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Developing and Characterizing Broccoli Trunk (Brassica Olaracea Var. Italica) Flour Subjected to Different Processes of Dehydration

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Research Article

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ABSTRACT

Broccoli trunk flour was characterized as a raw material. Broccoli in Guatemala is one of the most relevant crops for the economy; as a non-traditional export, it is part of the national revenue. The flour properties were determined by chemical, functional, vitamin C, antioxidant capacity, granulometry, and yield analysis. The trunk flour was compared with commercial flours such as wheat, rice, maize, and yucca, to show the possible mixtures hence, developing model foods such as nachos with acceptable organoleptic qualities.

INTRODUCTION

Broccoli is a vegetable from the Brassica family. This vegetable family grew from wild cabbage or Brassica oleracea 400 years ago. It is also known as “calabrese” or broccoli sprout. The most used parts of this plant is the inflorescence, which consists of the florets and the minor stems. It has a high nutritional and medicinal value due to its vitamin C, antioxidants, glucosinolates, proteins, carbohydrates and mineral content [1].

Several broccoli flour related studies have found significant amount of nutritional value in the after being exposed to various processes. Much interest has been directed towards the florets and the sprouts, discarding the trunk and roots. There has been no study directed specifically towards the trunk after a process of dehydration.

Broccolis national production provides employment and much revenue. In 2009, its crop provided 1, 206, 000 jobs and Q23, 759. 30 (US$3089.33) per hectare [2]. This product export creates plenty of income but also waste; since the importing countries only uses the florets. Of all exports, 15% is wasted, not counting the trunk, leaves and roots [2].

Guatemala suffers from chronic malnutrition, the most affected area being Huehuetenango (64.39%), Totonicapán (73.24%), Sololá (73.17%) and Quiche (64.79%); including cases from school age children. A census by INE (National Institute of Statistics of Guatemala), found an increase in population from 12 million in 2003 to 14, 713, 763 in 2011 [3,4].

Studies have shown that components of broccoli like glucosinolates, vitamin C, and antioxidants are beneficial to the diminishing of cardiovascular diseases, cancer, and controlling cholesterol. This is due to the decreasing power towards oxidative degradation [5].

The objective of this work is to develop flour that substitutes or fortifies wheat flour, since there is a growing population and chronic diseases and food is becoming scarce. It is also desired to take advantage of the broccoli processing waste and give a new option in the nutritional, commercial and economical aspects.

MATERIALS AND METHODS

More than 200 pounds were provided by ALCOSA a broccoli processing industry in San Jose Pinula, Guatemala, with broccoli cultivated in Patzún, Chimaltenango; and the other type of broccoli from El Tejar, Chimaltenango. Throughout the whole study the trunk provided by ALCOSA is identified as "from ALCOSA" and the other one as "from Chimaltenango". The broccoli was stored at 4°C. The trunks were sanitized, selected and disinfected with 20 ppm chlorine solution for 20 min. It was later downsized with an industrial blender. Eight types of dehydration/blanching treatment were realized as described: although it was 17 in total due to the use of two types of broccoli and an evaluation of microwave power. Blanching was done by water (97°C), microwave and vapor (94°C). To test the blanching peroxidase test was used. The weight was written down after each process. A cyclone grinder mesh 100 was used.

Methodology Used for Experimental Data Analysis

Vitamin C: A modified Volden [6] HPLC method. A wavelength of 234nm and water extraction were used, no need for c-18 columns filtration. All dehydration and blanching processes were evaluated.

Total Polyphenol Content: Folin-Ciocalteau, by Barnerjee [7]. A calibration curve with different concentration of cathecol was used; the polyphenol content was calculated by equivalents of cathecol in µg/g of flour. Several types of flour processes were evaluated: freeze-drying, microwave and convection oven dehydration. Blanching by water, and no blanching was evaluated in the conventional oven process.

Antioxidant Capacity: Radical Scavenging Activity-DPPH, by Barnerjee [7] and Brand-Williams [8]. Several concentrations with different types of flour processed by freeze-drying, microwave dehydration, and convection oven dehydration.

Water and oil absorption index by Viena L [9]. All processes of dehydration and blanching were evaluated. Flour by convection oven and blanching by water from ALCOSA and hard wheat, soft wheat, all-use wheat, maize, yucca and rice flour were compared.

Yields: For every process yields were evaluated and calculated; it was decided to work with the more viable process: dehydration by convection oven and blanching by water. The percentage of trunk over whole broccoli, percentage of trunk over industrial waste and others were also calculated.

Cost: An approximation of the dehydration process was made for convection oven dehydration, microwave dehydration and freeze-drying using voltage.

Granulometry: The different flours produced from the two types of trunks were sieved and compared to commercial flours: hard wheat, soft wheat, all-use wheat, and maize.

Drying curve: A drying curve was done for the two types of broccoli trunks and mass flows were calculated in kg/h.

Density: density for the two types of flours from the 2 types of trunks was calculated and compared.

Evaluation of the broccoli trunk flour obtained by the selected process:

Chemical analysis: AOAC methods were used for proteins, humidity, dietary fiber, ashes, fats and carbohydrates by difference:

- Humidity, 925.10, air oven
- Ashes, 923.02, direct method
- Fat, 9222.06, ethereal extract
- Protein, 920.87, Kjeldahl
- Dietary Fiber, 985.29, enzymatic gravimetric
- Carbohydrates by difference

Shelf life: Calculated by Arrhenius equation and extrapolation by lineal regression. The parameters used were scent, flavor, appearance, and water activity. The flour was stored in polyethylene bags.

Product modeling: Nachos were produced with 6 different formulations, using wheat and maize flour as base, and different percentages (0, 8, 20, 32, 35%) of broccoli trunk flour. The use of crushed blanched trunk in the nachos was also evaluated.

Texture: hardness by penetrometer, width and diameter were evaluated.

Sensory analysis: preference ranking test and paired preference test were used.

Statistics: Analysis of variance (ANOVA) of one factor and correlation tests were used.

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RESULTS AND DISCUSSION

Table 1 shows vitamin C results in flours obtained by different drying processes, where vapor blanching and freeze-dried have the highest concentration in the trunk from ALCOSA, while in Chimaltenango's the trunk flour dehydrated by convection oven and blanched by microwave has the highest concentration.

Table 1. Vitamin C concentration in flours obtained by different drying processes.

	ALCOSA (Patzún, Chimaltenango)		Chimaltenango	
Type of treatment	$\bar{x} \pm s$ mg/g	vitamin C concentration	$\bar{x} \pm s$ mg/g	vitamin C concentration
No blanching dehydrated by oven	4.811	± 0.897	13.34	* ± 3.002
Blanching by water dehydrated by oven	3.798	± 0.557	8.27	± 0.362
Blanching by vapor dehydrated by oven	2.08	± 0.658	9.3	± 0.257
Blanching by microwave dehydrated by oven	10.71	± 0.567	14.35	* ± 2.943
No blanching dehydrated by microwave 1200W	8.41	* ± 1.108	10.31	± 0.260
No blanching dehydrated by microwave 1100W	8.7	* ± 1.037	-	-
Blanching by vapor dehydrated by microwave	8.73	± 0.645	13.01	* ± 2.09
No blanching freeze-dried	7.1	± 0.363	9.94	± 0.131
Blanching by vapor freeze-dried	10.84	± 0.266	9.817	± 0.462

*variance analysis was calculated.

Vitamin C

In the case of the trunk flour from ALCOSA, the process that preserved a highest concentration of vitamin C was freeze-drying and blanching by vapor. It can also be seen that there is a similarity between the dehydration processes by convection oven, where the highest loss of vitamin C concentration was obtained [10]. With the exception of the dehydration process where blanching by microwave was used, more than double the concentration was obtained during all the other processes of blanching. This may be since the heat produced by the microwave can produce in a lesser extent Maillard reaction; being that during this reaction the vitamin C (due to its amino acids) is more easily degraded. This effect can be confirmed being that with the microwave dehydration process it is seen a similar behavior where the vitamin C concentration is higher. The freeze-drying process had the highest vitamin C concentration (according to ANOVA, it is significant) with regard to the processes of convection oven dehydration, due to its nature [11]. In regard to the difference between blanching processes in convection oven dehydration, it can be said that the blanching by microwave had a higher vitamin C concentration in comparison with the blanching by water and vapor, but it cannot be confirmed due to the none existence of a trend between each type of blanching; given that in the processes of convection oven dehydration, the no blanching process maintained a higher vitamin C concentration, though in the processes of microwave dehydration and freeze-drying, the blanching promoted the retention of vitamin C compared to the not blanched. In relation to the power used to dehydrate by microwave (1100 w and 1200 w), it is shown that lower the power the higher concentration of vitamin C [12].

In regard to the origin of the broccolis, it can be seen that in the case of the trunk from Chimaltenango there are some differences in the previous mentioned trends [13]. The processes of oven dehydration kept a higher concentration of vitamin C than the trunks from ALCOSA. It is shown that the no blanching process had a similar behavior to ACOSA's, since it maintained the highest concentration of vitamin, but the blanching by vapor was second in contrast with ALCOSA's, where the blanching by water had the highest [14]. The trend that continued was the blanching by microwave and then dehydrated where it is seen the highest vitamin C over all the processes 14mg/g. This could be a confirmation of the previously discussed about Maillard reaction. It can also be compared with the other species of trunk where the process of microwave dehydration and blanching by vapor, retains a higher concentration of vitamin C, whereas during freeze-drying it is shown that the no blanching process had a higher concentration of vitamin C. When blanching by vapor, the enzymatic activities should be prevented by heat by vapor, in contrast to the blanching by water where water could penetrate the surface and damage it more. The freeze-drying process could damage the vitamin C during the freezing stage [15].

According to the data, it exist a greater variation during the process of microwave dehydration and blanching by microwave, probably caused by undefined condition changes [16]. In order to check these variations, an analysis of variance was done to find that there exist in fact differences among the processes [17]. It can be said also, that the trends discussed between each process and type of broccoli, are correlated due to the fact that their coefficient is 1; with the exception of the process of freeze-drying where there is no tendency.

These results can be compared with the data obtained by Wambui A [10], where 15.1 mg/g in fresh broccoli trunk treated with thermal blanching was found, and an amount from 2.5 to 13.3 mg/g of ascorbic acid in grinded and dehydrated trunks. The values obtained in this study are inside this range. The difference with Wambui, A's study, is the type of processes evaluated and pH used. Their HPLC method for determining concentration also varies in regard to Volden J [6] due to them used different solvents for the columns and a different wavelength for UV absorption.

Table 2 shows the results of the determination of total polyphenol content where it is shown there is a higher concentration in the process of dehydration by convection oven for the trunk from ALCOSA and in the process of dehydration by microwave for Chimaltenango.

Table 2 shows that there is no tendency in regard to both types of used broccoli; since the ALCOSA's and Chimaltenango's flour samples had no significant difference in total polyphenol content [18]. It can be confirmed with the correlation analysis where the coefficient alienates from 1. The process with higher catechol concentration in ALCOSA's was the process by convection oven dehydration, whereas the highest concentration in Chimaltenango's was the process by microwave dehydration. It can also be seen that the same flour dehydrated by microwave had the highest concentration of polyphenol content [19]. The blanching process was also evaluated in order to compare it to the dehydration by convection oven without a blanching process. It was found that there was a lower content of polyphenols when the blanching process was applied; being that there was a double thermal treatment. The blanching process was evaluated due to the fact that the flour used in the sensory analysis was subjected to this treatment and because it is a common process in the vegetable flour industry [20]. It could be mentioned that with a stronger treatment such as the dehydration by convection oven (compared to microwave and freeze-drying), there was a higher availability of polyphenols like lignans and lignins, and when heat was applied the surface area was expanded, exposing other compounds. This can be seen in ALCOSA's broccoli; in Chimaltenango's case there could have been a greater thermal effect exposing more polyphenols from inside the trunk; so that the availability is due to the level of particle penetration, whereas the convection dehydration and freeze-drying had a general superficial penetration.

Table 2. Total polyphenol content; equivalents of catechol in flour samples obtained from different processes.

sample	$\bar{x} \pm s$ **µgeqCatechol/gfllour** **ALCOSA (Patzún, Chimaltenango)**	**CHIMALTENANGO**
Freeze-dried	624.47 ± 0.01	**607.75 ± 0.01**
Convection oven dehydrated	650.43 ± 0.01	**575.16 ± 0.01**
Microwave dehydrated	620.08 ± 0.01	**859.65 ± 0.01**
Blanched dehydrated by convection oven	641.28 ± 0.01	

These variations happened in the freeze-drying process, due to the heavily paced time taken by the capacity of the freeze-drier [21]. The microwave dehydration and the convection dehydration had a similar aspect due to the mass to be dehydrated variation. The time that the fresh broccoli was exposed to each treatment may have affected the level of penetration [22]. Other factors to considerate are the nutritional initial state of the plant and the cultivation and crop conditions.

These results are not directly comparable to Banerjee R [7], due to the fact that this study evaluated the total polyphenol content in broccoli powder used in goat meat nuggets. It is recommended to evaluate the trunk flour in a similar food product to obtain a direct comparison [23].

Table 3 shows the results for antioxidant capacity by DPPH method, where the freeze-dried sample had a higher EC50 and %IAR for both Chimaltenango's and ALCOSA's trunk.

Table 3. Antioxidant capacity by DPPH method.

	Alcosa(Patzún, Chimaltenango)		**CHIMALTENANGO**	
sample	**%IAR**	**EC50** $\bar{x} \pm s$ **g harina/gDPPH**	**%IAR**	**EC50** $\bar{x} \pm s$ **g harina/gDPPH**
Freeze-dried	7.45	13.42 ± 0.01	3.76	26.61 ± 0.01
Convection oven dehydrated	10.10	9.90 ± 0.01	9.31	10.74 ± 0.01
Microwave dehydrated	9.66	10.35 ± 0.01	7.45	13.42 ± 0.01
Blanched dehydrated by convection oven	17.91	5.58 ± 0.01		

Antioxidant Capacity

Antioxidant capacity is a required indicator to know the probable decrease of acquiring chronic diseases (cardiovascular or cancer) risk activity, of the produced flour. For this analysis, 3 types of dehydration process were evaluated and then the blanching in the convection oven dehydration process. The antioxidant capacity is presented as the percentage of free radical activity (amount of sample in grams needed to catch 100 g of DPPH), and as EC_{50} which shows the amount of grams of DPPH or radicals can catch a gram of flour [24]. **Table 3** shows both types of broccoli used, ALCOSA's had the lower antioxidant activity due to the comparison of EC_{50} to Chimaltenango's. It is possible to link the different process with the antioxidant capacity regardless of broccoli type [25]. A correlation analysis showed a coefficient close to 1 (0.999254), indicating a tendency. Being that, both types of trunk flour showed that freeze-drying has a higher EC_{50}, then microwave dehydration and last dehydration by oven [26]. It is possible that freeze-drying as a non-thermal treatment protects or preserves the active antioxidant compounds that are able to trap the radicals. Microwave dehydration happens at a molecular and wave level, meaning that it has a faster, more specific and efficient thermal effect. It is also notable that the time microwave uses is relatively short in comparison with the other processes. It can be said also that the microwave degrades only weak antioxidant compounds exposing more trapped antioxidant compounds in fiber like the polyphenols: lignins and lignans [11]. The flour with a previous blanching process shows a reduced antioxidant capacity. These results can be compared with Mahn A [11] where the powder was made with broccoli florets by freeze-drying. In this study the powder extract with blanching had an EC_{50} of 27.7, or the highest compared to 14.4 with fresh broccoli floret powder. This study determined that the blanching could have liberated antioxidant compounds increasing the free radical trapping activity. However this was not the case in the broccoli trunk, probably since the double thermal treatment caused first liberation of polyphenol compound and antioxidants by blanching, then during the dehydration by oven these compounds were lost due to their longer thermal exposition. It is recommended to evaluate the freeze-drying and blanching to observe if the antioxidant capacity also increases in the trunk as in the florets mentioned by Mahn A [11].

The variance analysis showed that there are differences between the processes. This is due not only to their processes type and time taken but also the extraction method of DPPH [27]. The extraction is different for every sample and calculation, and it is difficult to standardize the procedure. Another factor could be the storing time after the extraction, also the initial conditions of boron deficiency of the trunk and how much post-harvest time had the broccoli. It is recommended to repeat the procedure used by Mahn A [11] where there was a programmed germination and cultivation process, and the broccolis were enriched by selenium for the antioxidant capacity that this element provides [28].

Total polyphenol content- Antioxidant capacity connection

There is a connection between the total polyphenol content and the antioxidant capacity: if there is a higher content of total polyphenols in flour, there should be a higher probability of antioxidant capacity. However, this statement did not happened due to the fact that the polyphenols are trapped inside the fiber of the trunk, and so it is hard to make them more available. Correlations were calculated to establish a statistic tendency between the content of total polyphenols and antioxidant capacity; the correlation coefficient found was far from 1, concluding that there is not a tendency [29]. Despite this fact, a correlation was calculated to know if there was a tendency in the loss of polyphenol content and antioxidant capacity during the blanching process and the coefficient was 1, so it can be possible that the double thermal treatment causes first a liberation of antioxidant compounds (such as Vitamin C) during the blanching and during the dehydration they are degraded [30].

Figure 1 shows the oil absorption indexes for the different process obtained flours, where the no blanching and dehydrated by oven had the highest index in Chimaltenango's and the highest in ALCOSA's was in no blanching and freeze-dried.

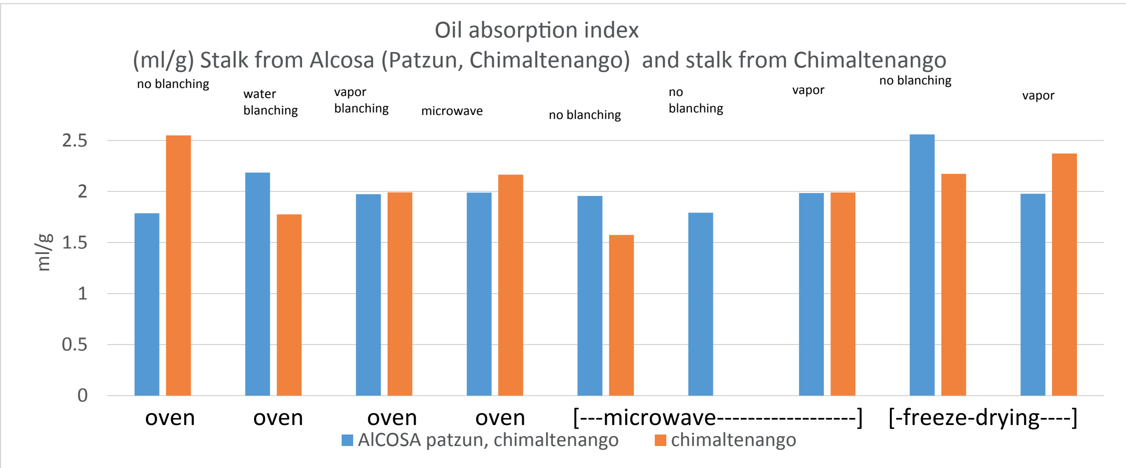

Figure 1. Oil absorption index of flours.

Figure 1 shows that both ALCOSA's and Chimaltenango's flours have no tendency. It is shown that the no blanching process and dehydrated by oven had a difference between both types of broccoli. This could be due to the physical conditions of the trunk before the blanching, such as boron deficiency. In the water blanching and dehydrated by oven there is a visual difference in a lesser amount with the previous process mentioned. There is little difference with the blanching by vapor. The no blanching process in Chimaltenango's and the water blanching in ALCOSAS had the highest index [31]. There is no significant difference according to the correlation analysis, the coefficient is 1. There is no big difference towards the microwave blanching and there is no tendency according to the correlation analysis [32].

In the process of microwave dehydration there was a loss in oil absorption ability depending on the power used; there is more absorption at 1200 W. There is also a difference in the process of no blanching between the types of broccolis. This difference is due to the conditions of boron deficiency previously mentioned and other variations that may exist. The boron deficiency causes a hole in the trunk [33]. Probably a bigger hole in the trunk could have exposed the broccoli to deterioration, causing a greater loss of lipid compounds during the dehydration. The vapor blanching shows little visual difference between both types of broccoli, however there is a better absorption in Chimaltenango's. There is no tendency between the blanching by vapor and no blanching, and between blanching by vapor and no blanching at 1100 W [34]. The freeze-drying processes had no correlation between both types of broccolis due to their different behavior.

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Figure 2 shows the water absorption index for the flours obtained by different dehydration processes, where the highest index is in the freeze-drying and no blanching process in both broccolis.

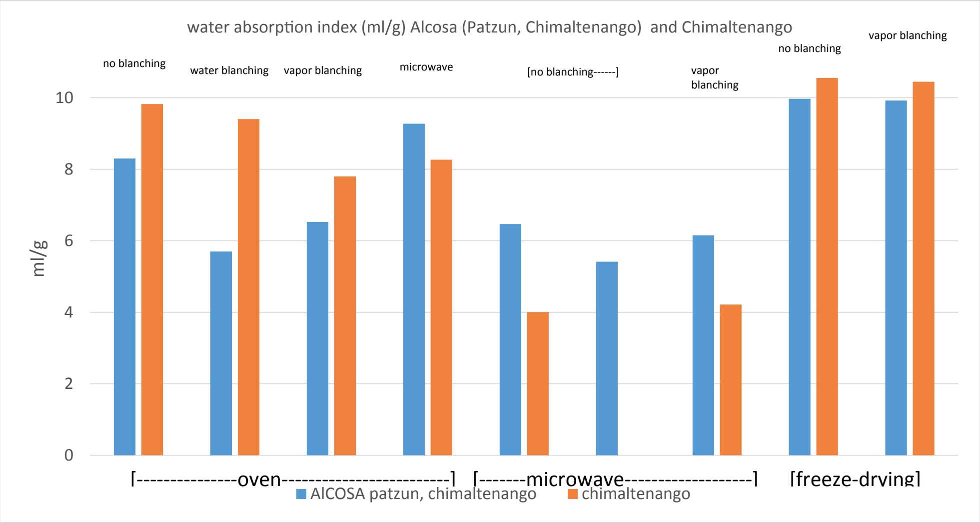

Figure 2. Water absorption index of flours.

Chimaltenango's trunk flour had the highest index regardless of the blanching or dehydration process. However in microwave blanching there was a difference. It is possible that the microwave blanching could penetrate to more exposed hydrophilic compounds in Chimaltenango's broccoli due to its degree of boron deficiency [35]. This statement may not be confirmed since the correlation analysis showed no tendency.

In microwave dehydration process, it can be seen that the highest index was at 1200 W. The blanching process had no significant difference in the results [36]. The notable aspect is that ALCOSA's flours had the highest index and this is a confirmed tendency by correlation.

During the freeze-drying process had a possible tendency where Chimaltenango's broccoli had a higher amount of hydrophilic compounds causing higher water absorption [37]. This tendency was confirmed by the correlation analysis due to the coefficient being 1. Over all, the flours subjected to freeze-drying had higher water absorption indexes [38].

ALCOSA's and Chimaltenango's flours had a confirmed by correlation tendency where both oil and water indexes increased. This means that there were indeed effects in every blanching and dehydration process and both lipophilic and hydrophilic compounds were degraded. However a significant amount of hydrophilic compounds were degraded compared to lipophilic, due to the fact that broccoli has a higher amount of carbohydrates and fiber. Water absorption helps in processing drinks and gaining size in foods [39]. Oil absorptions help to contain lipids and obtain better bonds with emulsions and as an emulsifier. However, the water absorption index is much higher than oil absorption; due to the high amount of fiber and carbohydrates, and low amount of fats present in the broccolis trunk. It is recommended to determine carotenoids present in the trunk flour. Water and oil absorption index values are within the range of Valenzuela's study.

Figure 3 shows the water and oil absorption index of several flours compared to broccoli trunk flour processed by the chosen method, where there broccoli trunk flour has a higher water absorption compared to the rest, whereas a similar behavior to the rest in the oil absorption index.

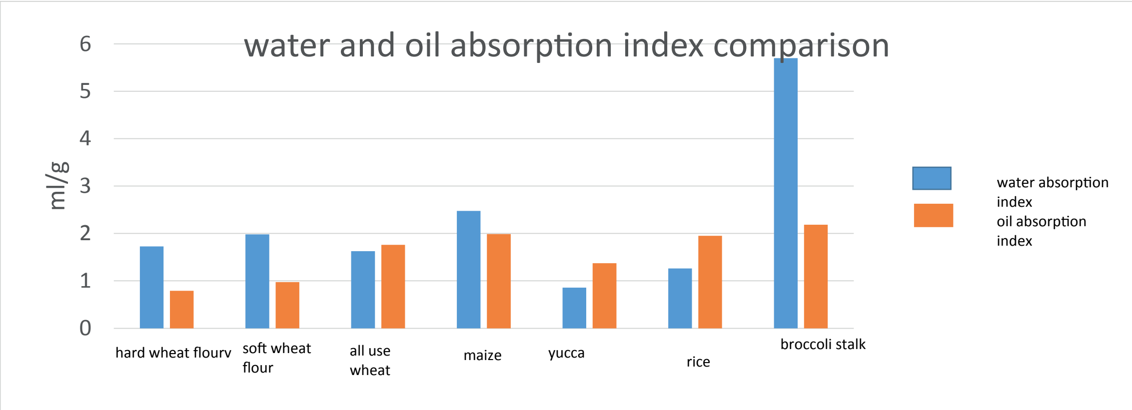

Figure 3. Water and oil absorption index in different types of flour compared to broccoli trunk flour.

Figure 3 shows both oil and water absorption indexes for yucca, wheat, maize and rice flours. Wheat flour was chosen to compare with due to its use in bakery and pastry industry; maize was chosen due to its use in tortillas and tamales; rice was used because it is the most relevant cereal in the world, and yucca because it is comparable with a starch [40]. Broccoli trunk flour had the highest water absorption index over all. Oil absorption index is slightly higher but not enough to have a significant difference according to the variance analysis. However it is possible to mention that the trunk flour has a higher absorption than yuccas indicating that it has functionality similar to a starch. This functionality could help at processing high absorption food products [41]. This water absorption capacity is due to the fact that the trunk had initially humidity content 92-94%; in order to be able to hold this amount of water the amount of carbohydrates and fiber should be high, and this is confirmed with the proximal analysis [42].

Figure 4 shows that both have a particle size greater than mesh 100.

For this analysis the flour used was the dehydrated by oven and water blanched, due that both of these processes are the most used, and it is more probable that the production plants have convection oven rather than microwave dehydrators or freeze-driers [43].

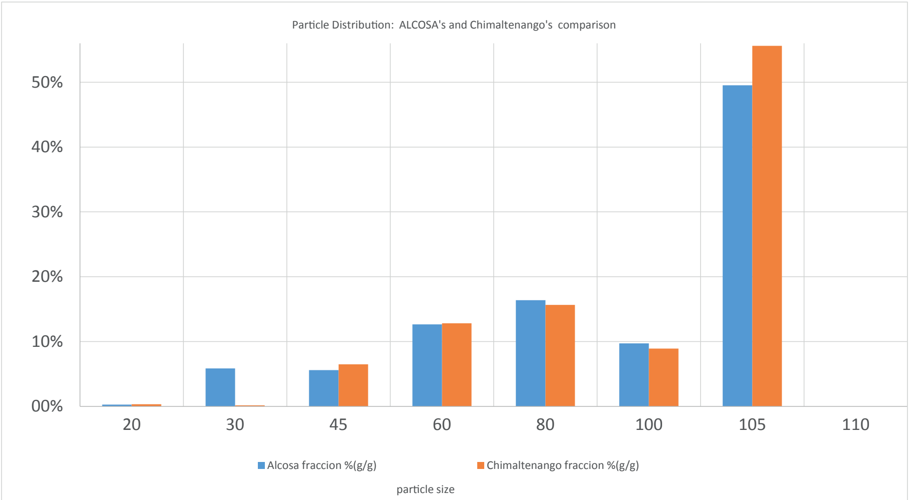

Figure 4. Particle distribution between both types of trunk flour.

Figure 4 shows that the particle size of the grains produces by the grinding process are found around mesh 100. It is notable that there is another peak in mesh 65 to 85. This peak is not significant due to the difference between 15% and 50%. This particle size of 100 mesh is due mostly to the fact that a cyclone grinder with a mesh 100 sieve size. It is important to note 65-85 peak because this particle size is the one that will mix with the maize and wheat flours in a food matrix. This is due to the fact that particles greater than mesh 100 are more likely to easily disperse; so it is possible that in an industry level the percentage of particles smaller to mesh 100 increases [44]. There is no significant difference between both types of broccoli since both flours were grinded by the same machine. Fiber content in each broccoli may have had an effect in the grinding process due to the friction and harshness of the particles.

Comparing the broccoli flour with other flours, it is seen that the trunk flour is greater than mesh 100 and the other ones are between 75 and 85. This may affects later mixing processes, and segregation may occur. To improve particle size similarity with other commercial flours, all flours should be grinded with the same machine. Percentages in the 75 to 85 range in trunk flour could be compared to the other flours but the peak is too small to be able to do it.

All use flour can be compared to trunk flour since its greater percentage is 44% is higher than mesh 100 similar to the trunk flour. Segregation can be avoided mixing these two flours together.

Drying curve in **Figure 6** shows a similar behavior between both types of trunk flours. Fourteen hour time lapse mentioned by Valenzuela was used in the convection by oven dehydration. There was no significant variance using this method because uniformity and control was used in the dehydration every 1 or 2 hours [45]. However according to Valenzuela 10% final humidity is required for flour, so the 14 hour time lapse should have been reduced. This could have an effect on the flour reducing water activity and increasing lipid concentration, which later could cause rancidity at storage. Despite the use of 65 °C, boron deficiency may have caused a higher damage to the product due to its greater exposure after trituration and a greater Surface area. The final humidity content obtained is compared to Maldonado, R.Pacheco-Delahaye, E.; their study found a 6.49% at 60 °C and with an initial humidity of 92%. Densities show that ALCOSA's flour was higher than Chilmatenango's [46]. This difference could be explained due to the fact that ALCOSA's had a higher humidity increasing its mass and occupying less volume than Chimaltenango's. Density shows the volume that the flour may occupy in a packing bag; so ALCOSA's would occupy more space, so it would cost more to pack it than Chimaltenango's.

Figure 5 shows a particle distribution comparison among different flours.

Figure 6 shows the tendency that the dehydration process had over the trunk. Chimaltenango's had a higher initial humidity than ALCOSA's.

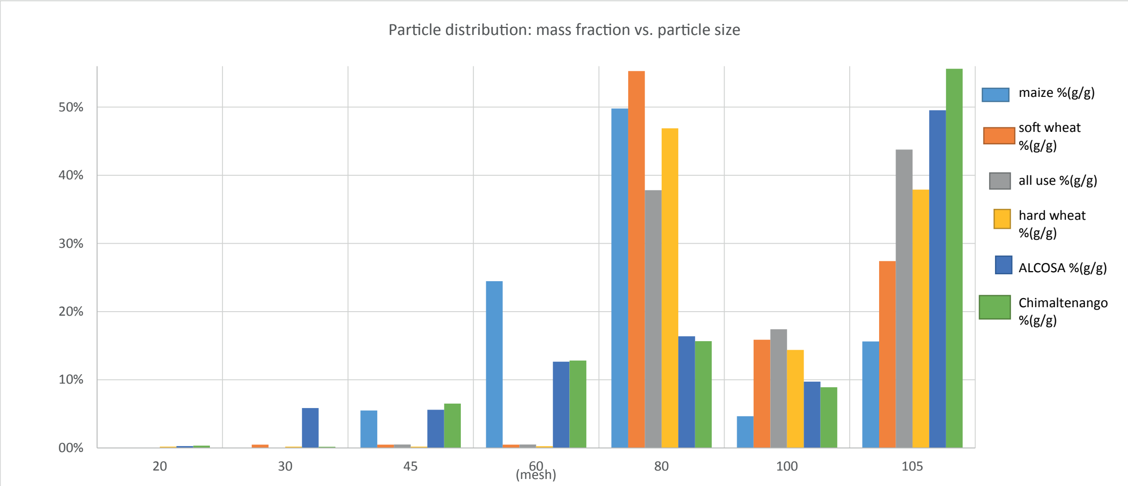

Figure 5. Particle distribution in comparison with other commercial flours.

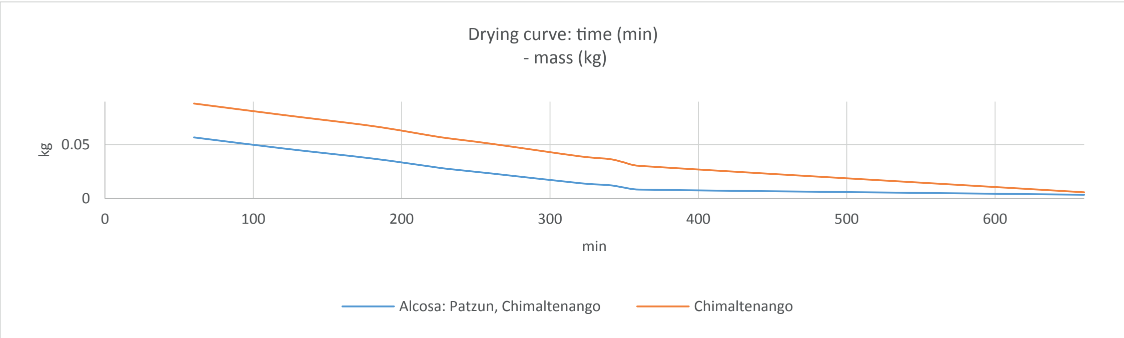

Figure 6. Dehydration by convection oven drying curve.

Table 4 shows the proximal composition of the chosen flour; there is a high content of carbohydrates, protein and dietary fiber.

Table 4. Proximal analysis of broccoli trunk flour.

	g/100g dry base	
Humidity	7.43	± 0.01
Protein	18.15	± 0.02
Fat	2.81	± 0.01
Ashes	12.75	± 0.01
Carbohydrates	47.04	± 0.01
Dietary fiber	34.07	± 0.10

Proximal analysis for the water blanching and dehydration by convection oven processed flour was conducted by AOAC methods. There is a higher protein content in the trunk flour compared to wheat, rice and maize (12-13 g/100 g); fat is higher on wheat and rice, but similar to whole wheat and maize; according to Dapcevic [18] figure. It is notable the amount of ashes in the trunk flour, this could be an indirect indicator of the high quantity of minerals in the trunk. However due to the high polyphenols present in the flour fiber it is difficult for these compounds to be bioavailable; these compounds could be chelated in the fiber and could not be able to expose them with any thermal treatment. It is recommended a mineral analysis in the final product. Dietary fiber, protein, humidity and carbohydrates are higher compared to Valenzuela's study. It is relevant for the flour to have high carbohydrates and dietary fiber to give higher water absorption.

Table 5 shows the different parameters used in shelf life evaluation.

Table 5. Trunk flour shelf life.

Parameter	Time (month)
Scent	9.3
Color	21.5
Appearance (insect presence)	54.6
Water activity	658.9

First 3 parameters are considered subjective with a value of 100 for highest intensity and 10 for the less intense. Trunk flour was evaluated during 30 days; the flour was packed in a polyethylene bag at room temperature. According to this analysis the parameter with the lowest shelf life is scent, being that the flour loses its scent more easily and it is estimated a 9.3 month shelf life. Color changed from green/yellow to just yellow, calculating a 21.5 month shelf life [47]. The change in color is a possible change in chlorophyll concentration and it is recommended to realize a colorimetric analysis related with chlorophyll concentration in the initial state of the trunk and during the various changes in the different processes. Appearance was measured by presence of insects or insect eggs, this is a risk that flours are used too; but there were only black stones in the flour since it was packed in a bag. This parameter gave a 54.6 month shelf life.

Water activity shows an indirect microbial activity; higher water activity, higher probability that microorganisms grow in the flour. Water activity slightly increased due to the packaging, indicating that the package protects against outside humidity. This parameter calculated 658.9 months of shelf life. Shelf life to be used is 9.3 months.

Table 6 shows the formulations realized for the nachos based on compound flours concept, where percentages of trunk, wheat and maize flour varied.

Table 6. Nacho formulations.

Flour	F1 0%broccoli trunk	F2 8% broccoli trunk	F3 20% broccoli trunk	F4 0% wheat/35% broccoli trunk	F5 0% wheat/32% broccoli trunk/ pizza	F6 0% wheat/ fresh broccoli trunk
Maize	80	74	64	65	58	65
Wheat	20	18	16	-	-	-
Pizza	-	-	-	-	10	-
Broccoli trunk	-	8	20	35	32	35

In order to evaluate functionality and organoleptic characteristics of the trunk flour, nacho formulations were decided as matrix due to the salty snack's probable consumer acceptance. The nacho formulation included wheat all use flour and maize, which were already compared to the trunk flour. Six formulations were made as seen on **Table 6.** Formulation 1 was control, since it had no broccoli trunk flour; formulation 2 had 8% trunk flour, and formulation 3, 20%, as used by Valenzuela and Silva E [19], in their studies. Formulation 4 had 35% trunk flour and formulation 5 had 10% pizza flour (grinded pizza in order to see if it was able to hide broccolis flavor) and formulation 6 evaluated the use of fresh broccoli trunk instead of flour with the same percentage as formulation 4.

In order to realize the sensory analysis, 2 preference tests were evaluated: ranking and paired. Fifteen panelists evaluated the formulations. Ranking preference tests determined that formulation 6 had a better preference in flavor, and the non-accepted formulations were the ones that had trunk flour and 20% trunk flour. Formulations with no trunk flour had no significance according to the statistic test so they should be considered as second to fresh trunk. In regard to scent, there was preference for the control formulation, which indicates that broccolis odor is a factor that compromises in the ranking test. There were no comments about scent specifically, instead comments about the fresh trunk formulation as a good flavor, scent and texture. There was no statistical significance in order to reject any sample and differentiate them from any other except the control formulation, so every other formulation remained as second.

In regard to texture, formulation with 35% trunk flour was rejected, due to its bitter taste. It is possible that this formulation had toasted or burnt taste, although the same conditions were used in their baking process as the other formulations. It may be that the tray position inside the oven had an effect.

Samples of 8% trunk flour, 20% fresh trunk and control were placed in second place since panelist didn't like their texture. Panelists' comments mention that the texture was either too soft or too hard, different to a commercial nacho and so they didn't like it.

It is relevant to mention that the nachos were round shaped to maintain a standard, there was not a standard acquired in the dough width.

Paired preference test determined that there is no real preference between pizza formulation and 35% broccoli trunk flour formulation. This test was designed in order to see if pizza flavor was enough to hide broccoli's flavor and produce a preference in the consumer. The results show that there was no real difference and that the panelists commented that they preferred 35% broccoli due to its crunchiness and that broccoli flavor made it more appetizing. The pizza sample was rejected for its thickness and softness and the panelists commented that they were not able to identify pizza flavor.

Regardless of the panelists' comments when evaluating the nachos texture, there was no significant difference (according to variance analysis) between each formulations width, penetration, hardness, and diameter. However it is possible to note slight tendencies, for example, fresh trunk formulation had a greater penetration than the other ones; due to the fact that fresh trunk has bigger particles compared to flour, giving an unbalanced texture and water transference. Compared to the other formulations, formulation 3 was the thinnest, it might be due to an over kneading in the kneading stage. In regard to diameter there is no significant difference, except the fact that some nacho edges were too lifted or too flattened due to the changes during the cooking stage.

Hence, the fresh trunk formulation was preferred and accepted and that its texture characteristics were acceptable, although there was a preference for broccoli flavor in formulation 35%. It is recommended another sensory study where a duo-trio or triangular test is made, in order to determine if there are really differences among the samples and perceived by the consumer. A change in formulations such as adding egg or an emulsifier to enhance texture, adding spices to hide broccolis flavor would also be recommended. In this study, the formulations made were simple in order to determine the effects of the trunk flour in a product. If trunk flour percentages were lowered, taste and flavor results would be better accepted, but the nutrients evaluated and needed such as proteins, antioxidant capacity, and vitamin C may not be enough to fulfill the dietary needs in the body. It is recommended to analyze vitamin C, total polyphenol content, antioxidant capacity and a biological test over the formulations in order to estimate a nutritional effect in the body. Further studies in fresh trunk are recommended, due to its preference and since it has a better yield than flour; the drawback of fresh trunk is that the shelf life and packaging would be different.

CONCLUSIONS

Broccoli trunk flour has a great potential as functional food ingredient due to its nutrients, vitamin C, antioxidants, and easiness at mixing with commercial flours. Further studies are needed for triturated fresh trunk and its use in order to enhance industrial yields.

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