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DEVELOPMENT OF A MORE NUTRITIOUS TORTILLA IN MEXICO

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Abstract: The objective was to improve the nutritional value of the tortilla added with soy flour (Glycine max) and oats (Avena sativa). A completely randomized design was used in the formulation of five treatments (T) and a control (100% corn). Two concentrations of corn (70 and 85 %) with 5, 10, 15 and 30 % soybean and oatmeal were evaluated. The proximal composition and the content of three minerals were analyzed. The results showed significant differences ($P \leq 0.05$). Finding that the tortillas made with 70% corn and 30% soy contained 21.43% protein, 440, 6.3 and 2.9 mg of Ca, Fe and Zn, respectively. Followed by the formulation with 70, 15 and 15% corn, soybean and oats, containing 19.78% protein, 560 mg of Ca and 2.85 mg of Zn. It is concluded that the preparation of corn tortillas added with soybeans and oats significantly increases the content of protein and minerals of nutritional interest.

Keywords: Protein, Calcium, Iron, Zinc.

INTRODUCTION

In Mexico, like several countries in the world, poor nutrition is a serious public health problem (Rodiles-López et al., 2019). It is important to rescue and guide the population towards the preference of traditional foods such as beans, quelites, corn and amaranth, among others, as well as fruits and vegetables (Levy, Amaya and Cuevas, 2015). The addition of ingredients of high nutritional value can improve the potential of foods as dietary supplements due to the simplicity in their preparation, durability and acceptability (Delgado-Vidal, Ramírez-Rivera, Rodríguez-Miranda and Martínez-López, 2013; Cabal, Melo, Lissbrant, Gallego, La O and Tofiño, 2014).

Maize (Zea mays L.) represents the base of the diet in Mexico. The tortilla is one of the main products made from nixtamalized corn cooked with calcium hydroxide and is part of the diet of all social strata with a daily consumption of 328 g per capita (Cruz and Verdelet, 2007). The annual per capita consumption of maize in the country is 120.5 kg per year, compared to the world average of 17 kg; This figure explains that in Mexico the population consumes more food derived from corn than in any other part of the world (Ortiz-Rosales and Ramírez-Abarca, 2017). The tortilla is the most important component in the diet in Mexico and it is gaining more and more international relevance (Rodríguez, Chávez, Thomé and Miranda, 2017). However, the protein content in tortillas is around 4.12 % (Rodiles-López et al., 2019), and the proteins contain low concentration of lysine and tryptophan, in addition to being unbalanced in the proportion of leucine and isoleucine. (López-Alarcón et al., 2017). However, Cortés et al., (2016) evaluated the bromatological and sensory quality of tortillas made with mixtures of corn flour and oat flour, and found significant differences, the tortillas added with 40 % oat flour presented high content of protein and fiber, but less acceptability, while those of 10 and 20 % presented better acceptability, flavor, texture and higher protein content. On the other hand, Canul (2012) evaluated tortillas fortified with lysine and tryptophan, in the growth of malnourished preschool children in two rural areas of the state of Yucatan, in Mexico, and found an improvement in all the growth variables studied in the children who consumed fortified tortillas compared to the control group, although the level of statistical significance was not reached ($p > 0.05$), it was concluded that the consumption of tortillas fortified with lysine and tryptophan did not contribute to significantly improve the nutritional status of children, since it is not the only factor that causes malnutrition, however, it did lead to an improvement in weight gain and anthropometry. Similarly, Quintero et al. (2014) characterized a toasted corn-based

tortilla added with the alga Ulva clathrata in a 92:8 ratio, corn:seaweed and reported that the toasted tortilla added with seaweed is a good source of soluble fiber and carotenoids.

One of the richest seeds in protein is soybean (Glycine max), it contains up to 40%, rich in essential amino acids, vitamins, minerals and is free of starch (De Luna, 2007). It also contains anti-carcinogenic compounds such as isoflavones, genistein, phytosterol, phenolic acid and lecithin. The Food and Drug Administration of the United States (FDA) qualifies soybean as a functional food for its nutritional value and the components that can prevent pathologies or provide health (Segura et al., 2006). Due to these properties, soy has been used in some Latin American countries in various feeding programs, with the purpose of improving the nutritional status of the vulnerable population (Ridner, 2006).

On the other hand, oats (Avena sativa) is a cereal with an energy value of 361 kcal per 100 g. It is a low-cost source of protein and has a high fiber content. When compared with other cereals, it has a low content of carbohydrates and a higher lipid content than the rest. It also provides the diet with monounsaturated and polyunsaturated fatty acids, considered healthy fats. Regarding micronutrients, oats have a high content of iron, magnesium, zinc, phosphorus, thiamin (vitamin B1), vitamin B6 and folates, as well as being a source of potassium and vitamin E (Gómez et al., 2017) and it has considerable amounts of sulfur-containing amino acids such as methionine (Ortega et al., 2016). Several studies suggest that oat consumption produces health-promoting effects, since it is a cereal that contains soluble and insoluble fiber, such as alpha-glucans, arabinoxylans and cellulose, as well as proteins, lipids (unsaturated fatty acids), vitamins, antioxidants and phenolic compounds. The soluble fiber of oats (inulin, pectin; gums and fructooligosaccharides) retains water and is capable of forming gels, which accelerates intestinal transit and slows gastric emptying (Ortega et al., 2016). Due to the nutritional importance of the tortilla in the diet of the Mexican population, the objective of this study was to evaluate the nutritional value of the tortilla with the addition of soybean (Glycine max) and oat (Avena sativa) flour to increase its value. nutritional. antioxidants and phenolic compounds. The soluble fiber of oats (inulin, pectin; gums and fructooligosaccharides) retains water and is capable of forming gels, which accelerates intestinal transit and slows gastric emptying (Ortega et al., 2016). Due to the nutritional importance of the tortilla in the diet of the Mexican population, the objective of this study was to evaluate the nutritional value of the tortilla with the addition of soybean (Glycine max) and oat (Avena sativa) flour to increase its value. nutritional. antioxidants and phenolic compounds. The soluble fiber of oats (inulin, pectin; gums and fructooligosaccharides) retains water and is capable of forming gels, which accelerates intestinal transit and slows gastric emptying (Ortega et al., 2016). Due to the nutritional importance of the tortilla in the diet of the Mexican population, the objective of this study was to evaluate the nutritional value of the tortilla with the addition of soybean (Glycine max) and oat (Avena sativa) flour to increase its value. nutritional.

MATERIALS AND METHODS
FLOURS

In the preparation of the tortillas, commercial nixtamalized corn flour (Maseca®) was used with a starch concentration of 68.4%, amylose content of 30.3%, ethereal extract of 3.9%, ash content of 1.4%, calcium 0.125, fiber raw 1.57 % and protein 9.67 % (Flores et al., 2002). Commercial Defatted Soybean Flour (AMAS®) (Protein 44.0%, Fat 1.9% and Fiber 5.9%) and Oats (Quaker®), protein 3.8%,

Soluble Dietary Fiber 1.0%, Insoluble Dietary Fiber 1.3%, available carbohydrates 18.3% and total fat 0.3%. The oats were ground in an industrial blender (Torerey®) and sieved into 80 mesh, which corresponds to 0.177 mm pore opening.

TREATMENTS AND PREPARATION OF TORTILLAS

Five treatments were formulated, evaluating two proportions of corn (70 and 85%) and four concentrations of soybean and oats (5, 10, 15 and 30%). A control made from 100 % corn flour was used, as shown in Table 1.

Treatment	Flours (%)		
(T)	Corn	Soy	Oatmeal
1	70.0	30.0	0.00
2	70.0	0.00	30.0
3	70.0	15.0	15.0
4	85.0	5.00	10.0
5	85.0	10.0	5.00
Witness	100.0	0.00	0.00

Table 1. Design of treatments for the development of a multigrain tortilla based on corn, soybeans and oats.

The flours were weighed on a scale for the formulation of the treatments, 1055 ml of purified water (San Miguel®) per kilogram were added to each of the samples. They were manually kneaded until a moldable dough was obtained, keeping them at rest for 10 min; the tortillas were made in a commercial industrial machine.

PROXIMAL ANALYZES

To know the proximal composition of the treatments, humidity (NMX-F-083-1986), ash content (NMX-F-066-S-1978), and fat concentration (NOM-086-SSA1-1994) were determined. and proteins (AOAC (1997). Crude fiber was determined by the Van Soest method (NOM-086-SSA1-1994) and the nitrogen-free extract was obtained by difference between the weight of the food sample and the sum of moisture, ash, fat, protein and crude fiber values.

MINERAL ANALYSIS

Calcium was determined by means of an atomic emission spectrophotometer, using the Perking Elmer Spectrophotometer 3110 Massachusetts, USA. Iron and zinc were determined by the wet digestion method (AOAC, 974.27) using atomic absorption spectrophotometer.

ANALYSIS OF DATA

The experiment was established under a completely randomized design, with five treatments (T) plus an absolute control (T0). The analyzes of each of the variables to be measured were performed in triplicate. The results were analyzed by means of an ANOVA and comparison of different means by the Tukey method ($P < 0.05$) with the statistical package of Olivares Ver. 1.6 (Olivares, 2015).

RESULTS AND DISCUSSION

The consumption of corn tortillas in Mexico is carried out throughout the territory. It is part of the diet of the various economic strata and is consumed with most foods. One strategy to improve the nutrition of the population is to improve the nutritional content of this widely consumed food. In this work, soybeans and oats were added with the intention of analyzing the proximal composition and mineral content in nixtamalized corn flour tortillas.

PROXIMAL COMPOSITION

The moisture content was determined between 39.36% in the mixture composed of 70% corn, 15% soybean and 15% oats up to 47.15% moisture in the treatment with the

addition of 30% soybean meal. However, the statistical analysis did not indicate significant differences between the treatments. The concentration of water in food is important as it can affect its shelf life and storage conditions. In addition, it is a factor that can be adverse for quality (Carrillo & Reyes, 2013).

The pH determination showed values from 6.92 in the tortilla made with 100% corn flour, up to 7.39 in the combined treatment with corn flour and soybean meal in a 70-30% ratio, placing these foods around neutrality. As in the determination of humidity, in this parameter the statistical analysis did not show a significant difference in the treatments. Food products are considered basic when they have values greater than seven and acidic if their pH is less than seven (Casaubon-Garcín et al., 2018).

In a study carried out by Vázquez et al. (2011) found that freshly made tortillas have a basic pH (8.4 - 8.8) while packaged and stored tortillas have an acidic pH, between 5.3 and 5.8. The basic pH is related to the lime content (calcium hydroxide) used during the corn nixtamalization process. The proper use of lime in nixtamalization determines the desirable qualities of the traditional tortilla. The pH of the tortillas added with soybeans and oats in this study presented values close to those obtained in freshly made or fresh tortillas, being that, in Mexico, the highest consumption occurs in fresh tortillas.

In the same way, chemical analysis allows knowing the composition of food and grouping its components into categories of nutritional interest. Table 2 shows the concentration of the main components of the tortillas obtained in the five experimental treatments and the control. Regarding the ash content, in the treatment with corn and soybean (70-30) the highest ash content was found (2.94%) compared to the control made from 100% corn, where a concentration of 1.59% was obtained. In a study conducted by Cortés et al. (2016), compared corn tortillas added with oats and reported a decrease in ash concentration when increasing the oat flour content. Values from 2.0 % in 100 % corn tortillas were obtained, up to 1.7 with 40 % addition of oats.

In the fiber content, 100% corn flour presented the highest value of 1.94%, while the lowest value was obtained with the combination of 85% corn, 10% soybean and 5% oats, observing a inverse relationship to the addition of soybeans and oats. These results are mainly associated with the protein content of soybeans and oats (De Luna, 2017), which decreases the presence of dietary fiber. However, Cortes et al. (2016) found in tortillas added with oats the dietary fiber content increased with increasing oat content: from 1.6 in tortillas made with 100% corn to 1.9 with 40% added oats, probably associated with the composition of the oats used in the study.

On the other hand, the concentration of nitrogen-free extract showed a significant difference between the treatments, being the combination of corn flour with soybean (70-30%) where the lowest content was obtained, 25.56%. A food with a low content of nitrogen-free extract, is beneficial for certain sectors of the vulnerable population, such as diabetics and obese. However, in another sector of the population, such as young people between 14 and 18 years of age, their energy requirements are around 60% and it comes mainly from carbohydrates (Jiménez et al., 2015). For the young population, tortillas made with 100% corn flour will be the recommended option, presenting a concentration of 45.65% of nitrogen-free extract.

Another component was the determination of proteins, in Table 3 the concentration obtained in the treatments is shown, where it is observed that the protein content increased

T	Flours (%)			Ashes (%)	Fat (%)	Fiber (%)	ELN (%)
	Corn	Soy	Oatmeal				
T1	70	30	0	2.94 ±0.01a	1.3 ±0.07c	1.62 ±0.03c	25.56 ±1.78
T2	70	0	30	1.99 ±0.02e	1.4 ±0.03b	1.50 ±0.05d	40.70 ±2.38
T3	70	fifteen	fifteen	2.81 ±0.01b	1.5 ±0.09a	1.80 ±0.03b	34.75 ±1.68
T4	85	5	10	2.02 ±0.01d	1.4 ±0.02b	1.42 ±0.02e	40.89 ±2.21
T5	85	10	5	2.07 ±0.01c	1.5 ±0.02a	1.36 ±0.07f	35.50 ±1.82
Witness	100	0	0	1.59 ±0.02f	1.4 ±0.09b	1.94 ±0.08a	45.65 ±2.19

Different letters in each column indicate different means by Tukey's method (P<0.05).

Table 2. Proximal analyzes of multigrain tortillas based on corn, soybeans and oats.

T	Flours (%)			Protein (%)	Protein intake (%) in children, RDI 22g	Protein intake (%) in adults RDI 54g	Protein intake (%) in women, RDI 60 g	Protein intake (%) of lactating women IDR 63 g
	Corn	Soy	Oatmeal					
T1	70	30	0	21.43 ±0.54a	97.40	39.68	35.71	34.01
T2	70	0	30	10.41 ±0.28e	47.31	19.27	17.35	16.52
T3	70	15	15	19.78 ±0.32b	89.90	36.62	32.96	31.39
T4	85	5	10	12.34 ±0.48d	50.42	22.85	20.56	19.58
T5	85	10	5	19.68 ±0.52c	89.45	36.44	32.80	31.23
Witness	100	0	0	7.73 ±0.18f	35.09	14.31	12.88	12.26

Different letters in each column indicate different means by Tukey's method (P<0.05). RDI, recommended daily intake.

Table 3. Protein content in multigrain tortillas based on corn, soybeans, oats, and their protein intake

T	Flours (%)			AC (mg)	Fe (mg)	Zn (mg)
	Corn	Soy	Oatmeal			
T1	70	30	0	440 ± 8.01b	6.30 ± 0.78a	2.90 ± 0.11a
T2	70	0	30	420 ± 7.02c	3.00 ± 0.21f	2.45 ± 0.12d
T3	70	fifteen	fifteen	560 ± 9.02a	3.60 ± 0.38c	2.85 ± 0.18ab
T4	85	5	10	350 ± 7.02d	3.55 ± 0.59d	2.80 ± 0.22b
T5	85	10	5	440 ± 7.03b	3.30 ± 0.73e	2.80 ± 0.18ab
Witness	100	0	0	340 ± 5.03e	5.75 ± 0.78b	2.65 ± 0.09c

Different letters in each column indicate different means by Tukey's method (P<0.05).

Table 4. Mineral content in multigrain tortillas based on corn, soybeans and oats.

significantly (277%) when adding 30% of soybean meal to the flour. corn. This is due to the fact that soybeans contain between 38 and 40% protein per 100 g, dry basis (De Luna, 2017), making it a feasible alternative to improve the proximal composition of tortillas.

The importance of protein in human nutrition is associated with its ability to provide amino acids for the maintenance of body protein and its increase during growth. The limitation in the contribution of energy and protein to the diet leads to a delay in the growth of children and young people. On the other hand, in adults, the loss of body protein is associated with numerous pathological alterations and an increase in mortality (Martínez and Martínez, 2006). The protein content in the tortilla is of interest because it is a basic food in the diet of Mexicans. In a study conducted by González et al. (2016) determined the protein content in tortillas of 12 landrace maize accessions and the value was 9.3 % on average on a dry basis. While Rodiles-López et al. (2018) develop a functional tortilla with the addition of 2.5% avocado flour and 2.5 nopal flour and increase the protein content from 4.9 to 5.59%. So the search for theAdding protein sources to tortillas is a strategy used by some researchers in order to increase the nutritional value. In a study conducted byQuintero the al. (2014) characterized a toasted corn-based tortilla and Ulva clathrata algae (92:8) and obtained the following composition: humidity, 9.4 %; ashes, 2.6%; crude fiber, 3.4%; calcium, 1789.2 mg/kg; sodium, 206.5 mg/kg; potassium, 3271.8 mg/kg; total carotenoids, 7.4 µg/g in which the highest amount was lutein (85%). In addition, in the sensory evaluation, 87.5% of general acceptance was obtained. The same way,Cortes et al. (2016), made tortillas with corn flour and oats (10:90, 20:80, 30:70 and 40:60%) where the tortillas added with 40% oats presented high protein and fiber contents, but low acceptability; while those of 10 and 20 % presented better acceptability, flavor, texture and higher protein content, compared to those of 100 % corn flour.

In relation to the nutritional content, all the treatments exceed the control treatment, emphasizing that the treatments T_1, T_3 and T_5, with the consumption of 100 g, cover close to 100% of the protein intake needs for children from 1 to 10 years of age. In addition, the T_2 and T_4 treatments are a good option for the adult population since the protein contributions are high, ranging from 47.31% to 56.09%. The results obtained in tortillas added with protein sources such as soybeans and oats can contribute to improving the nutrition of the population with malnutrition problems. In addition, the protein intake in adults with an RDI of 54 g per day, all the treatments exceed the control treatment when consuming 328 g of tortilla per day, exceeding the protein needs which would significantly improve nutrition for each person, in addition these treatments are also low in fat and carbohydrates, so they can be consumed by diabetics.

Table 3 shows that, when eating 328 g of tortilla, the best protein intake is provided by T1 with 70.29 g of the daily protein requirements. On the other hand, the lowest contribution was provided by the control treatment (T0), with 25.35 g. Treatments T1, T3 and T5 exceed the protein needs for women 11-51 years of age; Without a doubt, these contributions would improve women's nutrition, without consuming a high amount of tortillas, which sometimes leads to the problem of obesity. The improvements in protein content are associated with the levels of added soybeans and oats.

According to the United Nations Children's Fund (UNICEF, 2019), in the world, one in three children under five years of age is stunted, overweight and, in some cases, a combination of two of these forms of malnutrition. In Latin

America and the Caribbean, the figure is one in five. In 2018, 149 million children under the age of five were stunted and nearly 50 million were wasted. In Latin America and the Caribbean, 4.8 million children under the age of five suffer from stunting and 0.7 million from wasting.

Mexico ranks 11th among Latin American countries with child malnutrition problems, with 7.5% followed by Peru with 7.1%, with the highest being Guatemala, Haiti, and Honduras, with 24.2, 17.3 and 16.6, respectively. On the other hand, the Latin American countries with the best levels of child nutrition are Chile and Cuba with 0.8 and 4.1, respectively (Martínez and Fernández, 2006). In Tabasco, Mexico, the weight/age indicator registered a 41% prevalence of malnutrition, considering it as mild (26.12%), moderate (12.62%) and severe (2.39%). On the other hand, the National Center for the Health of Children and Adolescents (CENSIA) indicates that the prevalence in Tabasco, combined of overweight and obesity, is 5.3% in children under 5 years of age, 26% in children of 5 to 12 years, from 23.3% in young people from 13 to 19 years old and 70% in adults older than 20 years (Tisié, 2008).

MINERAL CONTENT

Table 4 shows the results of the mineral content in tortillas added with soybeans and oats. Regarding the calcium content, significant differences were found between the treatments, being the best treatment T3 (70-15-15) with a content of 560 mg, followed by treatments T1 and T5 with 440 mg; the lowest was the control treatment made with 100 % corn, T0 with 340 mg of calcium. In relation to the contribution of calcium in children, the T3 treatment with 70% corn, 15% soybean and 15% oats provides 70% of the total calcium requirements, which would improve the nutritional needs of children. In addition,

in the calcium intake for men and women aged 11-51, all treatments exceed calcium needs. In pregnant women, with the exception of treatments T0 and T4 with 92.93% and 95. 66% respectively, all treatments exceed calcium needs. The consumption of 100 g of tortillas in children from 1 to 10 years old can provide 90% of the RDI for calcium, while for adults, 270 g of tortillas per day cover 100%. With this nutritional quality of the tortilla, the problems of obesity and malnutrition in Mexico can be faced (Herrera, 2002).

Calcium is the mineral with the highest concentration in the human organism, corresponding to around 2% of body weight. It has skeletal and regulatory functions. Bones are made up of a protein matrix that is mostly mineralized with calcium, which is why its sufficient intake in the diet is necessary. In some populations such as the Spanish, the intake of this mineral is low in a significant percentage of the population, especially in older adults, mainly in women. Various studies relate its deficient intake in the diet with diseases such as osteoporosis, cancer, cardiovascular diseases and obesity (Martínez, 2016). In the determination of iron, the results show that in the tortillas of treatment T_1 (70-30-00) it is the best treatment, since it contains 6.3 mg, and the one with the lowest concentration was the T_2 treatment with 3.0 mg. Iron is known to have important activities in many parts of the body, including immune function, cognitive development, temperature regulation, energy metabolism, and work performance (Fernández et al., 2007).

The functioning of the human body is linked to iron, since it is part of enzymes such as catalases, aconitases, ribonucleotide reductase, peroxidases and cytochromes, which carry out reactions essential for life. The nutritional interest in this mineral focuses on its importance for the synthesis of hemoglobin and oxygen transport. It has been

found to be essential for many biochemical processes, especially for the production of the heme group and the Fe/S centers present in a myriad of proteins and enzymes linked to vital processes (Forrellat, 2016).

The results found in the determination of zinc in the tortillas indicate that the treatments T_1 (70-30-00) and T4 (85-05-10) are the best, since it contains 29 mg. The treatment with the lowest concentration was T_2 with 23.5 mg. All treatments exceed zinc requirements in children and adults. Zinc is an essential mineral in human health since it is an important part for the proper functioning of more than 300 enzymes, which participate in important biochemical reactions in the human body. In addition, it produces a direct effect on growth, neurological development, behavior and the immune system. The diagnosis of zinc deficiency in individuals is not possible since there is not yet a sufficiently sensitive marker (López, et al., 2010).

CONCLUSIONS

The addition of protein sources such as soybeans and oats in concentrations between 5 and 30 % to corn tortillas improved the proximal composition of this highly consumed food in Mexico. It was possible to produce tortillas with a high nutritional content since the protein, Ca, Fe and Zn content was increased, which makes them suitable for producing and distributing it, through federal programs, such as school breakfasts, by covering the nutritional needs of the population. In the same way, a low carbohydrate tortilla has been obtained, which makes it potentially edible for people with overweight, obesity and diabetes.

THANKS

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