Study of the physicochemical characteristics and viscosity profile of *Cucúrbita pepo* L.

Estudio de las características fisicoquímicas y perfil de viscosidad de la *Cucúrbita pepo* L.

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Abstract

Pumpkin cultivation is an agricultural economic activity that is carried out in several states of Mexico, of which mainly the seed is marketed. The pulp remains in some cases as a by-product and is used for livestock feed (some farmers discard it in the field and incorporate it into the soil, leaving it as an organic fertilizer (SADR, 2020). By having a physicochemical characterization of the different parts of the fruit and a viscosity profile of the seed oil, it is possible to identify its potential future uses in agroindustry. A proximal analysis of the parts and the viscosity profile of the pumpkin seed oil under isobaric conditions was carried out; obtaining the data of shell, pulp, seed (whole and raw), kernel (raw), seed husk, seed (whole and roasted); which serve as points of comparison with other studies carried out and decision making. The following physical properties were analyzed: moisture percentages, bound water, ash, crude fiber, and chemical properties: conductivity, pH, total nitrogen, protein percentage, lipids, organic carbon, C/N ratio, calcium and magnesium. For the oil extracted from the raw seed, viscosity and density were also determined at different temperatures under isobaric conditions.

Peel, Pulp, Seed, Seed oil, Viscosity isobar

Resumen

El cultivo de la calabaza es una actividad económica agrícola, que se realiza en varios estados de México, de éste, se comercializa principalmente la semilla. La pulpa queda en algunos casos como un subproducto y se utiliza para alimento de ganado (algunos agricultores la desechan en el campo y la incorporan al suelo, quedando como un abono orgánico (SADR, 2020). Al tener una caracterización fisicoquímica de las diferentes partes del fruto y un perfil de viscosidad del aceite de la semilla, es posible identificar sus potenciales usos futuros en la agroindustria. Se realizó un análisis proximal de las partes y el perfil de viscosidad del aceite de las semillas de calabaza en condiciones isobáricas; obteniendo los datos de cáscara, pulpa, semilla (entera y cruda), pepita (cruda), cascarilla de semilla, semilla (entera y tostada); que sirvan como puntos de comparación con otros estudios realizados y la toma de decisiones. Se analizaron las siguientes propiedades físicas: porcentajes de humedad, agua ligada, cenizas, fibra cruda, y las propiedades químicas de: conductividad, pH, nitrógeno total, porcentaje de proteínas, lípidos, carbono orgánico, relación C/N, calcio y magnesio. Para el aceite extraído de la semilla cruda, se determinó adicionalmente, la viscosidad y densidad a diversas temperaturas en condiciones isobáricas.

Cáscara, Pulpa, Semilla, Aceite de semilla, Isobara de viscosidad

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Introduction

Pumpkin (*Cucúrbita pepo* L.) is an annual crop of temperate climate very rooted in Mexico, although it can grow from sea level, up to 2700 metres. It has a great diversity of fruit sizes, colours and shapes, as well as ripening periods; it is part of the Mexican diet (Martínez Alvarado, 2000).

Pumpkin is one of the most important crops in Mexico, together with maize and beans, which is why Mexico is ranked 7th in the world in terms of production. The main pumpkin producers in the country are located in the states of Sonora, Sinaloa, Tlaxcala, Nayarit, Hidalgo, Puebla and Morelos (CANABIO, 2019).

Most of the states' production is destined for international markets (Japan, Canada and the United States). It is reported that, in recent years, pumpkin seed production has increased considerably, with more than 8,000 hectares currently under cultivation (IICA, 2018).

Pumpkin has nutritional properties, such as vitamin A, B, C and E. It also contains minerals, being rich in potassium, calcium, magnesium, iron and zinc. In addition, it has a high beta-carotene content (Agrolanzarote, 2012).

Regarding oil concentrations, several studies report 28% for pumpkin seed, 30% for sunflower seed and 15 to 23% for soybean seed (Hernández A. 2010). It is important to highlight that 10% of the weight of the pumpkin is the seed inside, being this the material of greatest interest for producers, which is the reason for this research (Hernández Ángel, 2010).

The pumpkin and its components have various uses, among them are: the production of sweets, soaps, oils, purees, flour, ornamental, snacks, mole de pepita, fodder for livestock, pots, medicinal (anti-inflammatory, laxative, source of fibre, deworming, healing of sores and burns, treatment of haemorrhoids), treatment of wastewater through enzymes (Espinosa, 2018).

The uses of the oil have diversified, for example: in the food industry, in the cosmetics industry, for bioenergy production, aromatherapy, gastronomy, crop protection, medical industry and others (Díaz Gómez, 2010).

The purpose of physicochemical characterisation of the pumpkin components: fruit peel, pulp, seed (whole and raw), kernel (raw), seed husk, seed (whole and roasted); is to determine the physical properties of the pumpkin components: moisture, bound water and ash. For the oil derived from the seed, to analyse viscosity, density at various temperatures, conductivity, and pH. As well as determining the chemical properties of the pumpkin seed components: total nitrogen, proteins, lipids, organic carbon, C/N ratio, crude fibre, calcium and magnesium, with the intention of identifying attributes of potential biotechnological development (Rössel *et al*. 2018).

Methodology to be developed

A sample of pumpkin was obtained from the Colegio de Postgraduados Campus Salinas de Hidalgo, S.L.P., and physicochemical analyses were performed with four replicates on the peel, pulp, seed (whole and raw), kernel (raw), seed hull, seed (whole and roasted).

Moisture determination

To determine the percentage of moisture by gravimetric method, the samples were placed in a drying oven at 65 °C until a constant weight was obtained between three consecutive weighings. For the calculations, the following formula was applied (NMX-F-083-1986, 1986).

$$\% \, Humidity = \frac{(B-A)-(C-A)}{(B-A)} x100 \tag{1}$$

Where:
A= Weight of bottle at constant weight [g].
B= Weight of bottle at constant weight with wet sample [g] [g
C= Weight of bottle at constant weight with dry sample [g].

Determination of Total Solids

The Total Solids (St) were obtained by difference, with respect to the percentage of moisture, with the following relation (NMX-F-083-1986, 1986).

$$\% \, St = 100\% - \% \, Humidity \tag{2}$$

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Determination of bound water

The bound water is determined by the oven gravimetric method. Dry samples at 65°C were placed in a drying oven at 135°C until a constant weight was obtained between three consecutive weighings. For the calculations, the following formula was applied (Skoog, West, & Holler, 2015).

$$\%Bonded\ water = \frac{(B-A)-(C-A)}{(B-A)} \quad (3)$$

Where:
A= Weight of bottle at constant weight [g].
B= Weight of bottle at constant weight with dry sample at 65°C [g] [g].
C= Weight of jar at constant weight with dry sample at 135°C [g].

Ash Determination

To determine the ash percentage by gravimetric method, one gram of the materials with moisture determined at 65°C was taken, put into the muffle and subjected to 600°C until a white-greyish residue was obtained; the ash percentages were calculated. This percentage was obtained by difference of weights, using the following formula (NOM-Y-607-NORMEX, 2013).

$$\%\ Ashes = \frac{[(crucible\ weight + Ashes)-(crucible\ weight)]}{sample\ weight} x100 \quad (4)$$

All expressed in grams [g].

Determination of volatile solids

Once the ash percentage was determined (NOM-Y-607-NORMEX, 2013), the percentage of volatile solids was calculated by difference, using the difference of ash percentages, with the following formula.

$$\%Sv = 100\% - \%Ashes \quad (5)$$

Determination of fats

Extractions of each of the pumpkin components were carried out in four replicates. The ethereal extract was determined by the Soxhlet method. The following formula was used: (NMX-F-615-NORMEX-2018, 2018).

$$\%Fats = \frac{(P-p)}{m} x100 \quad (6)$$

Where:
P = Mass of flask with fat [g].
p = Mass of the flask without fat [g]
m = Mass of sample [g]

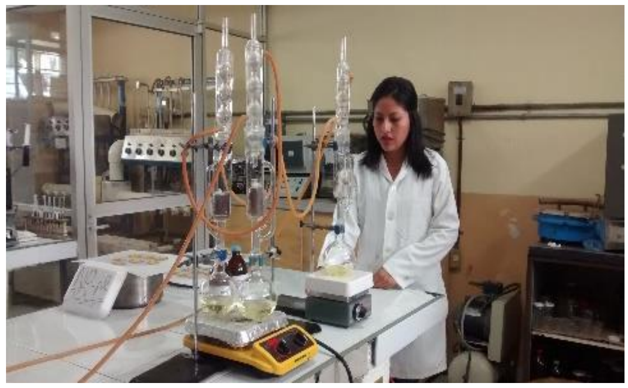


Figure 1 Fat determination
Own Source

Determination of total nitrogen

Total nitrogen was determined by the Kjeldahl method, based on the destruction of organic matter with concentrated sulphuric acid. Due to chemical reactions ammonia is released, which is recovered by distillation and received in sulphuric acid. Upon reaction, ammonium sulphate is formed, the excess acid is titrated (titrated) with sodium hydroxide, using methyl red as an indicator (NOM-F-68-S-1980, 1980).

Determination of organic carbon

To calculate the percentage of organic carbon from the percentages of organic matter (volatile solids). C/N ratios were calculated for each of the samples, using the following formulas (Skoog, West, & Holler, 2015):

$$\%Organic\ Carbon = \frac{\%\ Organic\ matter}{1.724} \quad (7)$$

Where:
1.724 = conversion factor

Determination of the Carbon/Nitrogen Ratio

From the data obtained for the percentages of organic carbon and nitrogen, the C/N ratio is determined using the following formula:

$$\frac{C}{N} = \frac{\%Organic\ Carbon}{\%Total\ Nitrogen} \quad (8)$$

Determination of Calcium and Magnesium

These minerals were determined by the complex-metric-volumetric method; for the extraction of calcium and magnesium minerals from solid ashes, concentrated hydrochloric acid (HCl) was added to the sample, heated and the crucible where the ashes were obtained was rinsed with distilled water to obtain an aqueous solution (Skoog, West, & Holler, 2015). For Calcium and Magnesium, the standard method for determination of Ca++ in water is used (NMX-AA-072-SCFI-2001, 2001).

Determination of crude fibre

Crude fibre was determined by acid and alkaline digestion of the different samples, obtaining a residue of crude fibre and salts, which with subsequent calcination quantifies the crude fibre for each component of the pumpkin seed (NMX-F-090-S-1978). The methods used for the physicochemical analysis of pumpkin oil were as follows:

Viscosity determination

To measure viscosity, the Oswald viscometer method was used, which is based on the principle of the driving force of gravity to make a substance flow through a capillary tube, where the time required for the oil to travel a known distance was measured (NMX-F-808-SCFI-2018, 2018).

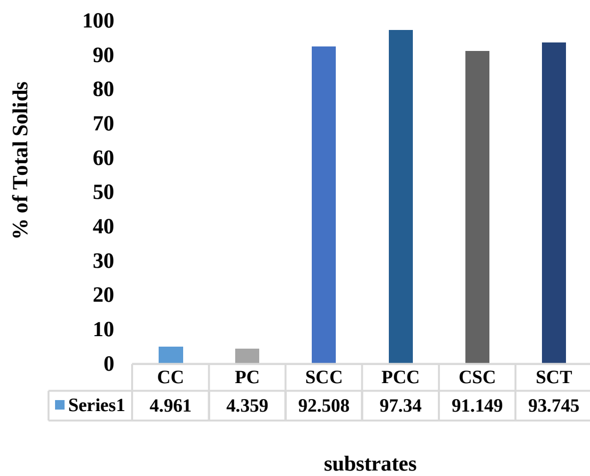
Figure 2 Viscosity determination
Own Source

Determination of Conductivity and pH

Conductivity and pH were determined with the multiparametric equipment, brand OAKTON, model PCD650.

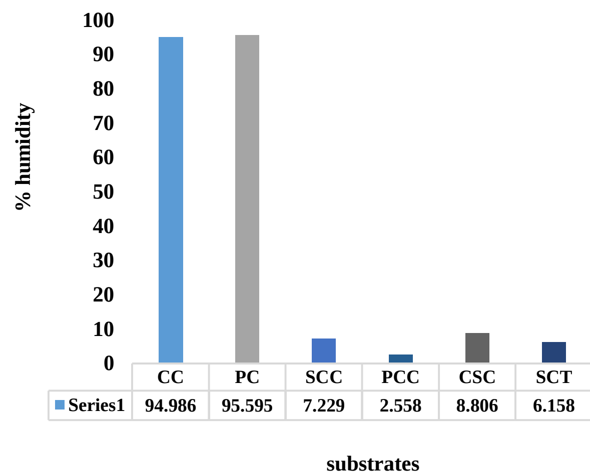
Results

The graphs with nested tables abstract the averages of the data determined for pumpkin peel "CC", pumpkin pulp "PC", whole and raw pumpkin seed "SCC", pumpkin seed (raw) "PCC", pumpkin seed hull "CSC", pumpkin seed (whole and roasted) "SCT".



	CC	PC	SCC	PCC	CSC	SCT
Series1	4.961	4.359	92.508	97.34	91.149	93.745

Graph 1 Percentage of total solids in the different substrates
Own Source

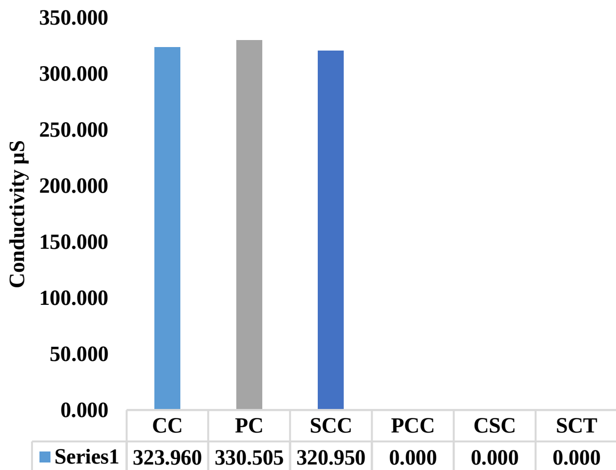


	CC	PC	SCC	PCC	CSC	SCT
Series1	94.986	95.595	7.229	2.558	8.806	6.158

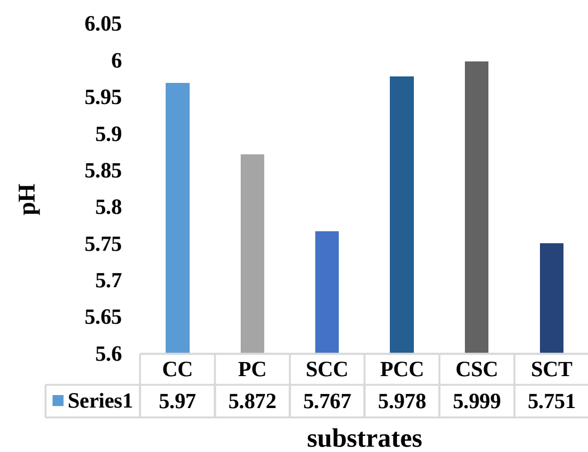
Graph 2 Percentage of moisture in the different substrates
Own Source

Graphs 1 and 2 correspond to the percentages of Total Solids and Moisture; the direct relationship between the contents of the substrates is observed. The pumpkin shell (CC) has 4.961% of Total Solids (St) and 94.986% of moisture; in the same way, the pumpkin pulp (PC) has 4.359% of St and 95.595% of moisture; in the same way it is observed in the substrates corresponding to the pumpkin seeds.

The direct relation of the contents of St and moisture, the whole and raw pumpkin seed "SCC" with 92.508% and 7. 229% respectively, pumpkin seed (raw) "PCC" 97 34% and 2.558%; with the same behaviour of these physical parameters, pumpkin seed husk "CSC" has 91.149% and 8.806% in line with the data; pumpkin seed (whole and roasted) "SCT" indicates 93.748% St and 9.158% moisture; it is in line with the data obtained for the pumpkin seed components. All results are within the expected range when compared to other studies (Rössel *et al.* 2018).



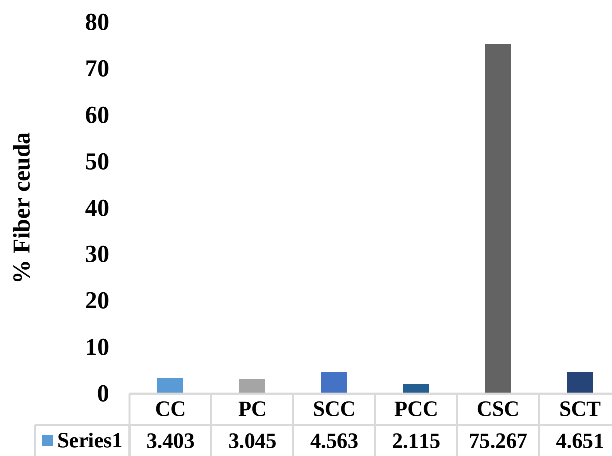
Graph 3 Conductivity µS on the different substrates
Own Source



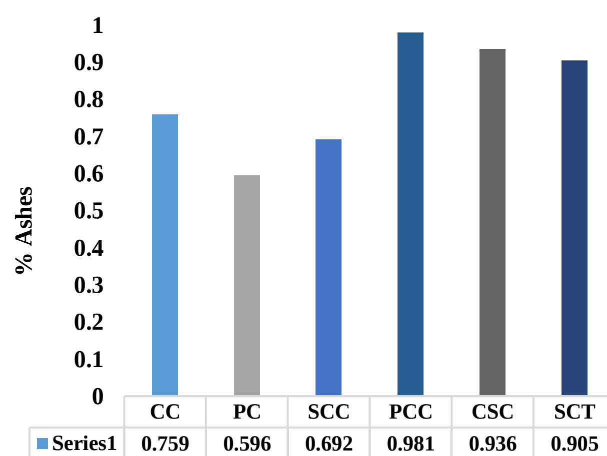
Graph 4 pH on the different substrates
Own Source

Graph 3 shows the conductivity of the pumpkin components, of which it was only possible to measure the pumpkin shell with 323.960 µS, pulp with 330.505 µS and seed with raw shell with 320.95 µS, in agreement with those reported by other studies (Ibid.).

Graph 4 shows that, for pH, the highest value is for pumpkin seed husk with a value of 5.999 and the lowest value is 5.751 for whole and roasted pumpkin seed; both values are slightly acidic due to the presence of oils (IICA, 2018).



Graph 5 Percentage of crude fibre in the different substrates
Own Source



Graph 6 Percentage of ash in the different substrates
Own Source

In relation to crude fibre, graph 5 shows that the seed husk is outstanding in all the samples analysed, with 75.267 gr/100 grams of sample, the other data being less than 4.7 gr/100. The results of ash according to graph 6, are in a range from 0.596% to 0.981%, which reflect very close values (NOM-F-90-S-1978, 1979).

The highest fat content according to graph 7 is found in the samples with the seed; the highest is in the whole roasted pumpkin seed "SCT" and the lowest is in the pumpkin seed hull "CSC" which represents 1.46%.

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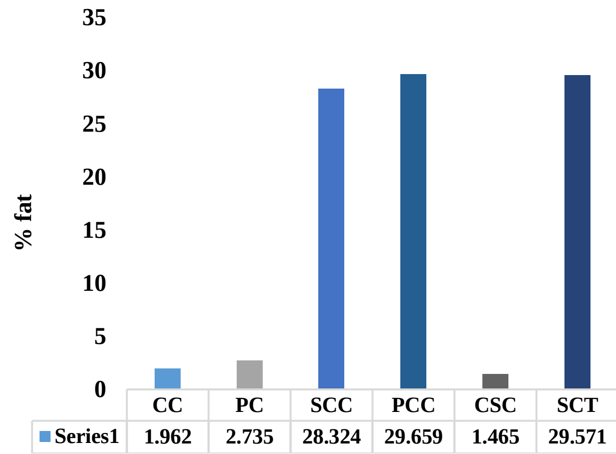
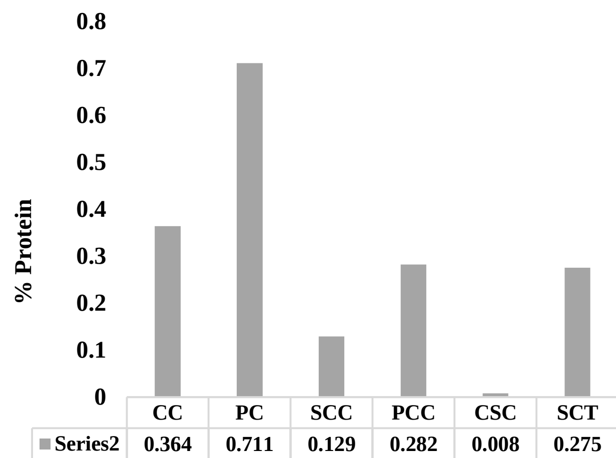
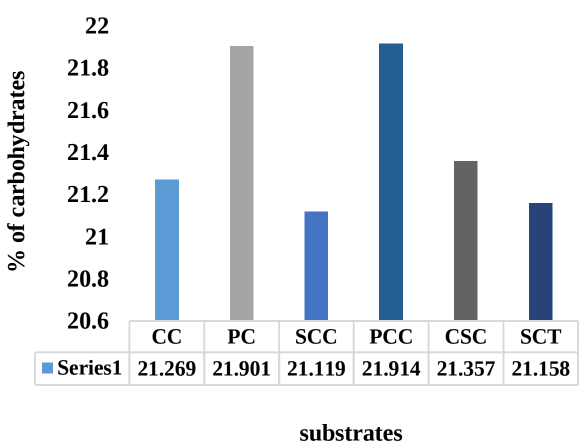


Graph 7 Percentage of fats in the different substrates
Own Source

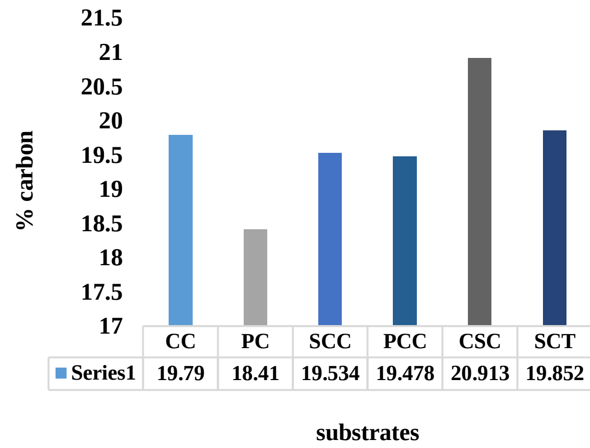


Graph 8 Percentage of proteins in the different substrates
Own Source

Graph 8 shows the percentage of protein, the pumpkin pulp "PC" has the highest value of 0.711% and the one with the lowest content is "CSC" with only 0.008%.

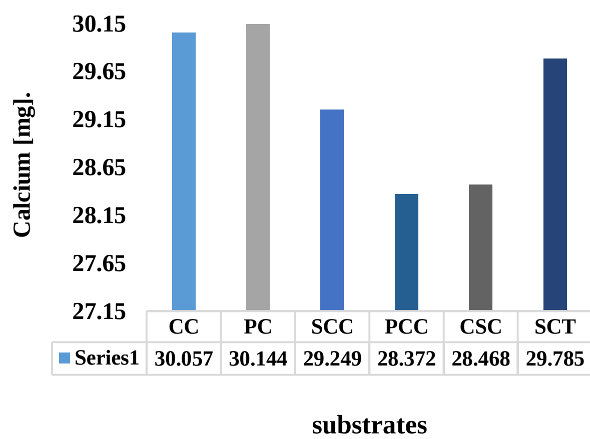


Graph 9 Percentage of carbohydrates in the different substrates
Own Source

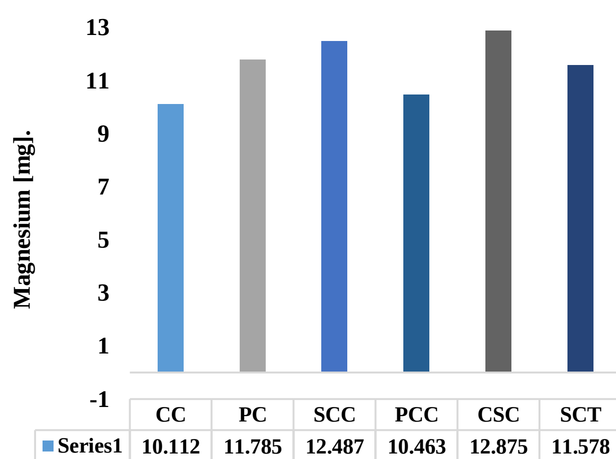


Graph 10 Percentage of carbon in the different substrates
Own Source

In carbohydrates (graph 9) all the values are very close, ranging from 21.119 % to 21.914%, with a minimal difference, which is not significant. In relation to the previous parameter is the percentage of carbon (graph 10), presenting the same behaviour due to the strong relationship between the two (Rodríguez Quispe, 2014).

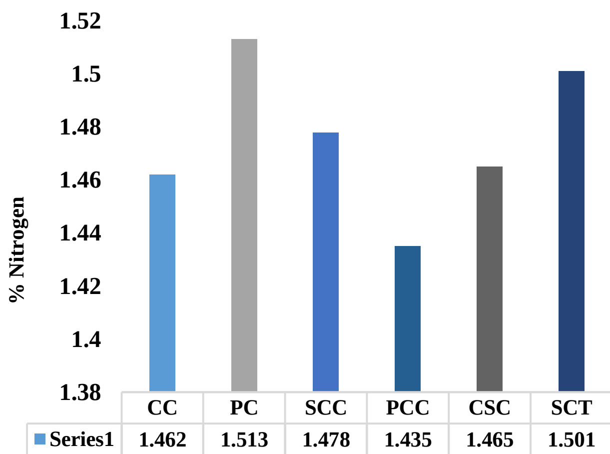


Graph 11 Calcium (mg) in the different substrates
Own Source



Graph 12 Magnesium (mg) in the different substrates
Own Source

Calcium shows a variable behaviour, according to graph 11, but the highest amount is found in the pulp with 30.144 mg and the lowest in the raw pumpkin seed with 28.372 mg. In graph 12, magnesium shows a more uniform presence, the highest rate being in pumpkin seed shell with 12.875 mg and with the lowest content in the peel with 10.112 mg (Rössel *et al*. 2018).



Graph 13 Percentage of nitrogen in the different substrates
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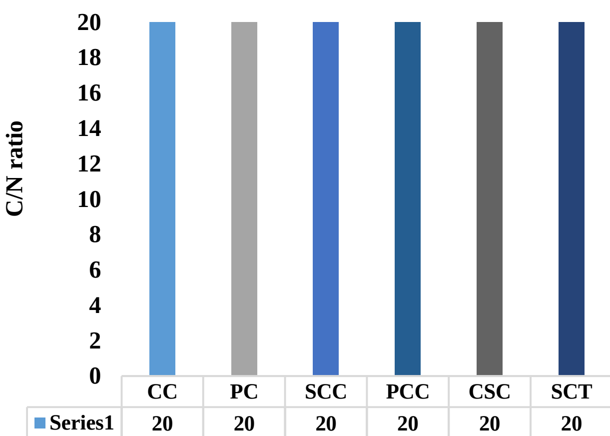


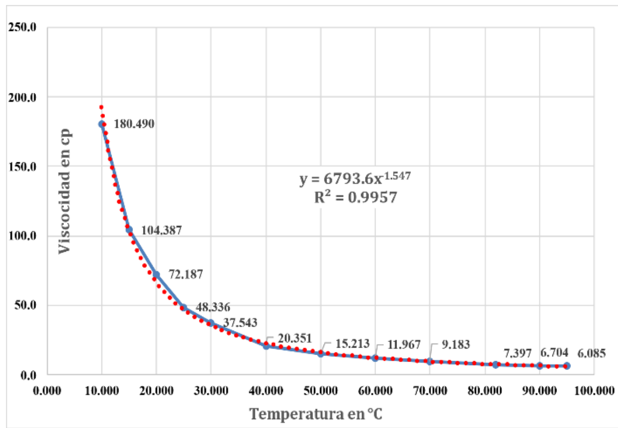
Graph 14 Carbon/nitrogen ratio in the different substrates
Own Source

The percentage of nitrogen (graph 13) is an important parameter, which is used to calculate the amount of protein present in a foodstuff. Of this, the highest content is found in the pumpkin pulp with 1.513%, and the lowest is found in the seed with raw peel with 1.435%, showing a uniform distribution in all the substrates analysed. The C/N ratio (graph 14) is uniform in all parts of the pumpkin analysed, giving a value of 20/1.

Table 1 shows the results of the oil viscosity and graph 15 shows the viscosity profile at different temperatures and isobaric conditions.

Temperature [°C]	Oil viscosity in [cp]
10	180.490
15	104.38
20	72.187
25	48.336
30	37.543
40	20.351
50	15.213
60	11.967
70	9.183
82	7.397
90	6.704
95	6.085

Table 1 Oswald viscometer method
Own Source



Graph 15 Viscosity isobar for pumpkin oil at one atmosphere pressure
Own Source

Viscosity shows an exponential behaviour curve, as can be seen in the equation and in the graph, viscosity is lower as the temperature increases and begins to stabilise at approximately 90°C.

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The support of a sample of *Cucúrbita pepo* L., obtained from the Colegio de Postgraduados Campus Salinas de Hidalgo, S.L.P., for this study is gratefully acknowledged.

Conclusions

The data obtained for the shell "CC" and pumpkin pulp "PC" have the highest moisture content above 94%; conversely, the whole and raw seed "SCC", the raw seed "PC", raw pumpkin seed "PCC" and whole and roasted pumpkin seed "SCT" have the lowest moisture content below 5% (Agrolanzarote, 2012).

With respect to conductivity, all the values obtained are in a very close range of 320 and 330 for the extracts studied; the same is true for pH, whose range is 5.751 and 5.999, which represents a slight acidity (Rodríguez Quispe, 2014).

Crude fibre is only significant in the pumpkin seed husk, the other parts analysed have a marginal contribution. The ashes of the samples are in a narrow range, from 0.596% to 0.981%.

Fats are only present in the substrates with pumpkin seeds, other substrates, their presence is marginal and can be disregarded. For proteins they are only important in pumpkin pulp; with these two terms it can be estimated that pumpkin pulp has the potential to be used as a food supplement.

Carbohydrates and carbon are present in all substrates analysed and their content is high, mainly due to the presence of proteins, fats and fibre. Similarly, calcium and magnesium are found in all pumpkin components.

Nitrogen is related to protein and to the amount of carbon present, as shown by the C/N ratio, which is twenty carbons for each nitrogen present.

In the viscosity graph of pumpkin oil, it can be seen that the inflection point is at approximately 85°C. This allows us to make decisions regarding the rheological behaviour of the fluid, which can be extracted by pressing, transported by piping or by carrying out a filtering process, allowing it to flow properly, with optimum energy expenditure.

Pumpkin is cultivated practically in all the agricultural regions of Mexico, with all the above mentioned, it is feasible to use pumpkin with great diversity, as: sweet (crystallised pumpkin), in atoles, fresh waters, confectionery, snacks, in stews, tamales, or simply as decoration; the seeds - roasted, cooked or boiled - as a complement in other preparations. In some regions the fruit, seeds and roots can be used for medicinal purposes. Some are useful as containers and are also used as fodder for livestock (cattle, goats and others) in livestock areas.

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