Influence of vegetable addition on physical and sensory properties of maize extrudates.

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Influence of vegetable addition on physical and sensory properties of maize extrudates.

-Abstract:

The characteristics of corn extrudates to which powdered vegetables have been added, specifically beets, carrots, onions, garlic and leeks, are studied through a series of physical analyses. The analyses carried out are determination of colour by spectrophotometry, rheological properties by RVA, water content by weight difference after drying and sample diameter.

-Key words:

Maize extrudates, colour, rheology, vegetables.

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Influencia de la adición de vegetales en las propiedades físicas y sensoriales de los extrusionados de maíz.

-Resumen:

Se estudia mediante una serie de análisis físicos las características de los extrusionados de maíz a los que se les ha añadido vegetales en polvo, en concreto remolacha, zanahoria, cebolla, ajo y puerro. Los análisis realizados son color mediante espectrofotometría, propiedades reológicas mediante un RVA, contenido de agua por diferencia de pesos tras un secado y diámetro de la muestra.

-Palabras clave:

Extrusionados de maíz; vegetales; color; reología.

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Content:

From the first half of the s XIX, food manufacturers increased the production and also the variety of new products so, nowadays, it is very common to see extrudate products at the supermarket.[6]

Snacks are one of the most common uses of extrusion in food technology, due its ease to be combined with any artificial flavour but also because it is easy to conserve them without additives. This leads to a big amount of variety of snacks for children and also for adults.

Figure 1: Extrudate product example.[4]

The big problem of this type of snacks is that they are full of flavouring and colouring chemicals that can cause health problems to their consumers, especially if they are young people.[10]

The aim of this project is to study some of the physical and sensorial properties of maize extrudates to which have been added vegetable powder, with the objective to improve the composition of snacks and make them more nutritive.

2-Theoretical part.

2.1-Composition of selected vegetables and health effect on their ingredients.

2.1.1-Corn grits.

Maize is the caryopsis part of the *Zea mays* plant. Originally from America, it was one of the first plants in the region being domesticated about 5000 years ago, in the zone of Mexico. It is the most important cereal in that continent, so it is mostly produced there. Maize is a good substitute to wheat for people with celiac disease, due it is gluten free. It is a good source of complex carbohydrates and it has a good amount of proteins, but with limitation of the aminoacid lysine.[8]

Energy (kJ/kcal):	1437/339
Fat (g):	2
Saturated (g):	0.1
Carbohydrates (g):	78
Sugars (g):	1.3
Proteins (g):	7.4
Fibre (g):	4.2
Salt (g):	0.02

Table 1: Nutritional values of corn.[15]

Maize is the main ingredient of our experiment, due its relation between the starch and proteins quantity, we can ensure it is a great material for an extrusion experiment. The moisture of the corn grits is about 12%.

2.1.2-Beetroot.

Beetroot is a red-purple root of the beet plant *(Beta vulgaris).* It is the taproot and functions as nutrients storage of the plant. Due its easy production in non-tropical weathers, it is used industrially to produce white sugar, especially in Europe and north-Asia.[8] This vegetable is rich in sugars, and it has big antioxidant properties due the presence of betaine. This molecule is used to treat some illness like homocystinuria, but also helps with the prevention of some types of cancer.[10]

The composition of the dry beetroot is:

Energy (kJ/kcal):	1452/347
Fat (g):	1.07
Saturated (g):	0.11
Carbohydrates (g):	70.0
Sugars (g):	45.90
Proteins (g):	11.3
Fibre (g):	6.09
Salt (g):	0.04

Table 2: Nutritional values of beetroot.[13]

The main nutrient of the beetroot is sugar, as mentioned before, but it also has about 24% of starch. Due the presence of natural colorants and sugar, it is to be expected that the final product will have a reddish colour and a sweeter flavour.

2.1.3-Garlic.

Garlic is the bulb part of the *Allium sativum* plant. It is produced all over the world, but mostly in Asia. Garlic is one of the most used condiments, as it has a strong flavour that combines very easy with the food.[8] Also, it has properties that helps with respiratory diseases, it is bronchodilator, fluidises mucous and stimulates the immunologic system.[16]

The composition of dry garlic is:

Energy (kJ/kcal):	1481/354
Fat (g):	0.31
Saturated (g):	0.07
Carbohydrates (g):	70.35
Sugars (g):	21.04
Proteins (g):	15.77
Fibre (g):	4.72
Salt (g):	0.041

Table 3: Nutritional values of garlic.[13]

Garlic has a very strong flavour, so it is expected that the final product will have a strong flavour. Dry garlic has a very good amount of proteins, but also of starch (about 49%), that will affect to the expansion rate.

2.1.4-Onion.

Onion is the bulb part of the *Allium cepa* plant. It is the most produced plant of the Allium genre, so it is produced all over the world.[8] It has anti-inflammatory properties, but also helps to diabetic people to handle the resistance to insulin.[11]

The composition of dry onion is:

Energy (kJ/kcal):	845/202
Fat (g):	9.3
Saturated (g):	0.3
Carbohydrates (g):	35.3
Sugars (g):	28.6
Proteins (g):	10.5
Fibre (g):	36.4
Salt (g):	0.1

Table 4: Nutritional values of onion.[13]

Onion has a very strong flavour that is expected to be kept on the final product. It has very low quantity of starch, about 6.7% and a high quantity of fibre.

2.1.5-Leek.

Leek (*Allium ampeloprasum* var. *porrum)* is a plant that both the bulb and the leaves can be consumed. It is produced principally in Asia, but is consumed all over the world. Leek has laxative effects, and also is rich in vitamins and minerals. It helps with the regulation of water absorption and pH control of the blood.[8]

This is the composition of leek:

Energy (kJ/kcal):	1310/313

Fat (g):	1.54
Saturated (g):	0.21
Carbohydrates (g):	72.6
Sugars (g):	20
Proteins (g):	7.7
Fibre (g):	9.24
Salt (g):	0.01

Table 5: Nutritional values of leek.[14]

Leek has a greenish colour and a very specific flavour that is expected to be in the final product. It is rich in fibre, and has about 53% of starch.

2.1.6-Carrot.

Carrot is the main root of *Daucus carota* plant. It is produced and consumed all over the world. Carrot is rich in fibre, that helps with intestinal diseases. Also, carrot is rich in antioxidants, that help protecting the body from free radicals.[8]

This is the composition of the dry carrot:

Energy (kJ/kcal):	816/195
Fat (g):	1.45
Saturated (g):	0.3
Carbohydrates (g):	36.85
Sugars (g):	35.67
Proteins (g):	6.82
Fibre (g):	38.01
Salt (g):	0.495

Table 6: Nutritional values of carrot.[13]

Carrot has an intense orange colour, that is expected to be in the final product. Carrot has a big quantity of fibre and less of starch, about 1.18%.

2.2-Extrusion cooking.

Extrusion cooking is a process used in industries like construction or metallurgy, and it is used in food technology to make snacks, baby food or breakfast cereals, among others. An extruder consists principally in one or two endless screws within a barrel and a die at the end where the food goes out. The mixture goes in through a funnel, then through the extruder thanks to the rotating screws that can be one or two. During this time, the food is compressed, sheared and heated. That creates a dough that expands as it goes through the die due to pressure difference.

The extrusion process involves creating a very specific conditions to obtain the desired product, with high temperatures, high pressure and short time of process.[11]

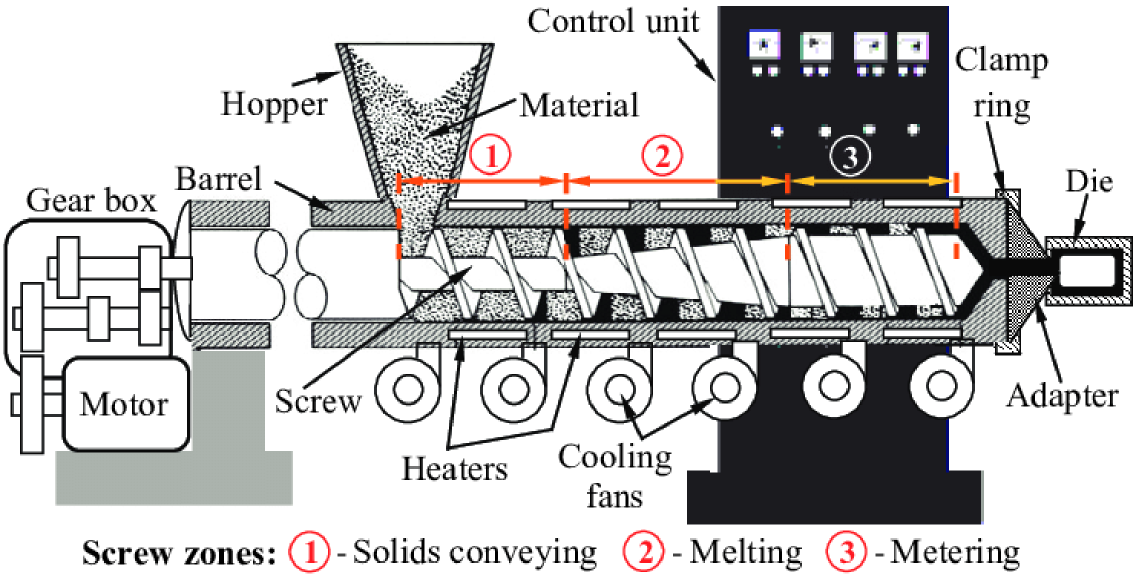


Figure 2: Extruder scheme.[1]

The principal variables to know that affect the final result are:

-Ratio between starch and protein content: Protein makes stronger interactions so the final product will be less expanded, more dense and more resistant to humidity. Starch makes the final product more fragile but more expanded. So, the objective is to find a mix between maize and vegetables that allows a great expansion but has to resist the storage conditions.[12]

-Temperature and humidity: Those variables will determine the gelatinization grade of starch. Before the extrusion, we need the humidity necessary to have the starch in a rubbery state, to ease the gelatinization. This humidity is around 14%-16% depending on the maize used, but is possible to increase it to around 40% depending on the final product. Water content will affect the shearing forces (more water, more shearing) which will decrease the final product resistance. Temperature will also affect the gelatinization of starch, increasing the gelatinization grade due temperature. Also, it will increase the denaturalization of proteins, which will decrease the solubility of the final product and will increase the digestibility. Temperatures over 120ºC will ensure the gelatinization of the starch and the denaturalization of proteins.[12]

-Pressure and orifice size: A high pressure and a small orifice size will allow a higher expansion of the final product (less density) with less water content due to evaporation. Lower pressures and higher size orifices will allow a final product with higher density that will soften and expand in contact with high temperatures (air or oil) due the residual water. [12]

-Speed of axis: This will affect to the time that the product is at the extruder, so we need the time necessary to the starch to gelatinize. It has to be as low as possible because we do not want to overcook and lose nutritional factors.[12]

2.3-Types of extruders.

Extruders can be classified by their temperature and their construction.

2.3.1-Classification by temperature.

-Cold extrusion (or just extrusion): The food just receives the heat produced by the friction in the screw, so the temperature barely rises over 50ºC. It is used for raw pasta, meat for hot dogs or for some bakery products.[12]

-Hot extrusion (or extrusion cooking): The extruder is heated between 100ºC and 180ºC during a short period of time, and the pressure can increase up to 25 MPa. Due the high temperatures, there is an inactivation of enzymes and a diminution of the quantity of microorganism. It is used for breakfast cereals, some snacks and pet's food.[12]

2.3.2-Classification by their construction.

-One screw: the premix goes through one screw, that mixes, shears and compresses the matter between the screw and the wall. [12]

-Two screws: the premix goes between two screws, that also mixes, shears and compresses the food. The main differences are that with two screws there is not that much heating due to friction, so the temperature is easier to control, it is more versatile due it is possible to use oily products that in one-screw extruder would flow back. Also, the efficiency of the two-screw extruder is higher due the production does not depend of the feed, just on the screw rotation. [12]

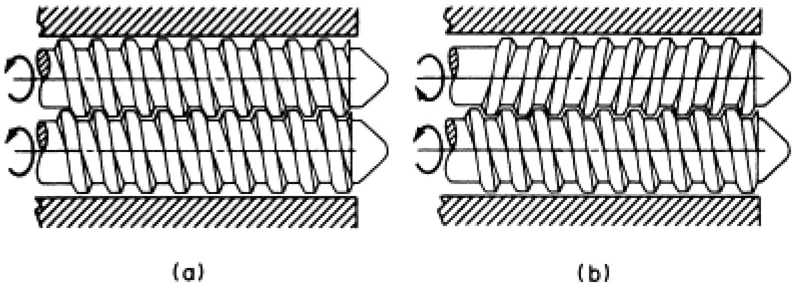


Figure 3: Doble screw scheme.[17]

2.3.3-Coextrusion:

Coextrusion consist on the addition of a tube in the exit of the extruder that adds filling, so it is possible to create stuffed products.[12]

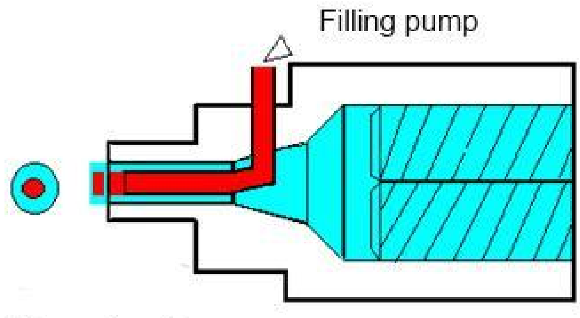


Figure 4: Coextrusion scheme.[5]

3.-Experimental part.

The experiments were done in the laboratories of the Department of Carbohydrates and Cereals from the University of Chemistry and Technology, in Prague.

3.1-Chemicals and ingredients.

The ingredients used to prepare the premixture were corn grits, distilled water and dry vegetables, specifically dry carrot (les fruits du paradis), dry beetroot (les fruits du paradis), dry garlic (les fruits du paradis), dry onion (les fruits du paradis) and dry leek (zdravělevně)

For the analytical part, only distilled water was used with the extrudates.

3.2-Instruments.

To prepare the premixtures, the material was weighted in a laboratory balance, and mixed with an electric mixer. The premixtures were stored in plastic zip-bags and frozen in a freezer until the use. A small shovel was used to insert the premixtures in the extruder, that was a cooking extruder with one screw (Compact extruder KE19/25, Brabender, Germany). The extrudates were stored in plastic zip-bags until the analysis. The analysis instruments are explained in the next chapter.

3.3-Methods.

3.3.1-Moisture of the premixtures.

Before preparing the premixtures, it was necessary to know the moisture of the dry vegetables so the humidity of the premixtures can be controlled. To do that, about 2 g of the dry vegetables were weighted in an analytical balance and putted in a dried and weighted vessel. The samples were inserted in a oven (Binder) at 130ºC for 3 hours and then let them cool down in a desiccator. After that, they were weighted again in an analytical balance. With the following formula, the moisture was calculated.

$$\%Water\ content = \frac{Vessel\ with\ sample - Vessel\ with\ dried\ sample}{Vessel\ with\ sample - Vessel} * 100$$

Equation 1: Calculation of water content.

Vegetable	Water content (%)
Onion	6.16
Garlic	5.89
Carrot	7.92
Leek	8.65
Beetroot	5.98

Table 7: Water content of the premixtures.

3.3.2-The premixtures.

The composition of each premixture was calculated using 1000 g of corn grits as a base and with a final moisture of 15%. The quantity of each vegetable had to be enough to reach a 5%, 10% and 15% of the final premixture. So, in total we had to get 18 samples, of which 15 had to be each vegetable with a different percentage, and the other three were just corn grits with a humidity of 23%, 18% and 15%, just to make the extruder work.

Sample	Vegetable added (g)	Water added (g)	% of vegetable
Onion	55	40,99	5
Onion	116	47,40	10
Onion	186	54,65	15
Garlic	55	41,17	5
Garlic	116	47,77	10
Garlic	186	55,25	15
Carrot	55	39,85	5
Carrot	116	44,96	10
Carrot	185	50,73	15
Leek	55	39,38	5
Leek	116	43,95	10
Leek	150	39,79	15
Beetroot	55	41,11	5
Beetroot	116	47,65	10
Beetroot	186	55,06	15
Maize	0	35,29	0
Maize	0	70,00	0
Maize	0	140,00	0

Table 8: Composition of the premixtures.

After weight each ingredient, each sample was prepared in an electric mixer. The corn grains and the water were mixed first, during 2 minutes. After that, the vegetable was added and mixed again for 5 minutes. The premixtures were stored in a tagged plastic zip-bags and frozen until the extrusion.

3.3.3-The extrusion.

The extruder was turned on and set to a maximum temperature of 130ºC, with a die of 3mm, a compression ratio of 1:3, a screw speed of 150 rpm and a dosing speed of 15 rpm. The screw had a diameter of 19mm and 475mm length.

A small amount of the Maize-23 premixture was inserted through a hopper. After about 5 minutes of letting the extruder be cleaned and ready, the premixture Maize-18 was added, and after a few minutes the premixture Maize-15. After that, each premixture was added in increasing order of the percentage of the vegetable, and obtained an extrudate sample of each.

To obtain the samples, the premixture was added, and after a small transition phase between premixtures, the extrudate went out. The sample was recollected at the exit of the extruder and stored in plastic zip-bags. It was important not to let the hopper being empty, because in order to the extrudate to go out, it needs the screw to be full.

The values obtained from the extruder were:

Sample	T1 ºC	T2 ºC	T3 ºC	T4 ºC	Pressure (bar)	Engine load (%)	mass flow (kg/h)
Blank-A	50	89	105	133	130	53	2,55
Carrot-5	50	91	108	131	70	46	2,05
Carrot-10	52	87	109	13	50	37	1,87
Carrot-15	55	91	110	130	25	36	1,69
Onion-5	55	97	109	130	120	50	1,90
Onion-10	50	89	109	130	95	36	1,97
Onion-15	50	90	107	130	85	39	1,59
Blank-B	46	89	110	132	96	43	1,35
Beetroot-10	41	87	113	131	88	43	2,30
Beetroot-15	46	87	111	130	78	42	2,46
Beetroot-5	49	89	111	130	66	35	1,12
Leek-10	43	93	115	134	122	37	1,78
Leek-15	43	93	113	130	97	35	1,56
Leek-5	46	89	116	131	51	39	1,60
Garlic-5	44	93	117	132	105	58	2,08

Table 9: Values of the extruder.

The extruder had 4 thermometers along the screw that indicates the temperature on each point. It has a pressure indicator and an engine load indicator. These values are just a mean during the process. The mass flow was calculated taking a sample during about 3 minutes and weighting it.

As it can be observed, Garlic only has the 5% sample. That is because when the premixture of Garlic 10% was added to the extruder, it stuck inside and we had to stop the operation, so the garlic at 10% and 15% were not possible to be done. Also, as we did the operation in two times, we obtained samples of the Maize-15 two times, (named Blank-A and Blank-B, respectively).

3.4-Analytical methods.

After the extrusion, we proceeded to analyse the samples.

3.4.1-Diameter.

The diameter of the extrudate is a value that will indicate the expansion level in comparison with the blank sample, so the mean diameter of the sample will increase with the expansion rate and vice versa. To measure it, we use a vernier calliper tool, selecting 10 points of each sample and measuring the diameter three times on each point.

After this analysis, all the samples were blended with an electrical blender and inserted in a disc-mill to obtain a powder of about 0.8 nm. They were stored in plastic bottles.

3.4.2-Water content.

The method used to obtain the water content is oven-dry. This method consists in weighting the sample before and after an oven process, so the difference of the weights is due the water loses. First, the vessel with the cover was heated in the oven at 130ºC for one hour to remove the residual moisture and cooled down in a desiccator. Then they were weighted in an analytical balance. About 2 grams of the sample were weighted in the vessel and then dehydrated in the oven for 3 hours at 130ºC. After that, the samples were cooled down in a desiccator and weighted again. Using the next formula, the percentage of water was calculated:

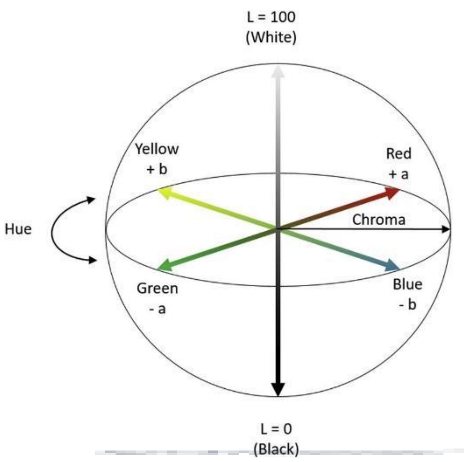
$$\%Water\ content = \frac{Vessel\ with\ sample - Vessel\ with\ dried\ sample}{Vessel\ with\ sample - Vessel} * 100$$

Equation 1: Calculation of water content.

3.4.3-Colour.

For the colour calculation, the method used was spectrophotometer UV-Vis (Unican UV). It consists on an apparatus that emits light in a specific wavelength that is reflected by the sample and measured. To quantify the colour values, we will use the CIE L*a*b colour space. This gives values for Luminosity (L), chromatic coordinates (a,b), chroma or saturation (C), and colour tone or hue (h).

To calculate the XYZ coordinates from which calculate the values for the colour, it is necessary to multiply the spectral distribution of the light emitter with the spectral distribution of the object and with the sensitivity curves corresponding to human eye.



In this experiment, the illuminative was type A10. The first thing was to calculate the coordinates XYZ, from which is possible to move the values to a colour space. To do that, we multiplied the reflectance data (in percentage) with the reference values (X0, Y0 Z0) and added it all, so we get the values for X, Y, Z. After that, using the next formulas, the values of CIE L*a*b were calculated. Values for Xn, Yn and Zn are the sum of all values for X0, Y0 and Z0 of the reference, respectively. [18]

$$L = 116\left(\frac{Y}{Y_n}\right)^{\frac{1}{3}} - 16$$

Equation 2: Calculation of “L” value.

$$a = 500\left(\left(\frac{X}{X_n}\right)^{\frac{1}{3}} - \left(\frac{Y}{Y_n}\right)^{\frac{1}{3}}\right)$$

Equation 3: Calculation of “a” value.

$$b = 200\left(\left(\frac{Y}{Y_n}\right)^{\frac{1}{3}} - \left(\frac{Z}{Z_n}\right)^{\frac{1}{3}}\right)$$

Equation 4: Calculation of “b” value.

$$C = \sqrt{(a)^2 + (b)^2}$$

Equation 5: Calculation of “C” value.

$$h = arctan\left(\frac{b}{a}\right)$$

Equation 6: Calculation of “h” value.

3.4.4-Rheological properties of dispersed ground extrudates.

Rheological properties values were obtained using a RVA (Perten). The principle is to measure the shearing forces of the sample with a certain humidity when the temperature changes. A certain amount of sample is introduced in a vessel with 25 g of water to reach a specific moisture level, then is added a lid with a blade and inserted in the machine. The machine will rotate the blade, so depending on the viscosity of the sample, the blade will find the rotation easier or harder, and obtain a value of that. Then, the temperature will increase until almost 100ºC, so the viscosity will change due the physical reactions of the sample, like gelatinization of the starch.[2]

The variables that the RVA analyser reads are:

Cold peak: Maximum viscosity during the cold test.

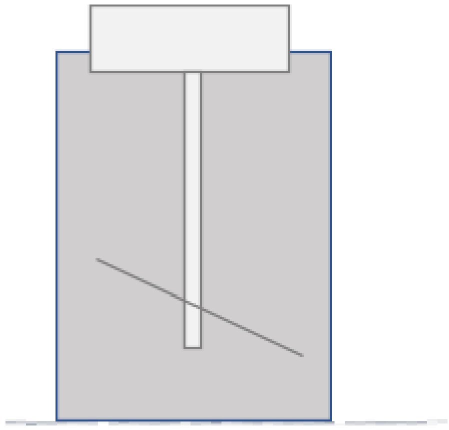
Raw peak: Maximum viscosity when the temperature starts to increase.

Hold: Minimum viscosity after the peak.

Breakdown: Peak viscosity minus hold.

Final viscosity: Viscosity at the end of the test.

Setback: Final viscosity minus hold.



3.5 Results and Discussion

3.5.1 Diameter of the extrudate.

To know the expansion rate of the samples, the diameter of each one was measured, so the results were:

Sample	Diameter (mm)	Sample	Diameter (mm)
Blank-A	11.4 ± 0.8	Garlic-5	12.5 ± 1.2
Blank-B	11.3 ± 0.9	Leek-5	10.9 ± 0.6
Onion-5	11.1 ± 0.7	Leek-10	7.3 ± 0.3
Onion-10	10.9 ± 0.6	Leek-15	7.2 ± 0.5
Onion-15	5.9 ± 0.5	Beetroot-5	9 ± 1.0
Carrot-5	11.9 ± 0.7	Beetroot-10	6.9 ± 0.5
Carrot-10	6.5 ± 0.3	Beetroot-15	6.1 ± 0.2
Carrot-15	3.8 ± 0.2		

Table 10: Diameter of the samples.

In this experiment, each sample was measured in 10 different points for 3 times to obtain an average diameter of each one. In every sample of each vegetable there is a diminution of the diameter with the addition of more vegetable powder. That means that the expansion ratio decreased when the quantity of the vegetable was increased. The modification of the composition of the premixtures makes that happen, principally the content of carbohydrates and fibre. The differences between the starch content and fibre affects the expansion rate, so higher quantity of fibre less expansion.

Carrot and onion are the ones with higher quantity of fibre, and the ones that change more with the addition of more vegetable. On the other hand, leek, that has more starch content, is the one that has expanded more with the addition of more vegetable from Blank samples.

Differences between Blank-A and Blank-B are not significant.

3.5.2 Humidity.

The water content of the samples was measured after the extrusion. The results were:

Sample	Humidity (%)	Sample	Humidity (%)
Blank-A	5.87 ± 0.04	Garlic-5	5.78 ± 0.04
Blank-B	6.4 ± 0.20	Leek-5	5.79 ± 0.014
Onion-5	5.4 ± 0.20	Leek-10	6.228 ± 0.010
Onion-10	6.20 ± 0.07	Leek-15	6.34 ± 0.06
Onion-15	6.05 ± 0.13	Beetroot-5	6.407 ± 0.002
Carrot-5	6.10 ± 0.40	Beetroot-10	6.55 ± 0.14
Carrot-10	6.47 ± 0.04	Beetroot-15	6.51 ± 0.03
Carrot-15	6.67 ± 0.03		

Table 11: Humidity of the samples.

The premixtures had an initial humidity of 15%, that decreases to around 6% due the expansion process. The differences between each sample are due the water retention ability of the mixture.

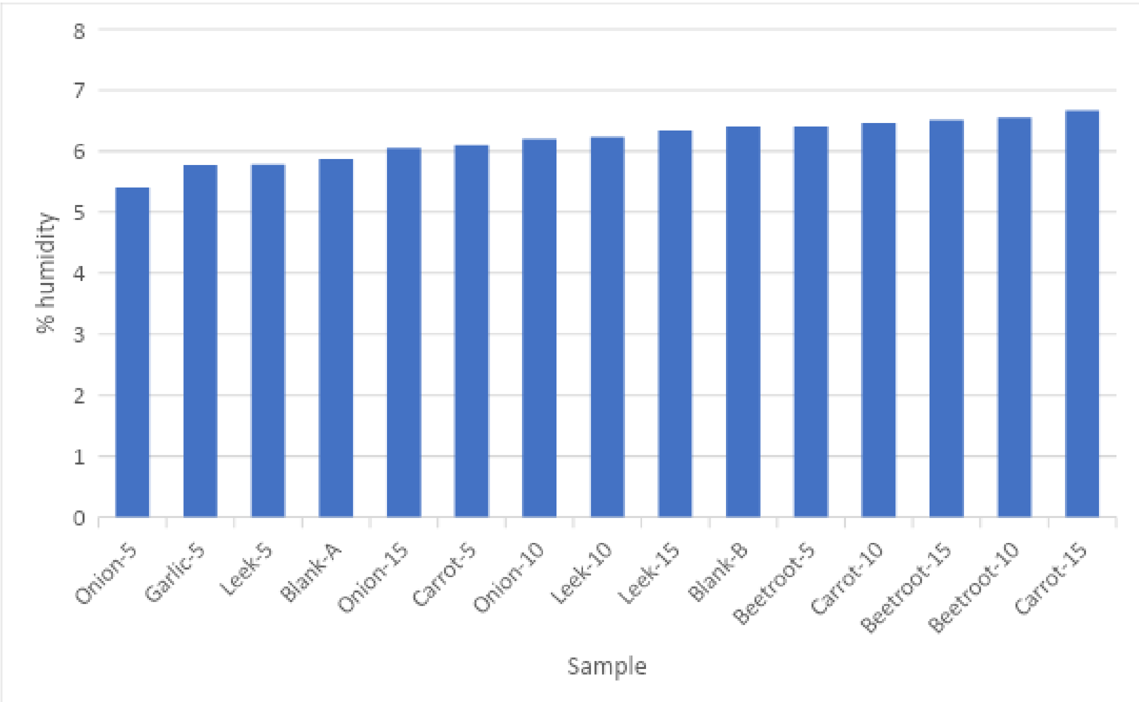


Figure 7: Humidity graph.

As seen in the graph (Figure 7), the differences between blank samples and the rest are slightly different, so we took the correlation coefficient between the samples and the quantity of vegetables added.

Sample	Correlation coefficient
Onion	0.207
Carrot	0.929
Leek	0.305
Beetroot	0.905

Table 12: Correlation coefficients between humidity and vegetable content of the samples.

A correlation coefficient over 0.9 means that there is a statistical relation between carrot quantity and water content, the same for beetroot, whereas for onion and leek there is no statistical relation for that.

3.5.3 Colour.

Due the difference of the interpretation of colour of each human eye, it is important to have objective data for it. Using CIE L*a*b coordinates, we have values for luminosity (L), chromatic coordinates (a,b), chroma or saturation (C), and colour tone or hue (h).

Sample	L	a	b	C	h
Blank-A	91.2	1.0	4.0	3.5	1.3
Onion-5	90.2	1.3	4.5	4.7	1.3
Onion-10	90.3	1.1	4.5	4.7	1.3
Onion-15	90.2	1.1	4.4	4.5	1.3
Carrot-5	90.3	1.2	4.8	4.9	1.3
Carrot-10	90.0	1.3	4.3	4.5	1.3
Carrot-15	90.1	1.1	4.2	4.4	1.3
Blank-B	90.7	0.7	3.4	3.5	1.4
Garlic-5	89.9	1.1	4.0	4.2	1.3
Leek-5	90.1	0.8	3.1	3.3	1.3
Leek-10	90.2	0.4	3.3	3.3	0.8
Sample	L	a	b	C	h
Leek-15	90.1	0.5	2.8	2.9	1.4
Beetroot-5	89.6	1.9	2.6	3.2	0.9

Beetroot-10	88.5	1.7	1.3	2.2	0.6
Beetroot-15	88.5	1.8	1.6	2.4	0.7

Table 13: CIE L*a*b values of the samples.

Samples has less L value than blanks, so the addition of vegetables darkens the sample.

If we plot this values in a graph a vs b, where more of 'a' means redder and more 'b' means more yellow, this would be the result:

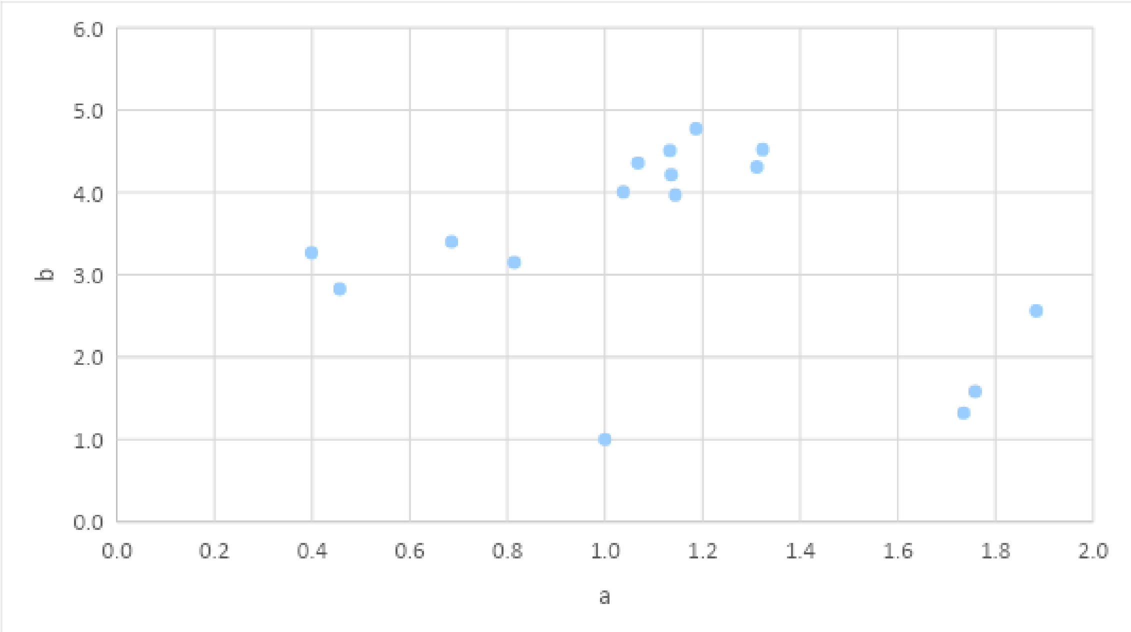


Figure 8: Plot of "a" and "b" values.

The samples with leek had a more greenish colour, so the values are closer to the 'b' axis, while beetroot, that the sample had a reddish colour, are closer to 'a' axis. Also, we can observe that for leek and beetroot at 10% the colours are closer to each axis than 15%. The rest of the values had a similar colour, but if we zoom the middle part of the graph:

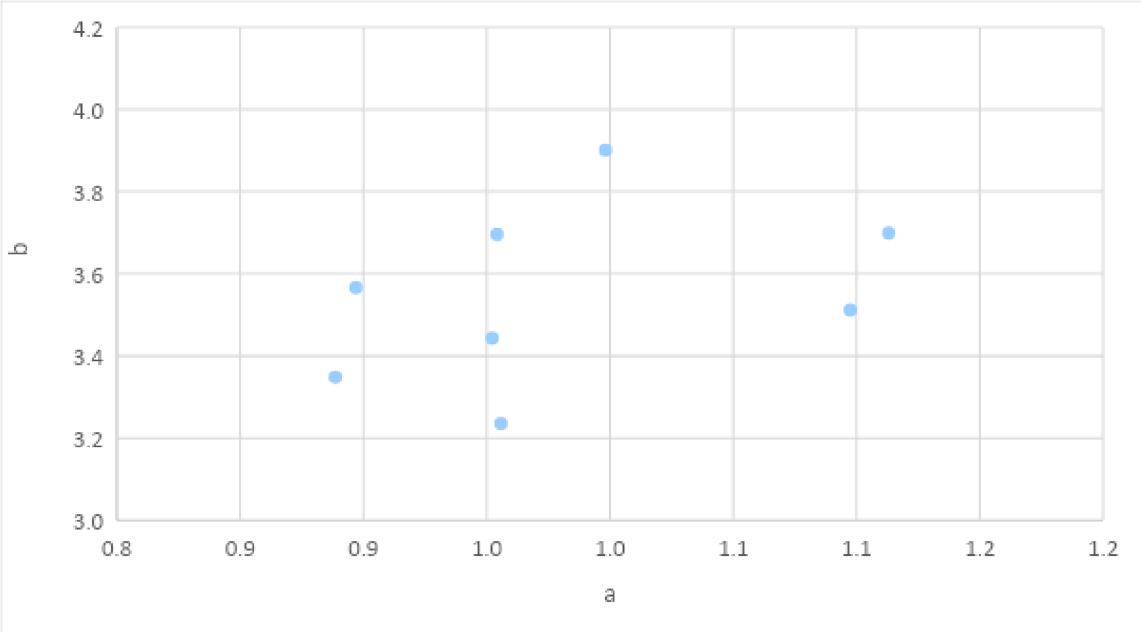


Figure 9: Plot of "a" and "b" values zoomed.

We can appreciate that the addition of onion to the premixture decreases the ‘a’ value, so the sample gets a yellowish colour, while increasing the carrot content of the premixture, the ‘b’ value decreases due its orange colour. However, these changes are not significant. Also, there is a notable difference between Blank-A sample and Blank-B sample, probably because as they were done in different times, there were some residues in the extruder that changed the colour.

3.5.4- Rheological properties of dispersed ground extrudates.

The values obtained from the RVA were:

Test	Cold Peak (mPas)	Raw Peak (mPas)	Hold (mPas)	Breakdown (mPas)	Final Visc (mPas)	Setback (mPas)	Peak Time (s)	Cold Peak Area
Blank-A	292	205	87	204	286	199	2,1	537,2
Blank-B	379	234	83	272	384	301	2,7	696,9
Onion-5	324	223	83	234	262	179	2,1	615,0
Onion-10	178	181	126	55	271	145	6,2	348,4
Onion-15	72	87	79	8	156	77	6,3	140,7
Carrot-5	542	335	90	434	327	237	2,1	1015,0

Test	Cold Peak (mPas)	Raw Peak (mPas)	Hold (mPas)	Breakdown (mPas)	Final Visc (mPas)	Setback (mPas)	Peak Time (s)	Cold Peak Area
Carrot-10	197	191	121	74	364	243	2,3	362,5
Carrot-15	69	146	128	18	385	257	6,5	120,2
Garlic-5	288	191	67	219	228	161	2,1	555,5
Leek-5	419	250	76	329	244	168	2,1	792,2
Leek-10	261	234	149	112	326	177	2,1	487,1
Leek-15	245	188	111	133	246	135	2,1	468,9
Beetroot-5	350	236	103	239	313	210	2,1	668,9
Beetroot-10	191	175	113	72	285	172	2,1	366,7
Beetroot-15	71	114	98	16	246	148	7,7	131,6

Table 14:RVA values.

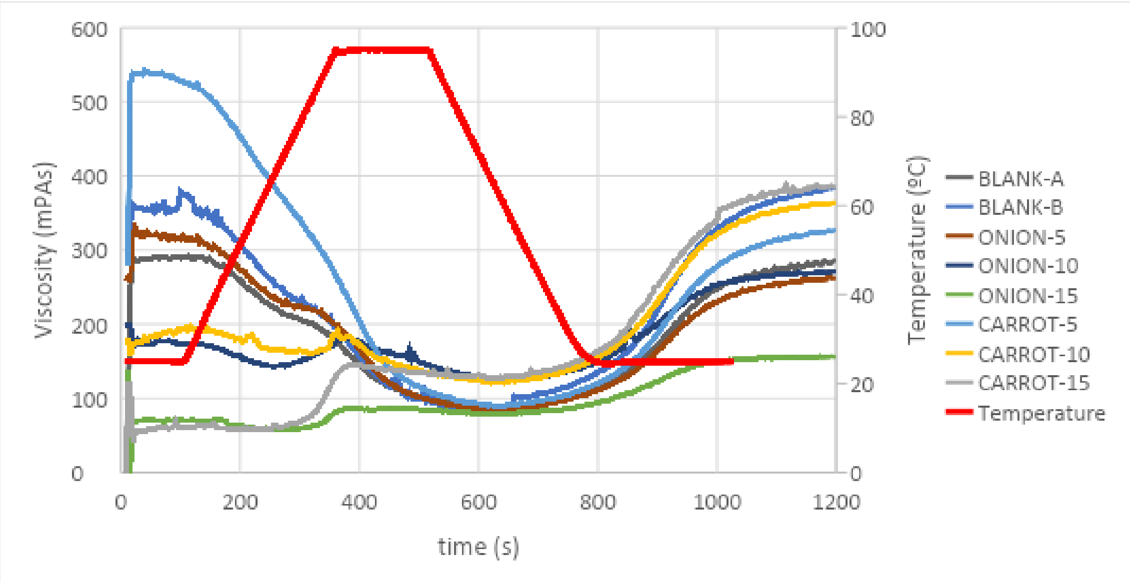


Figure 10: Viscosity vs time vs temperature.

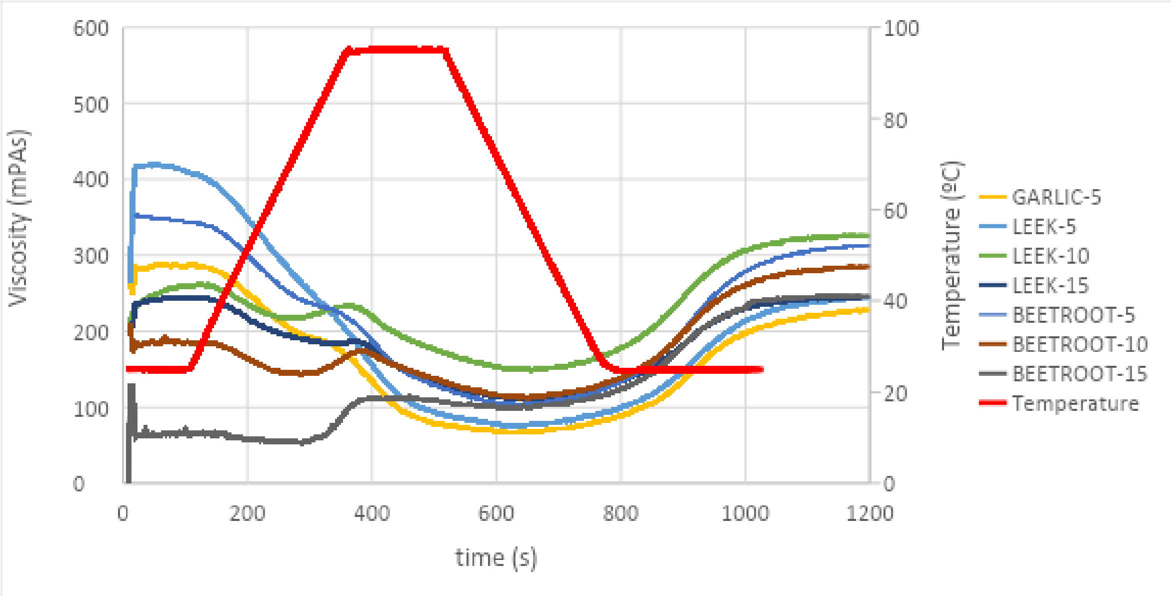


Figure 11: Viscosity vs time vs temperature.

To describe the dynamic viscosity, we need to divide the graph in three parts: the first one from t=0 sec to t=120 sec that will provide the cold viscosity, the second one from t=120 sec to t= 600 sec that will be hot viscosity, and the final one from t=600 sec to t=1200 sec will be the final viscosity.

Cold viscosity describes the shearing during the extruding process, so higher viscosities will be due high shearing during the extrusion process, but if there is an over-shearing the viscosity can be decreased. So, if we take the Blank A-B as reference, the samples with vegetable content of 5% have higher viscosity (except the garlic one), meaning that they had more shearing during the extrusion than the blanks sample. The rest of the samples has less cold viscosity than the blanks. The increasing of the vegetable content leads to a diminution of the cold viscosity, meaning that the vegetable content increases the over-shearing during the extrusion process. Garlic sample has less viscosity than the blank sample due his sticky properties increases the shearing effect on the extrusion process, but also the gelatinization of the starch increases the shearing.

Hot viscosity zone describes the degree of cooking of the extrudate. So, the more to the right is the raw peak, less cooked is the sample. This value is more appreciable in the table 13. If we look the raw peak values, we can see that the increasing of the vegetable content leads to a more cooked product, probably because the over-shearing that we talked in the last point increases the cooking of the samples. The hot viscosity values describe the final viscosity in heat conditions. It depends on the two values commented before, but there is no relation between the vegetable content and this viscosity.

The final viscosity value reflects the shearing and the cooking effects in the viscosity, so less cooked/sheared products will have a higher setback value, so this value is more related to the degree of cook of more raw products.

4-Conclusion.

The characteristics of each sample were affected by the composition of each vegetable. The samples with more fibre were less expanded, while the ones with more starch were more expanded. The colour difference was more notable in beetroot and leek samples. The addition of more vegetables increases the shearing of the extruder, but also the cooking level of the sample.

It is possible to add vegetables to maize extrudates, but it needs more study to know the compatibility of the different vegetables with the maize and how it affects to other parameters. It would be necessary to add more sensorial study to know the perception of the consumer at the time of buying this product.

5-References.

1-Abeykoon, C., & McAfee, M. (2011). Extruder melt temperature control with fuzzy logic. Retrieved from https://www.researchgate.net/figure/The-basic-components-of-a-single-screw-extruder_fig1_259687233

B. Crosbie, G., & S. Ross, A. (2007). *The RVA handbook.*

Chau K Ly, B., B Dyer, E., L Feig, J., & Chien, A. (2020). Research Techniques Made Simple: Cutaneous Colorimetry: A Reliable Technique for Objective Skin Color Measurement. *Journal of Investigative Dermatology*, 140(1):3-12.

Cheetos. (n.d.). Cheetos Twisted Flamin' Hot Snacks. Retrieved from https://www.amazon.co.uk/Pack-Cheetos-Twisted-Flamin-Snacks/dp/B01EX18BWK

Clextral. (n.d.). Coextrusion. Retrieved from https://www.clextral.com/our-offer/

Doll, G., Händle, F., & Spiessberger, F. (2009). Piston extruders. In *Extrusion in ceramics. Engineering Materials and Processes.* Springer, Berlin, Heidelberg. Retrieved from https://doi.org/10.1007/978-3-540-27102-4_14

F. Lechner, J., & D. Stoner, G. (2009). Red Beetroot and Betalains as Cancer Chemopreventative Agents. *Molecules*, 24. Retrieved from https://doi.org/10.3390/molecules24081602

García Breijo, F. (2004). *Biología y botánica. Tomo I.* Universitat Politécnica de Valencia.

Gonzalez Farras, A. (n.d.). *Scheme of a RVA vessel with blade.* Prague.

Hashem, M., Atta, A., Arbid, M., Nada, S., & Asaad, G. F. (2010). Immunological studies on Amaranth, Sunset Yellow and Curcumin as food colouring agents in albino rats. *Food and Chemical Toxicology*, 1581-1586. Retrieved from https://doi.org/10.1016/j.fct.2010.03.028.

Lee, C., Lee , H., Cha, Y., Joo, W., Kang, D., & Moon, J. (2013). In vivo Investigation of Anti-diabetic Properties of Ripe Onion Juice in Normal and Streptozotocin-induced Diabetic Rats. *Preventive nutrition and food scienc*, 18(3), 169–174. Retrieved from https://doi.org/10.3746/pnf.2013.18.3.169

Martín Esparza, M. (2019). Operaciones de Transformación. *Extrusión de alimentos*. Universitat Politécnica de Valencia.

Nutritional label. (2022). China: Les fruits du paradis.

Nutritional label. (2022). Egypt: Zdravé levné.

Nutritional label. (2022). Czech Republic.

Petrovska, B., & Cekovska, S. (2010). Extracts from the history and medical properties of garlic. *Pharmacogn Rev.*, 4(7): 106-110. Retrieved from https://doi.org/10.4103/0973-7847.65321

Stevenson, J. F. (1989). Specialty Polymers & Polymer Processing. *Comprehensive Polymer Science and Supplements*.

Talens Oliag, P. (n.d.). *Obtencion de las coordenadas de color XYZ a partir de una medida espectral en la region visible.* Universitat Politécnica de Valencia. Retrieved from http://hdl.handle.net/10251/68363