour, usually stated as its relative *chroma* or absolute *colorfulness* (www.handprint.com/HP/WCL/color7.html).

They were evaluated three colour parameters: L*, a* and b*. The a* value characterizes the colour of the red region (+ a *) to green (-a *), the value b * indicates yellow coloration in the range (+ b *) blue (-b *). The L value in providing light ranging from white (L = 100) to black (L = 0) (Harder, 2005). The croma is the relationship between the values of a * and b *, where you get the real colour of the object scanned. Hue- -angle is the angle formed between a * and b *, indicating the saturation of the object colour.

To calculate the chroma it was used the mathematical formula (1) and, to calculate Hue-Angle is used the formula (2). H^o = arctg b*/a* (2), and Chroma$= \sqrt{a^2 + b^2}$ (1). To

determine the colour it was used the portable spectrophotometer (CM-700d, Konica Minolta, Osaka, Japan), Figure 12. This medication consisted in: first calibrate the colorimeter according to the instructions of manual device's, next placed the part that reads upon reading of the peanut sauce powder, the sample was packed in vacuum bags and has done six readings in each replica, in different points of peanut sauce powder of the to obtain more reliable data and the average was reported.

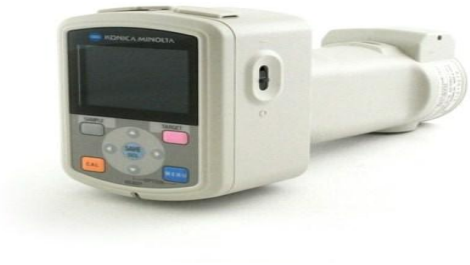


Figure 12: Portable Spectrophotometer (CM-700d, Konica Minolta).

7.3.5 pH

The ability of a microorganism to grow in a specific food is an important example of a process that is more dependent on hydronium ion concentration than on titratable acidity. The need to quantify only the free H3O+ concentration leads to the second major concept of acidity, that of pH (also called active acidity). In nature, the H_3O+ concentration can span a range of 14 orders of magnitudes. The term pH is mathematical shorthand for expressing this broad continuum of H_3O^+concentration in a concise and convenient notation. In contemporary food analysis, pH is usually determined instrumentally with a pH meter; however, chemical pH indicators also exist (Nielsen, 2010b).

The pH of the rehydratable peanut sauce was determined at the end of the whole production process using the pH meter (pH meter 744, METROM AG CH-9101 Herisau Switzerland) calibrated with standard buffer (pH 4,01 and pH 7,01). For the determination of pH of peanut sauce powder were weighed 5g of peanut sauce powder, added 50ml of distilled water, stirred for 30 minutes and then let to rest for 10 minutes. The pH determination was made. The analysis was performed in triplicate (Adolfo Lutz, 1985).

7.4 Sensory analysis

Sensory profiling or descriptive analysis methods consist of formal procedures for assessing, in a reproducible manner, specific attributes of a sample and rating intensity on a suitable scale. These methods can be used for evaluating aroma, flavour, appearance, and texture, separately or in combination (ISO, 1994). As such, descriptive sensory profiling is the most sophisticated sensory tool available to the sensory professional (Stone & Sidel, 1993). Results from descriptive analysis provide a complete sensory description of an array of products and can provide a basis for distinguishing those sensory attributes that are important for acceptance by consumers (Stone & Sidel, 1993).

Descriptive sensory tests are amongst the most sophisticated tools in the arsenal of the sensory scientist (Lawless & Heymann, 1998) and involve the detection (discrimination) and description of both the qualitative and quantitive Sensory components of consumer product by trained panels of judges (Meigaard, *et al.*, 1991). The qualitative aspects of a product include all aroma, appearance, flavour, texture, after-taste and sound properties of a product, which distinguish it from others. Sensory judges then quantify these product aspects in order to facilitate description of the perceived product attributes.

A major strength of descriptive analysis is its ability to allow relationships between descriptive sensory and instrumental or consumer preference measurements to be determined. Knowledge of "desired composition" allows for product optimization and validated models between descriptive sensory and the relevant instrumental and or preference measures are highly desirable and increasing, are being utilized within the food industry (Murray *et al*., 2001).

Descriptive sensory analyses are also used for quality control, for the comparison of product prototypes to understand consumer responses in relation to products sensory attributes, and for sensory mapping and product matching (Gacula, 1997). It may also be used to track product changes over time with respect to understanding shelf-life and packaging effects, to investigate the effects of ingredients or processing variables on the final sensory quality of a product, and to investigate consumer perceptions of products e.g. Free-Choice Profiling (FCP).

Sensory analysis was performed to verify the peanut sauce qualities as regards astringency, in this case were used sample was withdrawn in different stages of cooking from 0min, 30 min, 1hour, 2hours and 30 minutes that were cooked at 100^0C and 0min, 30min, 1 hour and 8 hours that were cooked at 80^0C.

The choice of different cooking intervals due to the fact that the evaluator had samples in which he can detect significant differences between the samples, was noted that before the sensory analysis were two samples as a standard one to 0 minutes of cooking and another 150 minutes of cooking, the evaluator had to first prove the standard samples to know the peanut sauce and then compare with the samples that were delivered for evaluation.

The descriptive text was carried out employing a 4-point scale ranging from a very to neutral astringent. The panellists were composed of a team of seven tasters from different nationalities enters them: Mozambique, Bolivia and French countries.

The evaluation was made in individual cabins, where the tasters had to analysis the samples placed on plastic cup, coded with three-digit numbers arranged randomly and accompanied by a cup of water to the rinse of mouth in each analyzed sample.

The other part of the analysis was carried out by trained evaluator, one which was directly connected to the cooking process, and as would taking samples for quantification polyphenols would also making the analysis of astringent flavour of peanut sauce.

7.5 Rehydration

The rehydration process was performed using the sample that were submitted to the drying process 50^0C (better sample) was added amounts of hot water to facilitate the dissolution process peanut powder (water temperature 80^0C), was added in 50g of peanut sauce powder, 600ml, 400ml and 200ml in each weighed 50g and was submitted to cooking (boiling at 100^0C) for 5, 10 and 15 minutes , in order to check what is the best ratio in terms of water content and amount of the powder and validated to which showed better results in the dissolution process that is, that showed the best functional properties of peanut sauce (foaming and emulsion stability).

7.6 Statistical analysis

Statistical analysis of average values for the concentration of phenolic compounds was carried out using a completely randomized design, i.e., the samples were taken using a factorial plan 2^n and $n \neq 0$, until the end of the cooking process and used the Student's t-test to performed significant differences, the value of $p < 0.05$ was considered to indicate statistical significance. Also the results were represented in a graph demonstrating the behaviour of phenolic compounds, to the data of sensory analysis, statistics was done using analysis of variance (ANOVA) single factor using the statistical programme Toolpak Microsoft excel 2007, value of $\alpha = 0.05$, also graphical representations of the results were made. And for all data were made statistics of average and their standard deviation.

8.0 Results and discussion

8.1 Quantification of Polyphenols

The results in Table 6 show the concentration of phenolic compounds in peanut sauce before during and after cooking. The concentration of these compounds vary from (118.89mg / L) ± 0.290% before the cooking process to (54.24 mg / L) ± 0.154% during the whole cooking process and until 127.09 mg / L ± 0.282 at the end. . A slight difference between the concentration of these compounds before and after cooking was observed.

Table 6: Results of first replica peanut sauce cooking at 100 ^{0} C for 2h and 30 min

Treatments	Duration of the cooking time in minutes							
	0	2	4	8	16	32	64	128
[Polyphenols] (mg /L) / CI	*118 ±0.290	*77.77 ±0.266*	*98.3 ±0.50	*54.24 ±0.154	*66.26 ±0.276	*81.94 ±0.083	*98.09 ±0.168	*127.09 ±0.282
SD	0.1169	0.1072	0.213	0.0623	0.1110	0.0334	0.0675	0.1134
CV in %	0.098	0.138	0.217	0.115	0.167	0.041	0.069	0.089

*Values presented in Average and confidence interval assuming probability 95%: three replicates / sample using statistical tables t (student) , n = 3.

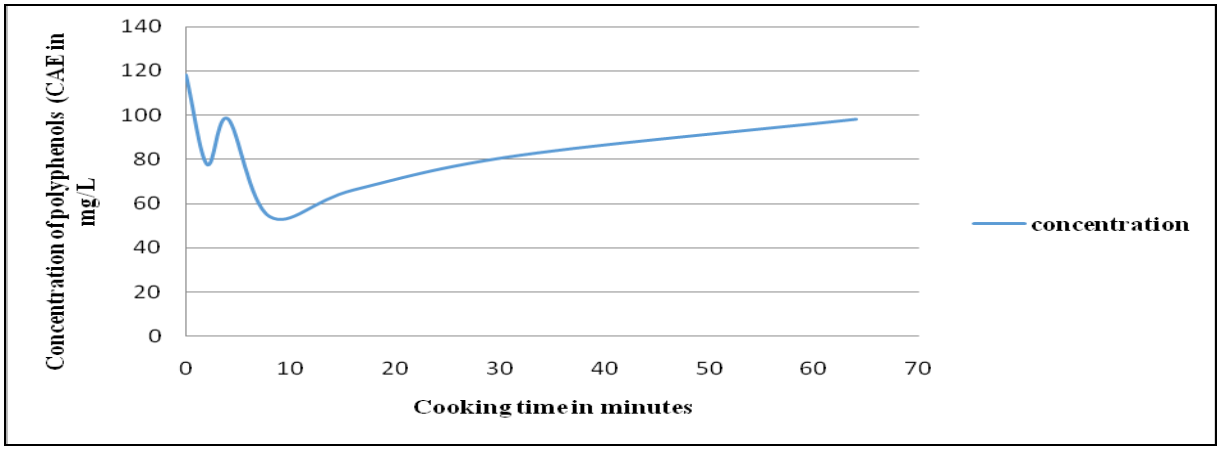


Figure 13: The characteristic of the first replica of polyphenols concentration on cooking peanut sauce during 2h and 30 min at 100 ^{0}C

The concentration of phenolic compounds in the beginning of cooking was 118mg/L lower than concentration after end the cooking (127.09 mg/L) of the peanut sauce. Was observed in principle of cooking a raw sauce and in the end a cooked sauce, that showed the effect of temperature/time in the increase of these compounds, it can be justified that there may have been hydrolysis of some compounds which contributed to the increase of the phenolic compounds. These oscillations of phenolic compounds in peanut sauce may be that submission of peanut sauce at the high temperature of cooking.

(Talcott *et al*., 2005) did a study in eight cultivars and four experimental genotypes of raw, shelled peanut kernels (*Arachis hypogaea L)*; roasted at 175 C for 10 min in a Pyrex forced air convection oven and they concluded that the total polyphenolics quantified by HPLC were generally higher for roasted compared to raw peanuts. Whole raw peanuts contained an average of 25 mg/kg of p-coumaric acid that ranged from 8 to 66 mg/kg among cultivars. Concentrations appreciably increased following roasting with an average of 69 mg/kg that ranged from 19 to 117 mg/kg among cultivars concentrations appreciably increased following roasting with an average of 69 mg/kg that ranged from 19 to 117 mg/kg among cultivars. Concentration differences following roasting were attributed to esterified and/or bound forms of p-coumaric acid present in both raw and roasted peanuts, with identity based on their closely related spectral properties to free p-coumaric acid.

These compounds were hypothesized to be hydrolyzed and released under roasting conditions and may have originated from glycosides (*p*-coumaric acid-b-D-glycosides), protein–phenolic complexes, lignin, or from cell wall materials.

These values were compared with those obtained in this study, showed that peanut sauce was above the aforementioned value because was quantified all phenolic compounds existing in peanut sauce, whereas the study by (Talcott *et al*., 2005) was quantified a concentration of specific phenolic compound, but in general can say that the cooking increased the concentration of phenolic compounds.

Table 7: Results of second replica peanut sauce cooking at 100 ^{0} C for 2h and 30 min

Treatments	Duration of the cooking time in minutes							
	0	2	4	8	16	32	64	128
[Polyphenols](mg / L) / CI	*83.78 ±0.089	*91.77 ±0.00	*88.13 ±0.054	*82.90 ±0.074	*74.32 ±0.041	*81.56 ±0.036	*110.38 ±0.041	*140.8 ±0.036
SD	0.0360	0.00	0.0218	0.0297	0.0165	0.0143	0.0165	0.0143
CV in %	0.043	0.00	0.025	0.036	0.022	0.0175	0.015	0.010

*Values presented in Average and confidence interval assuming probability 95%: three replicates / sample using statistical tables t (student) , n = 3.

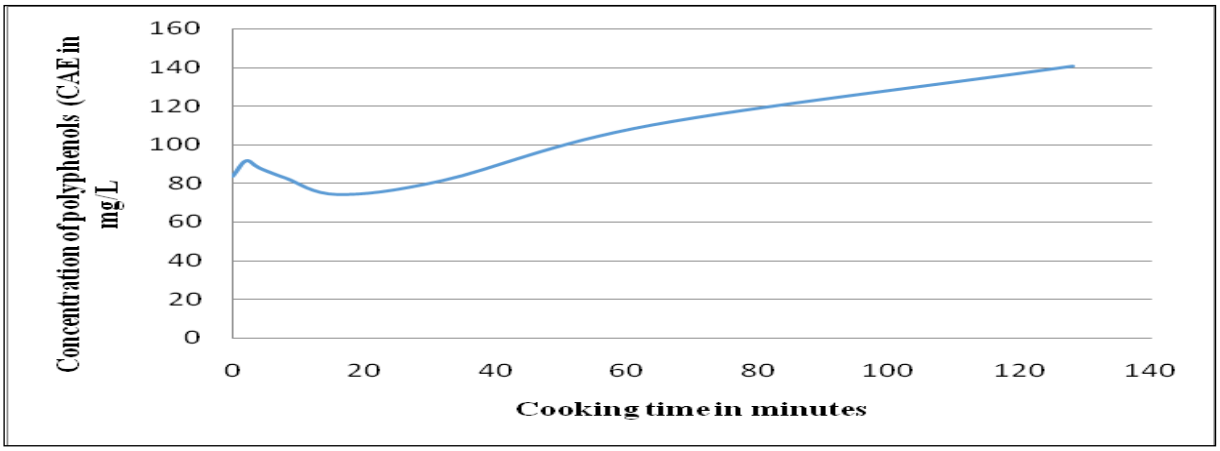


Figure 14: The characteristic graphic of the second replica of polyphenols concentration on cooking peanut sauce during 2h and 30 min at 100 ^{0}C

Regarding to the second cooking despite having submitted the same conditions of cooking and preparation with the first replica the results showed a slight difference in relation of the concentration of phenolic compounds in principle, this can be by the fact that non-presence of remains skin in peanut flour, the concentration values were 83.78 mg/L ± 0.089%, very low relative to first cooking, having been registered relatively low values after 32 minutes of cooking that when comparing with the first cooking, low value verified at 8 minutes, variations continued throughout the cooking process where the concentration peaked at 140.8mg/L ± 0.036% at the end of cooking, i.e. at 128 min. was shwoed that the values represent the maximum concentration of the second replica.

There is a difference, generally about 12 mg/L of the concentration of phenolic compounds in relation to cooking of the first replica, this difference can be related to this a small amount of skin on the first replica, then it is possible that the compounds has migrated to the raw sauce and as the cooking may be there have been some that have been lost, which in the second replica of peanut sauce was observed almost without skin and this showed an increased of phenolic compounds concentration.

Table 8: Results of third replica peanut sauce cooking at 100 ^{0} C for 2h and 30 min

Treatments	Duration of the cooking time in minutes							
	0	2	4	8	16	32	64	128
[Polyphenols](mg / L) / CI	78.09± 0.00	74.84 ±0.00	86.58± 0.021	81.44 ±0.089	110.38± 0.241	118.13± 0.742	109.49± 0.054	134.82± 0.041
SD	0.00	0.00	0.0082	0.0360	0.0972	0.2987	0.0218	0.0122
CV in %	0.00	0.00	0.010	0.044	0.088	0.2528	0.019	

*Values presented in Average and confidence interval assuming probability 95%: three replicates / sample using statistical tables t (student) , n = 3.

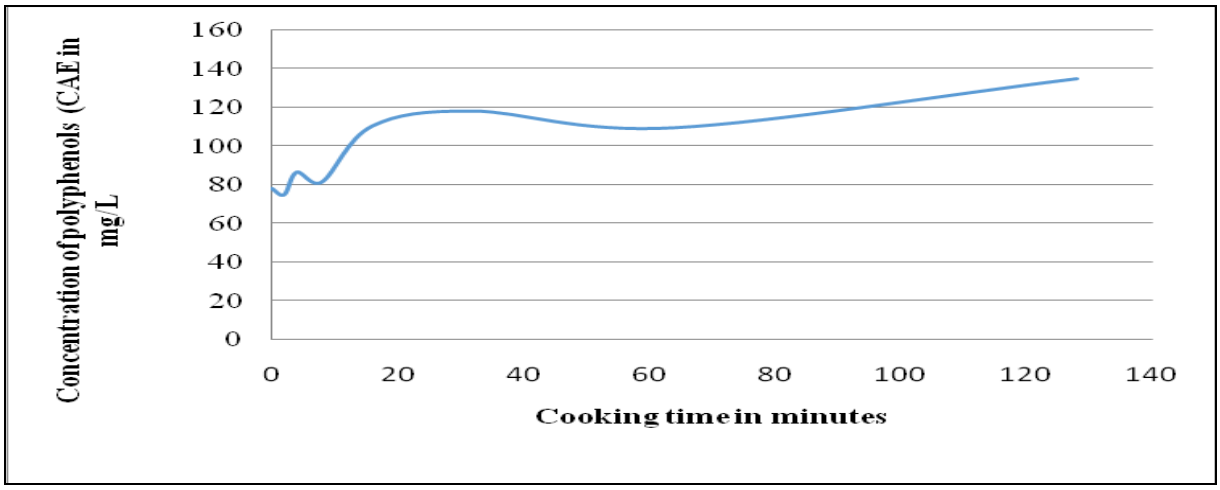


Figure 15: The characteristic of the third replica of polyphenols concentration on cooking peanut sauce during 2h and 30 min at 100 ^{0}C.

The third replica it showed greater concentration of phenolic compounds in relation to other two replicas, soon at 16 minutes of cooking about 110.38mg/L, a much higher value compared to the other two, that this difference was approximately 44mg/L for the first replica and 36mg/L for the second replica, these values showed very high this may be the fact that the last used peanut flour contained more fat than the other two replicas and according to (Camargo, 2012) peanut contains tocopherols which are responsible for the antioxidant activity of the lipid fraction of peanut, then this value 110.38mg/L was observed at the 16 minute of the third cooking replica can associate the existence of this compound in peanut flour because it was visible the presence of the oils which may have contributed to the increase of phenolic compounds.

Generally in the three replicates were found different polyphenols values, in Table 6 was noted highest concentration of polyphenol before the start of cooking process that may be for the fact of the presence of certain amounts of peanut skin on peanut flour, because during the milling peanut grain process to obtain the flour, a finer flour was obtained and when it crunched was found a more coarse, although the mixing between the two peanut flours the presence of skin was observed a lot in the first replica, with this higher concentration of polyphenols, in the third replica was observed high values of polyphenols content may be the fact of existence of lipophilic phenolic compounds in peanut flour.

There were not found reported studies on the total content of polyphenols in the cooking process for obtaining peanut sauce, but several studies have reported the polyphenols content in raw, dry-roasted peanuts and other, and also for the cooking process and in this context by the ratio between the raw material and heat treatment used, the present study will compare with the studies that were found, thus (Craft, 2005) found in his study of the *Phenolic Profiles And Antioxidant / Radical-Scavenging Capacities Of Raw, Dry-Roasted, And Oil-Roasted Peanuts* that TPC for the 15 samples analyzed were variable, with a low of 104 and a high of 221 mg p-coumaric acid EQ/100-g EQ. Processing significantly affected the TPC of all samples assayed except for same samples. The TPC of 3 samples increased with dry roasting and the others 3 samples, all with increased oil roasting. The TPC of others samples, such as 2 samples, decreased stepwise from raw> dry-roasted> oil roasted sample. Essentially, TPC values were too variable to make concrete conclusions to the processing or farming effects on the phenolics content of peanut kernels. Overall, levels were not greatly altered via thermal processing.

A study by (Coward *et al.*, 1998) on *Chemical modification of isoflavones in soy foods during cooking and processing* in soy flour was either mixed with water to make a dough or mixed with wheat flour, sugar, butter, baking soda, and eggs to make a cookie,showed that the total isoflavone concentration in the food was not reduced under the normal cooking conditions. The food was burned, however, an increase in aglycones and a decrease in the total isoflavones was observed. The composition of the glucoside conjugates may have significant effects on the pharmacokinetics and bioavailability of the isoflavones;

In a study conducted by (Chukwumah *et al*., 2007) on *Changes in the Phytochemical Composition and Profile of Raw, Boiled, and Roasted Peanuts* concluded that boiled peanuts had higher overall isoflavone content with a two- and four fold increase in biochanin A and genistein content respectively. trans-resveratrol was detected only in the boiled peanuts, with the commercial peanuts having significantly ($p \leq 0.05$) higher concentration also, other ultraviolet (UV) absorbing compounds were detected in the boiled peanut extracts. These may be products of the hydrolysis due to boiling, may have migrated into the peanut kernels from the hull, during boiling, or may be components of the skin. Significantly ($P \leq 0.05$) higher levels of flavonoids and polyphenols full were observed in the boiled peanut extracts compared to raw and roasted peanut extracts. These may be products of the hydrolysis due to boiling, may have migrated into the peanut kernels from the hull during boiling, or may be components of the skin.

(Dabrowsk & Sosulki 1984) polyphenols occur in nature in free or bound forms; thus, some processing methods such as boiling or heating have been shown to increase the polyphenolic content of foods. In their study about the free and hydrolysable polyphenols, in 10 oilseeds, was showed that, defatted that defatted peanut flour contained *p*-coumaric, ferulic, and caffeic acids in esterified forms.

These studies all referenced above are related with existence of phenolic, some compounds that increase, others do not change, and relating to the present study may be said that certain compounds increase when submitted to cooking at 100^0C, others may be lost, which in general can affirm that peanut sauce cooking increases the concentration of phenolic compounds.

Table 9: Results of first replica peanut sauce cooking at 80 ^{0} C for 8hours

Treatments	Duration of the cooking time in minutes									
	0	2	4	8	16	32	64	128	256	512
[Polyphenols](mg / L) / CI	*86.13±0.00	*88.44±0.0	*83.2±0.036	*87.87±0.041	*103.59±0.233	*67.01±0.071	*128.35±0.074	*109.94±0.041	*122.39±0.041	*141.32±0.020
SD	0.0000	0.0000	0.0143	0.0165	0.0937	0.0286	0.0297	0.0165	0.0165	0.0082
CV in %	0.000	0.000	0.017	0.019	0.090	0.043	0.023	0.015	0.013	0.006

*Values presented in Average and confidence interval assuming probability 95%: three replicates / sample using statistical tables t (student) , n = 3.

The average results (Table 8) of the concentration of polyphenol in cooking at 80^{0}C for 8 hours showed that: at zero minutes was verified the initial concentration of polyphenols of 86 mg/L CAE, has been observed concentration of 83.2 mg/L at 4 min cooking a value with a slight difference to the value at zero minute, was noted that the maximum effect of the polyphenols concentration observed after cooking for 512 min was 141.32 mg / L, throughout the cooking it was noted a variation of the results.

Despite being extended time and used 80^{0}C the results showed that the combination of these factors was important in determination of the final concentration of phenolic compounds, low temperatures influence the transfer phenolic compounds of peanut sauce, or hydrolysis process occurs very slowly, which is influenced by temperature. These oscillations can be explained by the fact that: compounds where its greatest hydrolysis occurs at a given time, the same being lost and other compounds found in subsequent minutes, these compounds having an influence on the final concentration of phenolic compounds.

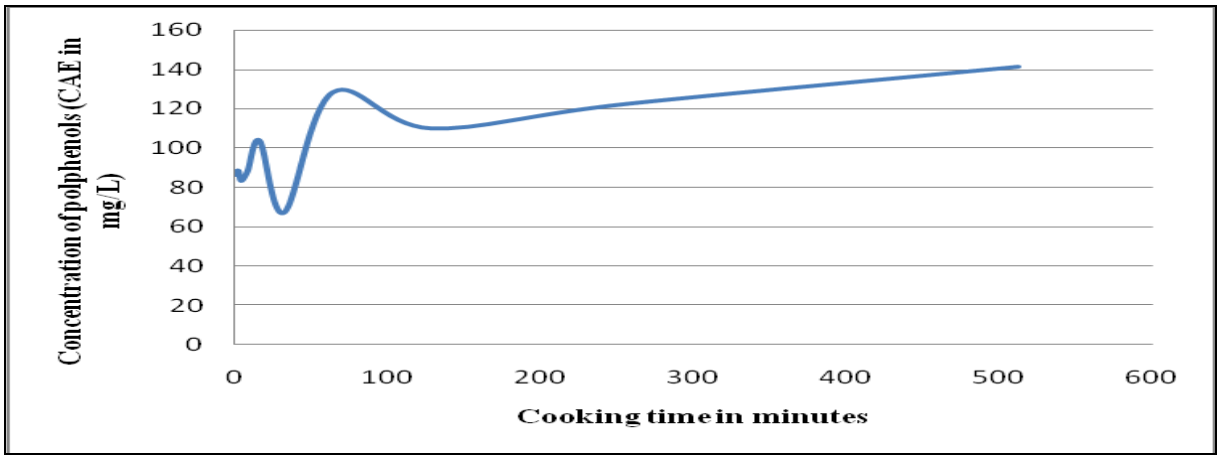


Figure 16: The characteristic of the first replica of polyphenols concentration on cooking peanut sauce during 8 hours at 80 ^{0}C

Table 10: Results of second replica peanut sauce cooking at 80^0 C for 8 hours

Treatments	Duration of the cooking time in minutes									
	0	2	4	8	16	32	64	128	256	512
[Polyphenols] (mg / L) / CI	*82.82 ±0.020	*102.26±0.089	*79.83 ±0.054	*91.10 ±0.041	*99.25 ±0.020	*95.63 ±0.020	*92.05 ±0.041	*106.40±0.041	*119.06±0.000	*130.12±0.082
SD	0.0082	0.0360	0.0218	0.0165	0.0082	0.0082	0.0164 95722	0.0164 95722	0.00	0.0330
CV in %	0.009	0.0352	0.027	0.018	0.008	0.009	0.018	0.0155 04192	0.00	0.025

*Values presented in Average and confidence interval assuming probability 95%: three replicates / sample using statistical tables t (student) , n = 3.

The concentration of polyphenols in the beginning of cooking (0 min) was 82.8 mg/L have been observed minimum value at 4 min 79.83mg/L and the maximum value of 130.12mg/L after 512 minutes of cooking. These results showed that the combination of long time/cooking temperature in this study lower was the transfer of polyphenols to the formulation for the peanut sauce. The concentration of phenolic compounds in comparison with the overall results, the boiling at 100^{0}C, increase de concentration of polyphenols, was showed that at lower temperature was not observed boiling sauce, the lower temperature of

cooking peanut sauce lower release phenolic compounds. Having recorded that higher concentration of polyphenols when was used 100^0C for cooking peanut sauce.

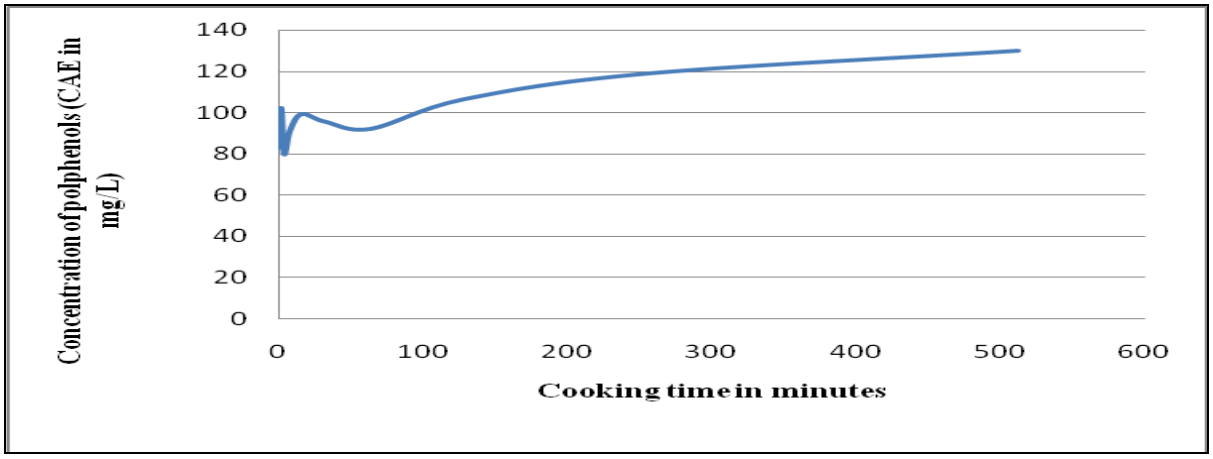


Figure 17: The characteristic of the second replica of polyphenols concentration on cooking peanut sauce during 8 hours at 80 ^{0}C.

8.2 Sensory analysis

For the implementation of the sensory analysis it was used peanut sauce samples taken in 4 stages of cooking. The descriptive test results regarding the characteristic astringency, are presented in figures 18 and 19 and in tables 11 and 12 respectively, where was noted that the withdrawal of the sauce at different stages of cooking has influenced significantly the qualifications of the evaluators.

Table 11: Perceived cooking o f the peanut sauce cooking 100^0C in 150 minutes

	Sample Nº 224	Sample Nº 335	Sample Nº 887	Sample Nº 912
Evaluator 1	4	2	4	3
Evaluator 2	3	2	2	3
Evaluator 3	3	3	2	1
Evaluator 4	4	4	4	3
Evaluator 5	1	1	1	4
Evaluator 6	1	3	1	4
Evaluator 7	2	2	3	3

Table 12: Perceived cooking o f the peanut sauce cooking 80^0C in 8hours

	Sample Nº 886 (0 min**)**	Sample nº 990 (30min)	Sample nº 199 (1 h)	Sample nº 171 (8h)
Evaluator 1	1	2	2	4
Evaluator 2	4	4	4	1
Evaluator 3	3	2	2	2
Evaluator 4	1	1	1	4
Evaluator 5	1	2	3	3
Evaluator 6	1	1	2	4
Evaluator 7	4	4	2	1

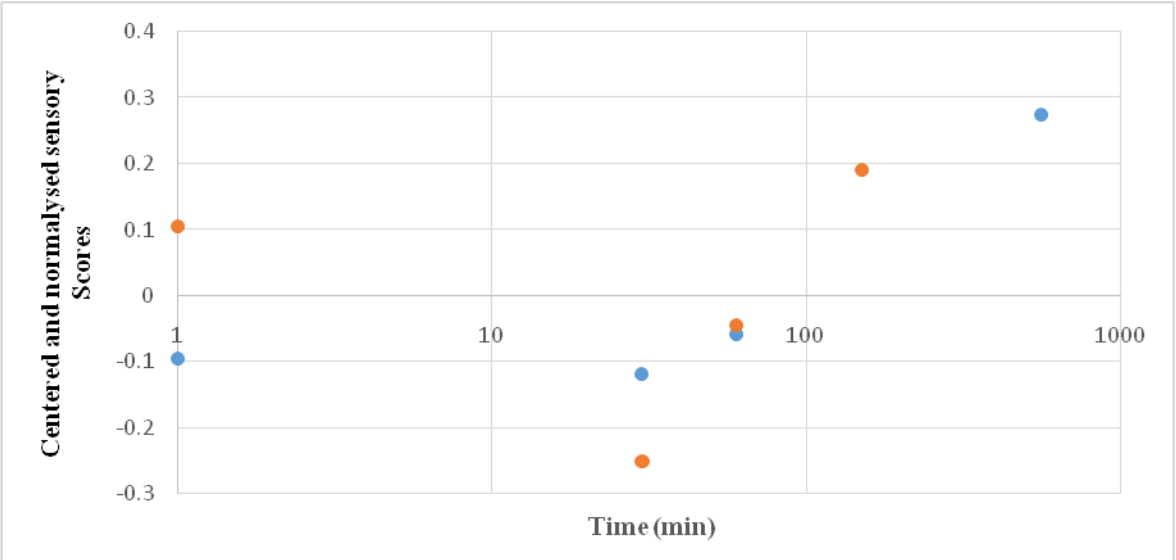


Figure 18: Results of normalized value of sensory analyses of peanut sauce

These graphs (Figure 18) were generated from the tables 11 and 12 based on what the evaluation panel awarded during the sensory evaluation, describing the perceptions of the astringent taste of peanut sauce, was noted that from the tables was not easy to understand exactly what evaluators perceived, but in Figure 18 was notorious the behaviour of the evaluators in sensory analysis, it was clear that few evaluators were able to make a proper evaluation in relation to the desired, as most made the assessment according to their perceptions.

The results on the evaluation of the perception of the astringent taste of peanut sauce are supported by systematic evaluation during the experiments (Figure 19), in this figure was

visible that: extent the cooking, decreases the intensity of the astringent taste, especially for the sample under cooking at a temperature of 100^0C, as noted at this temperature a peanut sauce boil which may have contributed to the decrease or no perception of astringency, over time for samples submitted to cooking at 80^0C was not easy to assess the same because at these temperatures does not happen boiling, simply a water evaporation in peanut sauce with it is perceived a small intensity of flavour until the end of cooking, although the same have taken much longer in relation the first cooking.

According (Belitz *et al*., 2009) the astringent taste is caused primarily by flavonol-3-glycosides. Quercetin-3-O-[α-L-rhamnopyranosyl-(1→6)-β-D-glucopyranside] is especially active with a threshold value of 0.001 µmol/l. Also of importance are (threshold values): kaempferol-3-O-[α-L-rhamnopyranosyl-(1→6)-O-β-D-glucopyranoside] (0.25 µmol/l), quercetin-3-O-β-15-D-galactopyranoside (0.43 µmol/l),quercetin-3-O-β-D-glucoside (0.65 µmol/l) and kaempferol-3-O-β-D-glucopyranoside. The astringent character of teas is decreased by the formation of complexes between phenolic compounds and proteins. The firing step also affects the balance of aroma substances. On the one hand there is a loss of volatile compounds, on the other hand, at high temperatures, an enhancement of the build-up of typical aroma constituents occurs, e. g., as a result of sugar-amino acid interactions.

According to this author, relating to this study, it can be said that: there are compounds in peanut sauce which degrade when submitted to the cooking process, also by peanut is rich in protein can be said that the astringency decreases by the formation of complexes between phenolic and proteins.

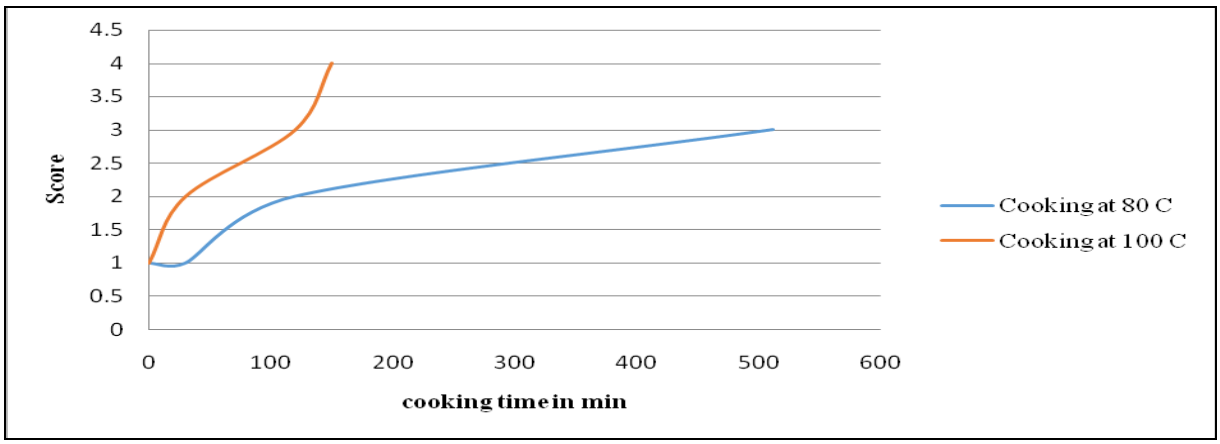


Figure 19: Perceived of trained evaluator of peanut sauce cooking

With regard to the statistical results of ANOVA (Table 13) it was possible to say that there was no significant difference, since the value of *F* is less than the value of

F(0.618983429>6.591382117*F crit* (see Table 1) and also it was possible to note with the value of p: which is greater than the value of alpha (0.638594656> 0.05),based on the results it can be said that there were no significant differences with respect to time/temperature of the cooking peanut sauce, but the astringent taste is very complex requiring a much more intensive training in relation to the evaluators who will carry out the sensory evaluation.

Table 13: ANOVA of sensory analyses (descriptive test) of peanut sauce cooked at 100 ^{0}C and 150 minutes of time.

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6258.894072	3	2086.298024	0.618983429	0.638594656	6.591382117
Within Groups	13482.0929	4	3370.523224			
Total	19740.98697	7				

SS -Sum of squares; df -Degrees of freedom; MS-variance; F-ration *p*- Probability that the result should occur just by random.

For ANOVA results (Table 14) there was no significant difference, since the value of *F* is less than the value of *Fcrit* (see table 1), can also tell the difference with the value of *p-value* is greater than the value of alpha (0.518413209> 0.05), These panellists were evaluated the peanut sauce samples at different stages of cooking, and the same had difficulties in sensory evaluation because, cooked peanut sauce at 80^{0}C hardly detects the reduction of the astringent taste, because at that temperature peanut sauce evaporates and didn't boils thereby influencing the difficulty of assessing the astringent taste the same

Table 14: ANOVA of sensory analyses (descriptive test) of peanut sauce cooked at 80 ^{0}C and 8 hours.

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	106221.9	3	35407.31002	0.891287809	0.518413209	6.591382
Within Groups	158904	4	39726.01181			
Total	265126	7				

SS -Sum of squares; df -Degrees of freedom; MS-variance; F-ration *p*- Probability that the result should occur just by random.

Compared to the two cooking it is possible to verify (Tables 11 and 12) that regardless of the time/ temperature of cooking, evaluators were able to detect differences, although cooking at 100^0C for 2 hours and 30 minutes have the maximum rating of 4 points than cooking at 80^0C for 8 hours rating also maximum of 4 points, simple and obviously clear that regardless of the time the temperature has an important role in the cooking of peanut sauce because happens to 100^0C boiling and evaporation of water.

8.3 Drying curve of peanut Sauce

8.3.1 Drying peanut past at 50^0C

Figure 20 shows the kinetics of drying or the speed with which food loses moisture at 50^0C and air velocity of 3m/s, relative humidity (vide appendix 9), to say that figure 20 have been presented three replicas graphs relating to drying, the samples had differences in the amounts of peanut sauce paste submitted to the drying process (273,3g replica 1; 163,4g replica2 and 200,2g replica 3), it is clear that the graphic behavior reveals in the replica1 greater amount of peanut sauce paste that was submitted to drying process, this can be justified by the fact that: the amount of paste was divided in two aluminum containers, having been the moisture loss was counted in both. In the three graphs through the behavior of the curves, the adaptation of peanut sauce paste drying conditions lasted about 5 hours, where the temperature was equal to the relative humidity, the process continues with decreasing of moisture loss for approximately 15 hours. At 21 hours of drying, starts the moisture resistance , where was increased internal resistance process of the product in relation to moisture loss, having been observed shrinkage, formation of a harder and firmer solid layer and also was noted the cracking of dried peanut sauce. The Samples of replicates 1 and 2 showed a similar behavior in relation to the loss of moisture content until 20 hours, having been with differences at 23 hour of time.

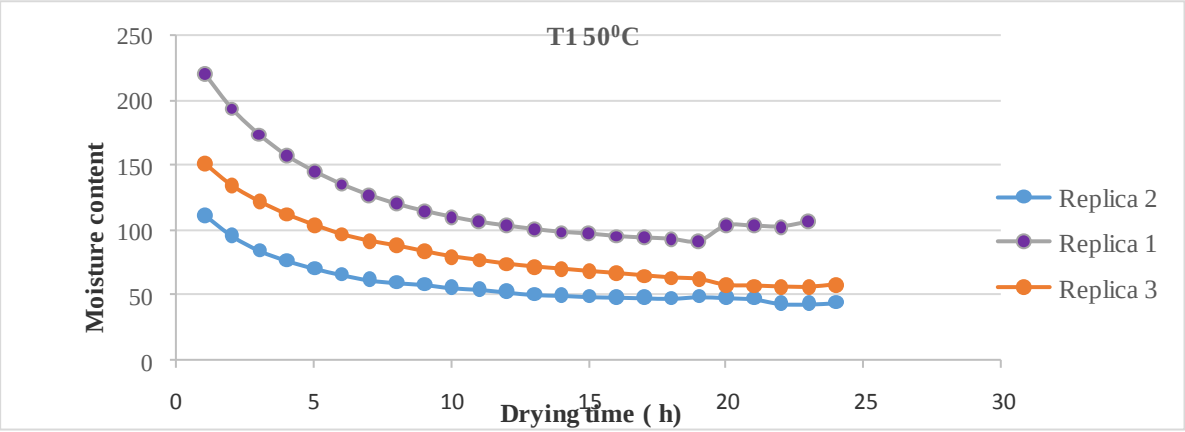


Figure 20: Drying curve of peanut sauce paste

According to (Gavrila *et al*., 2008) dehydration involves the simultaneous transfer of heat, mass and momentum in which heat penetrates into the product and moisture is removed by evaporation into an unsaturated gas phase. The drying rate and the heat flux depend on local air humidity and temperature, as well as mass and heat transfer coefficients in interaction

(Lima *et al*., 2003) on the process of drying fresh fruits and vegetables claim that similarly, the effect of superficial evaporation, the total energy transfer is significant, especially at low relative humidity of the air.

In general the three graphs show that the temperature had influence on the drying process because, with the time passing the moisture content was reduced.

The drying temperature, relative humidity, air drying velocity and the amounts of peanut sauce paste are factors that contribute to the speed as well as slowness of the drying process because despite having undergone the same conditions of temperature and airspeed, and difference in the amounts of peanut sauce paste there is a difference in the behaviour of the three charts because the drying was made in days, hours and quantities of peanut sauce paste, different relative humidity of air which in some time will have contributed to that had different values of loss of moisture content.

8.3.2 Drying peanut paste at 100^0C

Figure 21 showed the results of the drying peanut sauce paste at 100^0C, air velocity 3m/s cooked sauce to 80^0C). In the initial weight of the paste(before the drying process) the

amount of paste was: 203g for the replica 1; 103 g replicate 2;127.7 g replicate 3, comparing the behavior of the graphics, the figure illustrates that, there was had a difference in all of them, the replica 1 showed a loss of moisture almost continuously, having been changes to the course of about 4 -5 hours, after the start of drying and a slight decrease moisture loss from the course of 7 hours, his time characterized by constant moisture loss in which the minimum content of drying has been reached with the end of drying process.

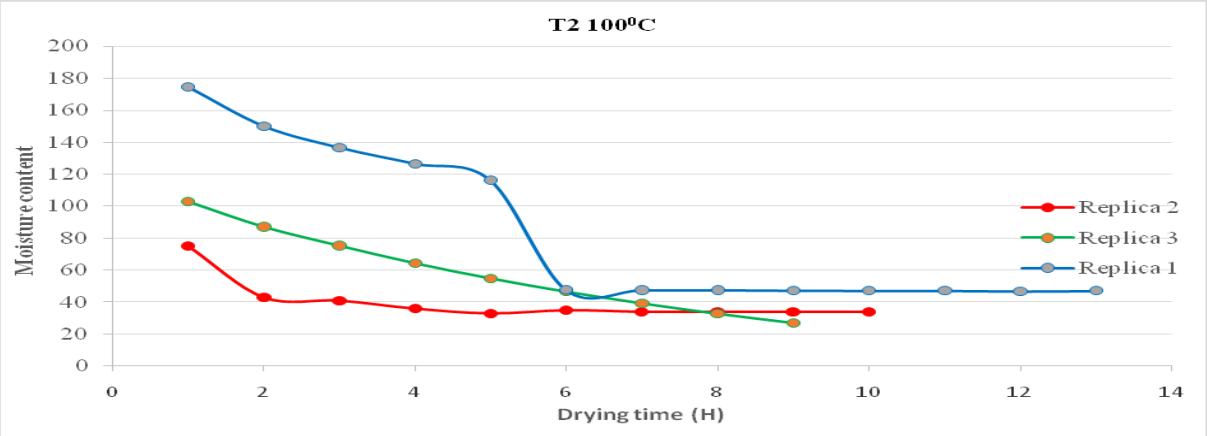


Figure 21: Drying curve of peanut sauce paste at 100^0 Celsius

For replica 2 as shown in figure 21, the graph started with moisture loss in the first 2 hours, when approaching to the 3 hour there was a decline in loss of moisture which lasted up to 6 hours and finally the drying process ceases with graph in the form of a straight line. The replica 3 had a different behaviour comparing with replicates 1 and 2, where the same marked up by a decrease in moisture loss during the first 4 hours, and the start time 4, increased the loss of moisture and from hour 8 loss observed steady loss of moisture which is a feature of the end of the drying process, thus it can be said that the amount of peanut sauce paste submitted to the drying process influence the behaviour graph. In general the amount of peanut sauce paste to dry and the relative humidity contributed to differences in moisture loss and thus different drying curves.

A study conducted by (Mariem & Mabrouk 2014) on Drying characteristics of tomato slices and Mathematical Modeling using drying temperatures ranging from 38^0C to 64^0C concluded that: the moisture content decreases with drying temperature and higher air velocities which can offer a bigger deficit of the water vapour pressure, which is one of the driving forces for the diffusion process of moisture to the outside. The increase of the drying potential and the reduction of the drying time can be explained by the fact that the

rise of temperature causes an increase of the heat transfer intensity. The increase of the drying temperature is responsible for the increase of the energy of water molecules, thus accelerating the migration of the water inside the product, what can escape more easily and more quickly.

On comparing to the drying curves shown in figures 20 and 21 drying (50^0 C and 100^0 C) it can be concluded that the moisture content decreases rapidly with the use of high drying temperatures, drying at 100^0C was faster than in drying at 50^0C. Note that the amount of peanut sauce paste also affected the drying speed as well as the drying delay time. The temperature of 100^0C greatly reduced the drying time of the paste but greatly affected the organoleptic characteristics of the final product.

8.4 Colour

Drying peanut paste affected the colour and lightens of dried paste. All experiments lost the original colour and had a darker colour in relation the original after drying indicated by increased a+ (red colour) and decreased L-value (darker colour) (Table 15). The changes were depending on the specific temperature, with a greater loss of brown colour when exposed for higher temperature of drying. In principle peanut grain began with a 71.50 brightness white almost next to and after the grinding process there was a slightly darker flour may perhaps justified by the reduction in grain size, a slight difference in the value of a + in relation to the value of b+ there was a slight difference in relation to peanuts grain and peanut flour, there was a tendency to yellow positive values (b +), and the drying at 50^0C was closest to the samples of raw material and there was a increase the value of b + to drying being carried out at 100^0C. For the sample brightness values T1 considerably decreased brightness with trends darker colour and having further lowered T2 where the colour of dry paste was even darker compared to the raw material as well as T1, and for the parameters a * values was an increase both T1 and T2 as is shown having larger amounts of red and a slight difference between yellow b+.

The characteristic golden brown colour attributed to melanin produced due to the Maillard browning reaction (Pattee *et al.,* 1991) is associated with desirable flavours and aromas, whereas dark colours are associated with burnt flavours. Brown colour development during processing and storage is desirable for many products such as baked foods, coffee, cookies. (McNeill *et al*., 2000)

The chroma values found (Table 15) for grain peanuts and peanut flour were 20.52 and 20.03 respectively. The colours tend to present some pure tone and where the T1 showed 20.56 and T2 24.01, these trends to increase colour purity and greater intensity. For Hue-angle, values were found in the intervals between the red and yellow. At T1 the Hue-angle was found closer to yellow, a light brown colour and at T2 a dark brown colour. It was also observed that drying at 100^0C it affects much the colour of the final product.

Table 15: Colour coordinates of the samples of grain, peanut flour and peanut sauce.

	Luminosity	a+	b+	Chroma	Hue Angle ^{0}
Peanuts grain	71,50	1,61	20,46	20,52	85,49
	±0,261	±0,036	±0,240		
Peanut Flour	75,99	1,16	19,99	20,03	86,69
	±0,415	±0,115	±0,305		
T1	61,454	4,04	20,16	20,56	78,68
	±3,261	±1,278	±0,89		
T2	50,619	9,45	22,07	24,01	66,83
	±2,0278	±0,556	±0,753		

*T1 drying temperature at 50^0C and *T2 drying temperature at 100^0C

8.5 Water activity, pH, and water content

The table 16 show the pH, moisture and water activity, (physical characteristics) of the two types of drying in dried peanut, was observed slight decrease in the an outcome made to measure wherein it is raising the drying temperature, i.e., 50^0 (T1) and 100^0C respectively (T2).

Table 16: pH, water content and water activity of dried peanut paste during drying process at 50^0C and 100^0C.

Treatment	Determinations	Average/standard deviation
T1	aw	0,36 ± 0,026
	pH	6,71 ± 0,093
	Water Content (%)	2.30 ± 0.647
T2	aw	0,35± 0,014
	pH	6,47 ± 0,047
	Water content (%)	1,36± 0,208

The pH showed a value of 6.71 for the peanut sauce paste dried at 50^0 C, higher than in relation to that found by (Dos Santos *et al*., 2011) to make the characterization of the Brazilian nut (*Bertholletia excelsa* HB K) and obtained results of 6,630g/100 g for pH; (Lima & Bruno, 2007) evaluated the stability of cashew nut butter and obtained pH 6.36 slightly below to the results found in this study in drying at 50^0C and slightly close to the result of the drying of peanut sauce to 100^0C.This result indicate the measurement of hydrogen ion activity and indicates the acidity of a solution, The pH showed for rehydratable peanuts sauce a pH next to the neutrality; (Burnett *et al*., 2000) studied the Survival of *Salmonella* in peanut butter and peanut butter and were found in samples of butters and spreads a pH ranged from6.1-6.4,these values can be compared to that found in the present study, when submitted to drying at 100^0C peanuts, as shown in Table 16 that, this value close to the above mentioned.

Was found in another study of Physical and chemical analysis of aqueous extract of peanut conducted by (Oliveira *et al.*, 2014) who obtained pH values in peanut milk of 6.66, that it is next to the one found in this study in relation to drying at 50^0C.

The moisture content is not sufficient to predict the food stability in this context was determined the water content and water activity of the rehydratable peanut sauce, the results showed that 2.30% and 0.36 for T1 and 1.36% and 0.35 for T2, these were the results of water content and a_w respectively, the same showed the effect of temperature on the total water content of the final product, then the measure increase the temperature, the water content value decreased and had a slight difference of the water activity value.

According to (Jangam *et al.*, 2010) the growth of most harmful microorganisms is inhibited at water activity below 0.60 or moisture content less than 10% in general,

(Lima & Bruno, 2007) found water content and water activity values of 1.29% and 0.36 respectively. These results corresponding to the study about Stability of cashew nut butter; Burnett *et al.* 2000 evaluated aw of peanut butters and peanut butters spreads ranged from 0.20 to 0.33, 0.5±2% water by weight.

Water activity is used as an indication of free available water in food product that can participate in microorganism's growth and chemical reactions. Results of drying in Tunnel dryer displayed low water activity for all experiments and the same showed that rehydratable peanut sauce had stability on microbial proliferation, can be considered this a safe food.

8.6 Rehydration

The process of rehydration of 50g peanut sauce during 15 minutes of boil, showed the best performance.The process of heating increased the protein stability, because didn't observe the foaming or raising sauce in the pot not were observed.

The temperature has an effect on the emulsion stability because there was no observed separation process of the sauce components with this, it can be said that sauce is a stable emulsion, and can be considered a food that can added value for the industry in providing food ready for consumption. The sauce exhibited forming characteristics in a small amount of foam (appearance of some bubbles) compared to the peanut sauce cooking process, it may be that boiling sauce has reduced the expansion and foam volume probably.

9.0 Conclusions

The cooking process at 100^0C for 150 min showed best results regarding the content of phenolic compounds, the peanut cooking temperature influences the concentration of these compounds, because as time went elapsing happened a few oscillations but in generally until the end of the 128 min showed a higher concentration of these compounds, with it can be said that there is an inverse link between the concentration of phenolic compounds and the astringent taste of peanut sauce, as it takes longer to cook reduce the astringent taste and increase the concentration of these compound due to increased degradation or breakdown of more complex structures of phenolic compounds in less complex structures those responsible for the astringent taste.

For sensory analysis can be concluded that the evaluators did not understood very well the astringent taste, because it is very complex and needs a lots and a lots of training, thus the results demonstrated that the evaluators had difficulties in making a proper evaluation of this type of taste characteristic of peanuts, but the evaluation made by the researcher trained in astringent taste of peanut sauce showed that when increase the temperature and the time, decreases the intensity of the astringent taste. In general the tasters as well as the analytical testing, in this case the quantification of phenolic compounds, showed that : can accepting hypothesis H0 (null hypothesis), therefore how much higher was the temperature, the highest was the degradation of phenolic compounds culminating with reduction of astringent taste or neutral peanut sauce astringency flavour.

The drying process was influenced by the temperature of the drying air humidity and the air velocity and also the amount of paste submitted to the drying process lower relative humidity, higher is drying process.

For the physical characteristics which were the moisture content and water activity got the conclusion that the best results was those of the sample submitted to the 50^0C drying process because the low water content of peanut sauce favour an extended a shelf life of dehydrated peanut sauce drying also showed a product having a water activity which does not favour microbial growth: despite having been observed low values drying 100^0C sample presented no pleasant organoleptic characteristics the sight of anyone who mainly has the appearance and odor of the sample was observed burned food with burnet.

The pH values lie close to a pH value close to neutrality with it can be concluded that the peanut sauce is a bit or less acid food.

The colour of peanut paste submitted to the drying process at 50^0C showed to be with a light brown colour, while the 100^0C dying showed dark brown, with a burnt sauce appearance, the drying temperature influenced peanut sauce colour, as more is the largest high drying temperature will be the food colour loss.

For the process of rehydration showed emulsion stability of the protein and also since it is not observed the appearance of foam in the hydrated sauce

10.0 Future research

The study included in present dissertation the peanut sauce development, the content of polyphenols, the physical characteristic of the dehydrated peanut sauce and final the sensory quality of peanut sauce but there are still missing some suggest analysis to do in dehydrated peanut sauce.

- The use of different types of dryer for the drying process and comparing the physical characteristics of the final product
- Determination of the particles size of peanut sauce powder after the drying process and the relationship with the rehydration processes;
- It is recommended to future studies that identify the type of phenolic compounds existing in peanut sauce and possible quantities, determine those that are responsible for the astringent taste and explain what happens in terms of the structures of these compounds responsible for the astringency in relation to time/ temperature of cooking sauce;
- Due to the presence of phenolic compounds it is recommended to determine the activity or potential antioxidant of peanut sauce considering such factors as the combination of time and cooking temperature.

11.0 References

Abidi, S. L. (2001). Chromatographic analysis of plant sterols in foods and vegetable oils. *Journal of chromatography A*, *935*(1), 173-201.

Adolfo, L. (1985). Normas Analíticas do Instituto Adolfo Lutz. *Métodos químicos e físicos para análise de alimentos*, 3. ed. Sao Paulo: IMESP, 1985.

Ahmed, E. H., & Young, C. T. (1982). Composition, nutrition and flavour of peanut. *American Peanut Research and Education Society, Yoakum, Texas*, 655-687.

Andersen, F. A. (2001). Final report on the safety assessment of peanut (*arachis hypogaea*) oil, hydrogenated peanut oil, peanut acid, peanut glycerides, and peanut (*arachis hypogaea*) flour. *International journal of toxicology*, *20*, 65-77.

AOAC. Association of Official Analytical Chemists. *Official methods of analysis*. 15th ed. Washington, 1995.

Awad, A. B., Chan, K. C., Downie, A. C., & Fink, C. S. (2000). Peanuts as a source of β-sitosterol, a sterol with anticancer properties. *Nutrition and cancer*, *36*(2), 238-241.

Ayres, J. L., Branscomb, L. L., & Rogers, G. M. (1974).Processing of edible peanut flour and grits. *Journal of the American Oil Chemists Society*, *51*(4), 133-136.

Azam-Ali, S. (2008). Drying of Foods. Practical Action The Schumacher Centre for Technology and Development.

Belitz, H. D., Grosch, W., & Schieberle, P. (2009).Coffee, tea, cocoa. *Food chemistry*, 938-970.

Bell, E. A., & Charlwood, B. V. (1980). *Secondary plant products.Encyclopedia of Plant Physiology.* Berlin, Heidelberg, New York. Springer-Verlag.

Bohm, B. A. (1998). *Introduction to flavonoids*. Harwood academic publishers.

Bortoli, S. A., Doria, H. O. S., Albergaria, N. M. M. S., Murata, A. T., & Vescove, H. V. (2005). Aspectos biológicos e nutricionais de Anticarsia gemmatalis Hüebner, 1818 (Lepidoptera: Noctuidae) em soja, amendoim e dieta artificial. *Bol. Sanidad Veg. Plagas*, *31*, 171-178.

Bravo, L. (1998). Polyphenols: chemistry, dietary sources, metabolism, and nutritional significance. *Nutrition reviews*, *56*(11), 317-333.

Burnett, S. L., Gehm, E. R., Weissinger, W. R., Beuchat, L. R. (2000). Survival of Salmonella in peanut butter and peanut butter Spread. *Journal of Applied Microbiology*, 89, 472-477.

Camargo, A. C. D.(2012). *Efeitos físico-químicos da radiação gama no amendoim e a utilização da sua película como antioxidante natural*, Tese de Doutorado. Universidade de São Paulo.

Carpenter, D. L., Lehmann, J., Mason, B. S., & Slover, H. T. (1976). Lipid composition of selected vegetable oils. *Journal of the American Oil Chemists Society*, *53*(12), 713-718.

Chen, X . D., & Mujumdar, A. S. (2008). *Drying Technologies In Food Processing*, Wiley-Blackwel.

Chukwumah, Y., Walker, L., Vogler, B., & Verghese, M. (2007). Changes in the phytochemical composition and profile of raw, boiled, and roasted peanuts. *Journal of agricultural and food chemistry*, *55*(22), 9266-9273.

Cobb, W. Y., & Johnson, B. R. (1973). Physicochemical properties of peanuts. *Peanuts-Cultures and Uses*, 209-263.

Conkerton, E. J., & Ory, R. L. (1976). Peanut proteins as food supplements: A compositional study of selected Virginia and Spanish peanuts. *Journal of the American Oil Chemists Society*, *53*(12), 754-756.

Coward, L., Smith, M., Kirk, M., & Barnes, S. (1998). Chemical modification of isoflavones in soy foods during cooking and processing. *The American journal of clinical nutrition*, *68*(6), 1486S-1491S.

Coultate, T. P. (2002). *Food: the chemistry of its components.* Fourth edition. Cambridge, UK: Royal;

Craft, B. D. (2009). Effects of processing on the chemistry and antioxidant capacity of endogenous bioactive compounds in peanut kernels and skins. PhD These.

Crozier, A., Burns, J., Aziz, A. A., Stewart, A. J., Rabiasz, H. S., Jenkins, G. I., & Lean, M. E. (2000). Antioxidant flavonols from fruits, vegetables and beverages: measurements and bioavailability. *Biological Research*, *33*(2), 79-88;

Dabrowski, K. J., & Sosulski, F. W. (1984).Composition of free and hydrolyzable phenolic acids in defatted flours of ten oilseeds. *Journal of agricultural and food chemistry*, *32*(1), 128-130.

De Almeida, B. B., De Castro, G. S. F., Jordão, A. A., & Chaparro, L. C. (2011). Projeto O Amendoim e a Saúde: Fatos e Mitos. NutriRP, Centro – Ribeirão Preto/SP.

Dos Santos O.V., Corrêa N. C. F., Da Silva, L. S. C. (2011). Caracterização física, físico-química, microbiológica em icotoxicologica da castanha-do-brasil (*bertholletia excelsa* H. B. K). *Revista Iluminart*, p 48-59.

Evans, E. R. (1982). Confectionery products from peanuts. *Cereal Food World 27*: 5993-596.

Fatland, B. L., K, J., Anderson, M. D., Mentzen, W. I., Cui, L. W., Allred, C. C., & Wurtele, E. S. (2002). Molecular characterization of a heteromeric ATP-citrate lyase that generates cytosolic acetyl-coenzyme A in Arabidopsis. *Plant Physiology*, *130*(2), 740-756.

Fellows, P. (2000). Food processing technology: principles and practice second edition,.

Fraser, G. E., Sabate, J., Beeson, W. L., Strahan, T. M. A. (1992) Possible protective effect of nut consumption on risk of coronary heart disease: the Adventist Health Study. *Archives of Internal Medicine*, 152 (7), 1416-1424.

Gacula, M. C. (1997). Descriptive Sensory analysis in practice. Trumbull, CT: Food and Nutrition Press.

Gava, A. J. (2000). *Princípios de Tecnologia de Alimentos*. São Paulo: Nobel, 200 p;

Gavrila, C., Ghiaus , A. G., Ion, G., (2008) Heat and Mass Transfer in Convective Drying Processes. *Proceedings of the COMSOL Conference Hannover*.

Gaydou, E. M., Bianchini, J. P., & Ratovohery, J. V. (1983). Triterpene alcohols, methylsterols, sterols, and fatty acids in five Malagasy legume seed oils. *Journal of Agricultural and Food Chemistry*, *31*(4), 833-836.

Geankoplis, C. J. (1993). *Transport Process and Unit Operations*. 3. Ed. New Jersey: hall, 921 p.

Griel, A. E., Eissenstat, B., Juturu, V., Hsieh, G., & Kris-Etherton, P. M. (2004). Improved diet quality with peanut consumption. *Journal of the American College of Nutrition*, *23*(6), 660-668.

Grosso, N. R., Nepote, V., & Guzmán, C. A. (2000). Chemical composition of some wild peanut species (Arachis L.) seeds. *Journal of Agricultural and Food Chemistry*, *48*(3), 806-809.

Harborne, J. B. (1989). General procedures and measurement of total phenolics. *Methods in plant biochemistry*, *1*, 1-28.

Harder, M. N. C. (2005). *Efeito do urucum (Bixa Orellana) na alteração de características de ovos de galinhas poedeiras* (Doctoral dissertation, Escola Superior de Agricultura "Luiz de Queiroz).

Higgs, J. (2005). The potential role of peanuts in the prevention of obesity..*Nutrition & Food Science*, *35*(5), 353-358.

Hollis, J., & Mattes, R. (2007).Effect of chronic consumption of almonds on body weight in healthy humans. *British Journal of Nutrition*, *98*(03), 651-656.

https://pt.wikipedia.org/wiki/Caril_de_amendoim, accessed on 05.05.2015.

http://lifestyle.sapo.pt/sabores/receitas/caril-de-amendoim, accessed on 05.05.2015.

http://www.portugal-linha.pt/sabores/mocamb/ca001.html, accessed on 05.05.2015.

http://www.photonics.com/EDU/Handbook.aspx?AID=25124, accessed on 17.08.2015

http://www.handprint.com/HP/WCL/color7.html) accessed on 17.08.2015

Irshad, M., & Sharma, C. B. (1981). Purification and properties of an α-amylase protein-inhibitor from Arachis hypogaea seeds. *Biochimica et Biophysica Acta (BBA)-Enzymology*, *659*(2), 326-333.

ISO, (1994. Sensory analysis Methodology Texture profile. 11036. International Organization for Standardization: Geneva.

Jangam, S. V., Law C. L., & Mujumdar, A. S (Ed)., (2010). Drying of Foods, Vegetables and Fruits. *Published in Singapore*, Volume 1 pp. 31-58.

Jasse, A. (2013) Cadeia de Valores de cereais e oleaginosas. *Relatório de Consultoria do estudo da cadeia de valores de Oleaginosas*, available in http://www.perene.org/wp-content/uploads/2013/12/Estudo-cadeia-de-valor-cereais-e-oleaginosas-PERENE-CESVI-01-04-2013.pdf accessed on 4/25/2015.

Jiang, R., Manson, J. E., Stampfer, M. J., Liu, S., Willett, W. C., & Hu, F. B. (2002). Nut and peanut butter consumption and risk of type 2 diabetes in women. *Jama*, *288*(20), 2554-2560.

Kris-Etherton, P. M., Zhao, G., Binkoski, A. E., Coval, S. M., & Etherton, T. D. (2001). The effects of nuts on coronary heart disease risk. *Nutrition Reviews*, *59*(4), 103-111.

Lawless, H. T. & Heymann, H. (1998). Sensory Evaluation of Food Principles and Practice. New York. Chapman and Hall.

Lima, J. R., & Bruno L. M. (2007). Estabilidade de pasta de amêndoa de castanha de caju. *Ciênc. Tecnol. Aliment,Campinas*, 27(4), 816-822.

Lima, L. D. A, Da Silva, J B. D, De Lima, A.G. B. (2003). Transferência de Calor e Massa Durante a Secagem de Sólidos Com forma Arbitrária: Uma Abordagem Concentrada. *Eng. Agríc., Jaboticabal, v.23, n.1, p.150-162.*

Lusas, E. W. (1979). Food uses of peanut protein. *Journal of the American Oil Chemists' Society*, *56*(3), 425-430.

Mariem, S. B., & Mabrouk S. B. (2014). Drying Characteristics of Tomato Slices and Mathematical Modeling. *International Journal of Energy Engineering*, 4(2A): 17-24.

Mattes, R. D., Kris-Etherton, P. M., & Foster, G. D. (2008). Impact of peanuts and tree nuts on body weight and healthy weight loss in adults. *The Journal of nutrition*, *138*(9), 1741S-1745S.

McManus, K., Antinoro, L., & Sacks, F. (2001). A randomized controlled trial of a moderate-fat, low-energy diet compared with a low fat, low-energy diet for weight loss in overweight adults. *International Journal of Obesity & Related Metabolic Disorders*, *25*(10)

McNeill, K. L., Sanders, T. H., & Civille, G. V. (2000).Using focus groups to develop aquantitative consumer questionnaire for peanut butter. *Journal of Sensory Studies*, 15, 163-174.

Meilgaard, M., Civille, G. V., & Carr, B. T. (1991).*Sensory evaluation techniques*. 2nd ed. Boca Raton, FL: Press.

Miller, N. J., & Rice Evans, C. A. (1995).Antioxidant activity of resveratrol in red wine.*Clinical Chemistry*, 41, 1789.

Mujumdar, A., & Zhonghua, W. (2008). Thermal drying technologies - cost-effective innovation aided by mathematical modeling approach. *Drying Technology*, *26*(1), 146-154.

Murray, J. M., Delahunty, C. M., & Baxter, I. A. (2001). Descriptive sensory analysis: past, present and future. *Food research international*, *34*(6), 461-471.

Nautiyal, P.C. (2002) *Groundnut: Post-Harvest Operations*, available in :

http://www.fao.org/fileadmin/user_upload/inpho/docs/Post_Harvest_Compendium_-_Groundnut.pdf, accessed on 07/17 /2015.

Nielsen, S. S. (Ed.). (2010a). *Food analysis laboratoty manual*.Second edition, New York, NY, USA:: Springer.

Nielsen, S. S. (Ed.). (2010b). *Food analysis*. Fourth edition, New York, NY, USA:: Springer.

Ntare, B.R. (2006). *ArachisHypogaea L. In Brink M and Belay G*, ed. Plant Resources of Tropical Africa. Vol.1. Cereals and pulses, Foundation PROTA, Wageningen, Netherlands Backhuys Publishers, Leiden, Netherlands. CTA,Wageningen, Netherlands. 328 p.

Oliveira, T. K. B., Almeida, F. D. A. C., De Castro, D. S., Nunes J. S., & Ramos, K. R. D. L. P. (2014). Analise físico-química do extrato aquoso do amendoim. *Revista Verde (Mossoró–RN-Brasil)*, *9*(2), 121-124.

Oliveira,T. K. B. , Almeida, F. de Assis Cardoso; de Castro, D.S; Pattee, H. E., Giesbrecht, F. G., & Young, C. T. (1991).Comparison of peanut butter color determination by CIELAB L*a*b* and Hunter color-difference methods and the relationship of roasted peanut color to roasted peanut flavor response. *Journal of Agricultural and Food Chemistry*, 39, 519-523.

Pancholy, S. K., Deshpande, A. S., & Krall, S. (1978). Amino acids, oil and protein content of some selected peanut cultivars. *Proceedings American Peanut Research and Education Association, Inc.*

Peixoto, A. R.(1992). Plantasoleaginosasherbáceas.São Paulo: Nobel, 1992. 171 p.

Pelkman, C. L., Fishell, V. K., Maddox, D. H., Pearson, T. A., Mauger, D. T., & Kris-Etherton, P. M. (2004). Effects of moderate-fat (from monounsaturated fat) and low-fat weight-loss diets on the serum lipid profile in overweight and obese men and women. *The American journal of clinical nutrition*, *79*(2), 204-212.

Perera, C.O. 2005. Selected Quality Attributes of Dried Foods. Drying Technology: An International Journal 23 (4):717 – 730

Perera, C. O. (2005). Selected quality attributes of dried foods. *Drying Technology*, *23*(4), 717-730.

Quideau, S., Deffieux, D., Douat-Casassus, C., &Pouységu, L. (2011).Plant polyphenols: chemical properties, biological activities, and synthesis. *Angewandte Chemie International Edition*, *50*(3), 586-621.

Renaud, S., & De Lorgeril, M. (1992). Wine, alcohol, platelets, and the French paradox for coronary heart disease.*The Lancet*, 339, 1523–1526.

Rice-Evans, C., Miller, N., & Paganga, G. (1997).Antioxidant properties of phenolic compounds. *Trends in plant science*, *2*(4), 152-159.

Sanders, C. T., De Masie, C.L., Kerr, W. L., Hargrove, J.L., Pegg, R.B, Swanson, R.b., (2014). Peanut skins-fortified peanut butters: Effects on consumer acceptability and quality characteristics. *LWT - Food Science and Technology*Pages 222-228.

Santos, R. C., Gondim, T. M. S., & Freire, R. M. M. (2006). Mercado e comercialização. Cultivo de amendoim. Available in: http://sistemasdeproducao.cnptia.embrapa. br/FontesHTML/Amendoim/CultivodoAmendoim/mercado. html. Accessed in, 06 /03 / 2014.

Saura-Calisto, F., Garcia-Alonso, A., Goni, I. (2000). In vitro determination of the indigestible fraction in foods: An alternative to dietary fiber analysis. *Agricultural and Food Chemistry*, 48, 3342-3347.

Scalbert, A., Johnson, I. T., & Saltmarsh, M. (2005). Polyphenols: antioxidants and beyond. *The American journal of clinical nutrition*, *81*(1), 215S-217S.

Silva, M. R., & Da Silva, M. A. A. P. (2000). Fatores antinutricionais: inibidores de proteases e lectinas tores antinutricionais: inibidores de proteases e lectina S. *Rev. Nutr*, *13*(1), 3-9.

Singh, B. (1985). Peanut utilization in food systems in developing countries.Annual Report Peanut CRSP. University of Georgia, Expt. Station, GA.

Singh, B., & Singh, U. (1991). Peanut as a source of protein for human foods.*Plant Foods for Human Nutrition*, *41*(2), 165-177.

Singleton, V. L., & Rossi, J. A. (1965).Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American journal of Enology and Viticulture*, *16*(3), 144-158.

Stone, H., and Sidel, J. L. 1993.Descriptive analysis.Pages 202-242 in: Sensory Evaluation Practices. 2nd ed. Academic Press: San Diego, CA.

Talcott, S. T., Passeretti, S., Duncan, C. E., & Gorbet, D. W. (2005). Polyphenolic content and sensory properties of normal and high oleic acid peanuts. *Food Chemistry*, *90*(3), 379-388.

Tsao, R., Khanizadeh, S., & Dale, A. (2006). Designer fruits and vegetables with enriched phytochemicals for human health. *Canadian journal of plant science*, *86*(3), 773-786.

Tsao, R., McCallum, J. (2009). Chemistry of Flavonoids. In Fruit and Vegetable Phytochemicals: Chemistry, Nutritional Value and Stability; de la Rosa, L.A., Alvarez-Parrilla, E., Gonzalez–Aguilar, G., Eds.; Blackwell Publishing: Ames, IA, USA, Chapter 5, pp. 131–153.

USAID. (2010). O Amendoim Uma Cultura de Boa Nutrição e Rendimento. Available in http://www.iiam.gov.mz/documentos/isfm/Manual_Amendoim.pdf accessed on 06 /19 / 2015.

Williamson, G., & Manach, C. (2005). Bioavailability and bioefficacy of polyphenols in humans. II. Review of 93 intervention studies. *American Journal of Clinical Nutrition*, 81, 243S–255S;

Woodroof, J.G (1983) Composition and nutritive value of peanuts ill peanuts: In: Woodroof JG (ed.), Production, Processing, Products. The AVI Publishing Company, Inc., Westpoit: Connecticut, pp. 165-180.

Appendix 1: Results of standard curve

Concentration	**Absorbance**
0	0.0014
0	0.0015
0	0.0011
10	0.1319
10	0.1308
10	0.1311
10	0.1315
20	0.2276
20	0.2269
20	0.2267
20	0.2268
30	0.2651
30	0.2641
30	0.2657
30	0.2651
40	0.3627
40	0.3627
40	0.364
40	0.3645
50	0.3885
50	0.3885
50	0.3884
50	0.3885

Appendix 2: Absorbance results, reading by the spectrophotometer

Cooking at 100^0C during 128 minutes

	0 min of cooking		2 min of cooking	4 min of cooking	8 min of cooking	16 min of cooking	32 min of cooking	64 min of cooking	128 min of cooking
	Readings	Absorbance							
Sample 1	1	0.8695	0.5815	0.725	0.4172	0.5027	0.6113	0.7241	0.9285
	2	0.87	0.5828	0.7255	0.4180	0.5012	0.6117	0.7248	0.9273
	3	0.8711	0.5828	0.7278	0.4179	0.5016	0.6117	0.725	0.927
Sample 2	4	0.6247	0.6804	0.6548	0.6181	0.5582	0.6089	0.8106	1.0236
	5	0.6244	0.6804	0.6549	0.6185	0.5582	0.6088	0.8106	1.0235
	6	0.6242	0.6804	0.6551	0.6184	0.5584	0.609	0.8108	1.0237
Sample 3	7	0.5846	0.5619	0.6441	0.6078	0.8099	0.8662	0.8044	0.9818
	8	0.5846	0.5619	0.6441	0.6081	0.8109	0.8661	0.8043	0.9816
	9	0.5846	0.5619	0.644	0.6083	0.8112	0.86253	0.8046	0.9818

Appendix 3: Cooking at 80^0C during 8 hours

Sample cooking at 80 degrees and dry at 100 degrees

		0 min of cooking	2 min of cooking	4 min of cooking	8 min of cooking	16 min of cooking	32 min of cooking	64 min of cooking	128 min of cooking	256min of cooking	512 min of cooking
	Readings	Absorbance									
Sample 1	1	0.6409	0.6571	0.6205	0.653	0.7625	0.5069	0.9365	0.8077	0.8946	1.0273
	2	0.6409	0.6571	0.6203	0.653	0.763	0.5071	0.9362	0.8075	0.8948	1.0273
	3	0.6409	0.6571	0.6204	0.6532	0.7638	0.5073	0.9366	0.8075	0.8948	1.0272
Sample 2	4	0.6177	0.7536	0.597	0.6758	0.7328	0.7074	0.6822	0.7827	0.8714	0.949
	5	0.6178	0.7538	0.5967	0.6758	0.7327	0.7074	0.6824	0.7827	0.8714	0.949
	6	0.6177	0.7541	0.5968	0.6756	0.7327	0.7075	0.6824	0.7829	0.8714	0.9486

Appendix 4: Model used in sensory analysis

Descriptive Test **Date_____**

Product: _____ **Time_____**

Please help yourself to indicate whether there are differences between the peanut sauce samples and the standard. Use the scale indicated below to qualify this difference. **Mark only one qualification for sample.**

1) Very astringent
2) Moderately astringent
3) Slightly astringent
4) Neutral astringent

Standard of peanut sauce

Sample	Quality
VA	Very astringent
N	Neutral astringent

Sample Nº 886	**Sample Nº 990**	**Sample Nº 199**	**Sample Nº 171**

Sample Nº 224	**Sample Nº 335**	**Sample Nº 886**	**Sample Nº 912**

Standard Samples

0 hours Sample number **834**	Very astringent
2 hours Sample number **546**	Neutral astringent

Cooking 80 degree Celsius in 8 hours

Sample Nº 886	**Sample Nº 990**	**Sample Nº 199**	**Sample Nº 171**
0 min	30 min	1hours	8 hour

Cooking 100 degree Celsius in 2houras e 30 minutes

Sample Nº 224	**Sample Nº 335**	**Sample Nº 887**	**Sample Nº 912**
0 min	30 min	1 hour	2h and 30 minutes

Appendix 5: Results of: water Content, water activity (aw), pH of dehydrated peanut sauce cooking at 1000C, drying at 500C (T1) and cooking t 800C, dry at 1000C (T2).

	Water content		Aw		pH	
	T1	**T2**	**T1**	**T2**	**T1**	**T2**
First replica	2.0963871	0.9153622	0.362333	0.321	6.7	6.54
	1.8093969	1.2330907	0.402667	0.335	6.81	6.51
	2.0788984	1.4937787	0.364333	0.342333	6.81	6.54
Second replica	2.4807896	1.4482211	0.362333	0.347333	6.72	6.41
	1.0234499	1.303477	0.402667	0.360667	6.79	6.47
	3.0784047	1.6188545	0.364333	0.336333	6.79	6.44
Third replica	2.8973	1.542053	0.32	0.345667	6.58	6.44
		1.3499171	0.334133	0.360333	6.61	6.44
	2.9249	1.3163581	0.343667	0.369333	6.61	6.42

Appendix 6: Results Colour

Sample n^{o}	Number of reading	Cooking at 100^{0}C , drying at 50^{0}C			Cooking at 80^{0}C , drying at 100^{0}C		
		L	a	b	L	a	b
Sample 1	1	64.39	2.67	19.67	50.64	9	21.69
	2	66.38	2.53	18.17	47.67	9.21	20.3
	3	64.83	2.79	20.28	50.46	9.22	22.33
	4	63	2.79	19	52.26	9.29	23.26
	5	65.72	2.7	20.24	50.19	9.47	21.98
	6	61.19	3.37	21.37	50.1	9.81	22.18
Sample 2	7	57.89	5.89	21.17	49.18	10.2	22.28
	8	56.78	5.81	19.6	50.71	10.03	22.61
	9	57.24	5.69	19.79	48.88	9.74	21.32
	10	56.9	5.73	19.56	47.6	10.29	22.23
	11	56.72	5.72	19.15	49.28	9.93	21.88
	12	58.83	5.41	20.53	49.9	10.44	23.04
Sample 3	13	63.37	3.57	20.5	54.27	8.89	22.3
	14	63.43	3.31	20.39	54.78	8.81	20.6
	14	63.33	3.44	20.19	50.03	8.9	22.55
	15	62.65	3.69	20.39	52.92	8.68	22.07
	16	61.15	3.72	21.28	49.61	9.11	21.92
	17	62.38	3.82	21.63	52.67	9.05	22.78
	18	64.39	2.67	19.67			

Appendix 7: Results of drying at 50^0C

Time (Hours)	Replica 3 average of weight before drying 185,9g	Time (H)	Average of weight	Results of Replica 1 before drying 273,3		Time (Hours)	Weight	Results of Replica 2 before drying 149,9 g			
1	152	21	57.3			20	103.7	Time	Average	Time	
2	134.8	22	56.5	1	220.6	21	103.7	1	111.6	19	48.5
3	122.6	23	56.3	2	193.6	22	103.1	2	95.4	20	47.8
4	112.6	24	58.3	3	173.66	23	106.7	3	84.1	21	46.8
5	104.4	25	58.3	4	157.6	20	103.7	4	76.4	22	43.2
6	97.2	26	57.2	5	145.6	21	103.7	5	70.4	23	42.9
7	92.1	27	57.5	6	135.6	22	103.1	6	65.5	24	43.9
8	88.4	28	56.5	7	127.3	23	106.7	7	61.4		
9	84	29	56	8	120.7	20	103.7	8	59.3		
10	80	30	55.6	9	115.1			9	57.9		
11	77.2	31	55.1	10	110.6			10	55.4		
12	74.3	32	54.8	11	106.7			11	54.2		
13	72.1	33	54.4	12	103.8			12	52.1		
14	70.4	34	54.2	13	101.1			13	50.2		
15	68.6	35	54.1	14	98.9			14	49.6		
16	67	36	53.9	15	97.6			15	48.6		
17	65.2	37	53.8	16	95.7			16	48.2		

18	63.6	38	53.9	17	94.5			17	47.7		
19	62.4	39	53.9	18	93.6						
20	57.8	40	53.7	19	91.7						
21	57.3	41	54.1	20	103.7						
22	56.5	42	53.9	21	103.7						
23	56.3	43	53.9	22	103.1						
24	58.3	44	54.1	23	106.7						

Appendix 8: Results of drying at 100^0C.

Weight before drying 103 g 2 replica		Weight before drying Replica 3 127,7g		Weight before drying Replica 1 203g		
tempo (H)	peso (g)			tempo (H)	tempo (S)	peso (g)
1	28	24.8	24.8	1	3600	28.5
2	60	40.6	40.6	2	7200	53
3	62	52.4	52.4	3	10800	66.4
4	67	63.4	63.4	4	14400	76.5
5	70	72.9	72.9	5	18000	86.9
6	68	81.2	81.2	6	21600	155.4
7	69	88.5	88.5	7	25200	155.5
8	69	95	95	8	28800	155.5
9	69	100.8	100.8	9	32400	155.8
10	69	100.8	100.8	10	36000	155.9
				11	39600	155.9
				12	43200	156.3
				13	46800	156

Appendix 9: Summarize of results of relative humidity of the air.

NO.	DATE	TIME	TEMPERATURE	RELATIVE-HUMIDITY	DEW-POINT
1	24.06.2015	10:27:31	24	39.2	9.2
2	24.06.2015	10:27:41	24	47.8	12.2
3	24.06.2015	10:27:51	24	42.5	10.4
4	24.06.2015	10:28:01	24	40.8	9.8
5	24.06.2015	10:28:11	24.1	42.2	10.4
6	24.06.2015	10:28:21	24.1	39.6	9.5
7	24.06.2015	10:28:31	24.2	39.8	9.6
8	24.06.2015	10:28:41	24.3	40.7	10.1
9	24.06.2015	10:28:51	24.4	40.7	10.1
10	24.06.2015	10:29:01	24.6	43.2	11.2
2668	24.06.2015	17:52:01	29.1	25.5	7.3
2669	24.06.2015	17:52:11	29.1	25.5	7.3
2670	24.06.2015	17:52:21	29.1	25.5	7.3
2671	24.06.2015	17:52:31	29.1	25.6	7.4
2672	24.06.2015	17:52:41	29.1	25.6	7.4
2673	24.06.2015	17:52:51	29.1	25.6	7.4
2674	24.06.2015	17:53:01	29.1	25.6	7.4
2675	24.06.2015	17:53:11	29	25.6	7.3
2676	24.06.2015	17:53:21	29	25.6	7.3
2677	24.06.2015	17:53:31	29	25.6	7.3
2678	24.06.2015	17:53:41	29	25.6	7.3
2679	24.06.2015	17:53:51	29	25.6	7.3
2680	24.06.2015	17:54:01	29	25.6	7.3
2681	24.06.2015	17:54:11	29	25.6	7.3
2682	24.06.2015	17:54:21	29	25.6	7.3
8052	25.06.2015	8:49:21	20.2	45.7	8.1
8053	25.06.2015	8:49:31	20.2	45.7	8.1
8054	25.06.2015	8:49:41	20.2	45.7	8.1
8055	25.06.2015	8:49:51	20.2	45.7	8.1
8056	25.06.2015	8:50:01	20.2	45.7	8.1
8057	25.06.2015	8:50:11	20.2	45.7	8.1
8058	25.06.2015	8:50:21	20.2	45.7	8.1
8059	25.06.2015	8:50:31	20.2	45.7	8.1
8060	25.06.2015	8:50:41	20.2	45.7	8.1
8061	25.06.2015	8:50:51	20.2	45.7	8.1
8062	25.06.2015	8:51:01	20.2	45.7	8.1
8063	25.06.2015	8:51:11	20.2	45.7	8.1

NO.	DATE	TIME	TEMPERATURE	RELATIVE-HUMIDITY	DEW-POINT
1	09.06.2015	17:16:02	24	53.8	14
2	09.06.2015	17:16:32	24.1	54.3	14.2
3	09.06.2015	17:17:02	24.2	47.2	12.2
4	09.06.2015	17:17:32	24.3	48.4	12.7
5	09.06.2015	17:18:02	24.5	49.3	13.1
6	09.06.2015	17:18:32	24.5	43	11.1
7	09.06.2015	17:19:02	24.6	42.1	10.8
8	09.06.2015	17:19:32	24.6	42.6	11
9	09.06.2015	17:20:02	24.7	41	10.5
10	09.06.2015	17:20:32	24.7	39.9	10.1
11	09.06.2015	17:21:02	24.6	39.7	9.9
12	09.06.2015	17:21:32	24.6	44.1	11.5
2872	10.06.2015	17:11:32	28.6	26.6	7.5
2873	10.06.2015	17:12:02	28.6	26.6	7.5
2874	10.06.2015	17:12:32	28.6	26.6	7.5
2875	10.06.2015	17:13:02	28.6	26.5	7.5
2876	10.06.2015	17:13:32	28.6	26.5	7.5
2877	10.06.2015	17:14:02	28.6	26.5	7.5
2878	10.06.2015	17:14:32	28.6	26.5	7.5
2879	10.06.2015	17:15:02	28.6	26.3	7.3
2880	10.06.2015	17:15:32	28.6	26.2	7.3
2881	10.06.2015	17:16:02	28.6	26.2	7.3
2882	10.06.2015	17:16:32	28.6	26.1	7.2
2883	10.06.2015	17:17:02	28.6	26.1	7.2
2884	10.06.2015	17:17:32	28.6	26	7.2
2885	10.06.2015	17:18:02	28.6	25.9	7.1
2886	10.06.2015	17:18:32	28.6	25.8	7.1
5811	11.06.2015	17:41:02	24	43	10.6
5812	11.06.2015	17:41:32	24	43	10.6
5813	11.06.2015	17:42:02	24	43	10.6
5814	11.06.2015	17:42:32	24	43	10.6
5815	11.06.2015	17:43:02	24	43	10.6
5816	11.06.2015	17:43:32	24	43	10.6
5817	11.06.2015	17:44:02	24	43	10.6
5818	11.06.2015	17:44:32	24	43	10.6
5819	11.06.2015	17:45:02	24	43	10.6
5820	11.06.2015	17:45:32	24	42.9	10.6

5821	11.06.2015	17:46:02	24	42.9	10.6
5822	11.06.2015	17:46:32	24	42.9	10.6
5823	11.06.2015	17:47:02	24	42.9	10.6
5824	11.06.2015	17:47:32	24	42.9	10.6
5825	11.06.2015	17:48:02	24	42.9	10.6
5826	11.06.2015	17:48:32	24	42.9	10.6
5827	11.06.2015	17:49:02	24	48.5	12.4
5828	11.06.2015	17:49:32	24.1	47.8	12.3
5829	11.06.2015	17:50:02	24.2	43	10.8