SUMMARY OF Ph.D. THESIS

The study of the quality parameters of the salty snack products obtained from mixtures of corn flour and legumes.

PhD student Giorgiana Ofelia Buzgău

Scientific coordinator **Prof.univ. dr. Mircea Valentin Muntean**

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INTRODUCTION

The consumption of salty snacks varies in Europe, but the average per capita is about 3.6 kg per year according to the CBI.eu website.

Thus, special attention is paid to the development of healthy, ready-to-eat snacks. Conventional foods are made from traditional grains to meet daily nutrient requirements. The unmet need is to improve people's health. In addition, mixing grains with plant proteins such as vegetables can improve the nutritional profile of the product (NISHA C., *et al*, 2017).

Increased consumption of healthy foods is needed to reduce the risk of chronic diseases. We have developed and evaluated a nutritious alternative to the highly consumed corn tortilla chips by adding vegetable flours. Vegetables, such as, chickpeas and lentils, are considered staple foods, are nutritious and improve health.

Due to advanced production technology and consumer trends that are constantly increasing, we considered it topical to develop, design, implement and produce salty snack products.

For the present PhD thesis the use of lentil and chickpea flour in a mixture with corn flour was studied, lentil and chickpea flour was used due to its high protein content (17-38%).

Lentil flour contributes vitamins, minerals, fiber and complex carbohydrates, however, lentil flour is a common ingredient with potential in the development of a new generation of healthy food products (MAN S., PĂUCEAN A., 2013).

Chickpea flour contributes protein intake (20-25%), fat (4-6%), non-nitrogen extractives (53-63%) (MUSTE, 2014).

Research was monitored throughout the PhD period to study product stability throughout the production and storage of tortilla chip products and the development of new recipes obtained by mixtures of corn, chickpea and lentil flours.

The products were produced on an industrial production line, the machinery and technological processes being common industry of obtaining tortilla chips type products.

AIM AND OBJECTIVES OF THE THESIS

The products studied, salty tortilla chip snacks, were developed, designed and produced industrially. This range of products is on an upward trend and the aim is to develop products with chickpea and lentil flour blends for diversity, nutrient intake, sensory impact and gluten free products.

Consumer acceptance of snack foods is mainly due to the convenience, value, attractiveness and texture that have proven to be specific to these foods, especially when it comes to snack products. (ANTON A.A., LUCIANO F.B., 2007).

The flour mixtures used to make new tortilla products will also change the colour of the products so they will be perceived differently. The addition of lentil and chickpea flour to the colour will positively influence the final appearance of the product, resulting in orange and yellow-brown products.

State-of-the-art manufacturing technology offers complexity and opportunity to obtain improved products by using different types of pulse flours

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AIM OF THE THESIS

The aim of this PhD thesis is to study the stability of the products throughout the production and storage process of tortilla chips and the development of the new recipe, obtained by optimal mixtures of corn, chickpea and lentil flours.

OBJECTIVES

1. Optimization of flour blends from gluten-free raw materials used to make tortilla chips
2. Sensory, physico-chemical and microbiological characterization of the product obtained.
3. Developing a new product with protein intake and gluten-free products.

STRUCTURE OF THE THESIS

The PhD thesis entitled "Study of the quality parameters of salty snack products made from mixtures of corn flour and legumes" is structured in two main parts, the first part "Current state of knowledge in the field of salty snack products made from mixtures of corn flour and legumes" including the literature study, and the second part "Original contributions to the development of knowledge in the field of savoury snack products made

from mixtures of corn flour and legumes" including personal contributions, results, conclusions and research perspectives.

The first part "The current state of knowledge in the field of salty snack products obtained from mixtures of corn flour and legumes" contains 5 subchapters in which results and discussions obtained after an extensive bibliographic study are presented. Aspects about the general technology of obtaining tortilla chip products, the functional properties of vegetable flours for the development of tortilla chip products, the role of chickpea and lentil flours in the manufacture of tortilla chip products, the use of high oleic sunflower oil in the salty snack industry.

The second part "Original contributions to the development of knowledge in the field of salty snack products obtained from mixtures of corn flour and legumes", is structured in four chapters.

Chapter II. The aim, objectives and experimental design, includes the specific aim and objectives of the thesis.

Chapter III. Materials and methods, presents the work methods and experimental samples discussed.

Chapter IV. Results and discussions obtained during five sub-chapters, the results obtained regarding the analysis of the obtained tortilla chips samples as well as their statistical interpretation.

Chapter V. Conclusions and recommendations presents the conclusions resulting from the studies carried out in the framework of the PhD thesis entitled "Study of the quality parameters of salted snack products made from mixtures of corn flour and legumes" and the fulfilment of the three objectives of the thesis, followed by the related recommendations.

THE PERSONAL CONTRIBUTION
CHAPTER III. MATERIAL AND METHODS

3.1 Raw materials used for research

The following types of flour were used to make the torilla chips samples:

- masa corn flour;
- chickpea flour;
- red lentil flour;
- high oleic sunflower oil for frying;
- recrystallized iodized salt for seasoning.

Fig. 1 Tipuri de făina utilizate/ Types of flour used.

Făină de porumb/Corn flour Făină de năut/ Chickpea flour Făină de linte/ Lentil flour

The flour mix variants studied are the following, according to table 1:

Tabelul/Table 1 Procentul de substituție a făinurilor și codificarea acestora/ The percentage of substitution of flours and samples enconding.

Probe luate în studiu/ Samples	Cod probe / Samples code	Concentrația procentuală de făina/ Percentage concentration of flour		
		Făină de porumb / Corn flour	Făina de năut/ Chickpeas flour	Făina de linte roșie/ Red lentil flour
Tortilla Chips din făină de porumb 100% - probă de referință Tortilla Chips corn flour (100%) - reference sample	TCP	100%	-	-
Tortilla Chips din făină de porumb + făină de năut (50%+50%) Tortilla Chips corn flour+ chickpeas flour (50%+50%)	TCN1	50%	50%	-
Tortilla Chips din făină de porumb + făină de năut (80 %+ 20%) Tortilla Chips corn flour+ chickpeas flour (20 %+ 80%)	TCN2	20%	80%	-
Tortilla Chips din făină de năut (100%) Tortilla Chips chickpeas flour (100%)	TCN3	-	100%	-
Tortilla Chips din făină de porumb + făină de linte roșie (50%+50%) Tortilla Chips corn flour+ red lentil flour (50%+50%)	TCL1	50%	-	50%
Tortilla Chips din făina de porumb + făină de linte roșie (20%+80%) Tortilla Chips corn flour+ red lentil flour (20%+80%)	TCL2	20%	-	80%
Tortilla Chips făină de linte roșie (100%) Tortilla Chips red lentil flour (100%)	TCL3	-	-	100%

3.2 Methods

The studied samples were processed and analyzed during the research period according to the experimental design presented below:

Tabelul / Table 2 Protocol experimental al cercetărilor privind caracterizarea produselor de tip tortilla chips/ Experimental design of the research regarding the characterization of tortilla chips products

Analize fizico chimice/ Physical and chemical determinations	Analize cromatografice/ Chromatographic determinations GC-MS / ITEX; GC-MS / HPLC/	Analiza ELISA/ ELISA analysis se bazează pe reacţia antigen - anticorp. / ELISA determinations	Analize microbiologice / Microbiological determinations
Umiditate /Moisture Grăsimi / Fat content Proteină/ Protein Determinarea Clorurii de sodiu/ Determination of sodium chloride Aciditate liberă/ Acidity Indice de peroxid/ Peroxid valeu	Acizii graşi/Fatty acids Compuşii de aroma/ Volatile profil	Gluten/ Determination of Gluten Aflatoxina B1/ Determination of Aflatoxin Deoxinivalenol (DON)/ Determination of DON Ochratoxina A/ Determination of Aflatoxin Fumonisinului/ Fumonisin determination Zearalenonei/ Determination of Zearalenone	Determinarea numărului de drojdii şi mecegaiurilor / Determining the number of yeasts and molds Enumerarea Enterobacteriaceelor/ Determination of Enterobacteriaceae

CHAPTER IV. RESULTS AND DISCUSSION

In this chapter the results are presented on the 7 tortilla chips prototypes obtained from mixing corn flour with chickpea flour and red lentil flour in proportions of 20%, 50%, 80%, 100%. In order to highlight the advantages and/or disadvantages of the flour blends. The reference sample being tortilla chips made from 100% corn flour.

Moisture content decreases over the one-year period, the reference period for the study. The amount of water added (48l) to make the is lower for the chickpea chickpea variants this is also reflected in the results obtained. Tortilla chips with red lentil flour have a significant amount of high-quality protein, increasing from 4.25% compared to the control sample

to 22.32% and 22.79% for the corn flour blend samples with 80% addition of red lentil flour and 100% red lentil flour respectively.

The differences reported between the study presented in this thesis and previous studies may be due to the different variety of corn used in tortilla chips.

Slightly higher protein contents for tortilla with 50% addition of chickpeas flour (TCN1) and 100% lentil flour (TCL3) were observed, i.e. 13. 97% and 22.79% as compared to previously reported of 13.38%. However, control sample in previous study had 4.25% protein content, with an increase of 9.36% by addition of chickpea flour, while in current study the increase of protein with 50% addition of chickpea (TCN1) is 13.79%. Decreased lipid contents from control sample (17. 6%) to the tortilla chips having 50% chickpea flour (15.85%) were observed. Same trend was reported by Morten et al. (2007). Increase of up to 2.11% and 1.02% with addition of chickpea flour and red lentil to the corn flour was observed.

The salt contents showed small, statistically nonsignificant differences. The salt content in tortilla with chickpea and red lentil flour mixture showed a slight increase of 1.35% (TCN1) and 1.17% (TCL1), respectively as compared to control (1.12%).

The acidity increased from 0.25% for 50% chickpea flour (TCN1) to 0.39% for 100% lentil flour (TCL3). The chickpea addition to corn flour, leads to an increase of 0.2 compared to control samples. These results are less than previously reported whereby an increase of 0.37% was observed by addition of the same percentage.

The results regarding on Pearson correlations show a positive significance for reference sample (TCP) with humidity. In the case of raw proteins, a positive correlation was identified with increased corn flour, regardless of variety. The same positive correlation was observed in the case of lipids, protein, fiber, acidity, NaCl, and energy value, for the samples with 50% addition of chickpea flour (TCN1).

The saturated fatty acids (SFA) were palmitic acid, stearic acid, myristic acid, margaric acid, and arachidic acid while linoleic acid, oleic acid, gamma-linolenic acid, and palmitoleic acid were major unsaturated fatty acids (UFA).

The highest values were shown by oleic acid. A decrease was observed with the addition of red lentil flour. There was a very significant positive correlation between the control sample and myristic, palmitic, oleic, arachidic, and palmitoleic acid, but a significantly negative correlation with the other three fatty acids. Addition of chickpea flour to the sample positively

influenced (5% significant) the linoleic acid, and negatively for five other fatty acids. Similarly, 20% positive influences are found for oleic and gamma-linolenic acids. Significant positive correlations were observed in the case of samples with 20% addition for stearic, gamma-linoleic, and palmitoleic acid (SCHLEGEL K., *et al*, 2020; WANG HW., *et al*, 2001).

The total quantity of UFAs in the tortilla chips with chickpea was 17.8 g. Linoleic acid (18:2, n-6) and gamma-linoleic acid (18:3, n-6), the main PUFAs, are essential fatty acids (EFAs) as they cannot be synthesized by the human body and must be assimilated from the diet. Tortilla chips having chickpea flour are an adequate source of EFAs. Saturated FAs contents in tortilla chips are less than 30% of all FAs and their quantity decreased with the addition of red lentil flour.

Tortilla chips with chickpea showed maximum volatile contents. The advantages of HS-ITEX/GC-MS for the analysis of volatile compounds in corn flour are well-known; however, it may be challenging to optimize the method when numerous factors are involved. Hence, multivariate optimization techniques may be required to lessen the intricacy of method optimization.

Five types of tortilla chips with various combinations of corn flour, chickpea flour and lentil flour did not show any quantifiable quantity of aflatoxins.

Remaining mycotoxins do cross-react. Some mycotoxins have high cross-reaction rate with their metabolites. Although antibodies can specifically recognize and bind to antigens, however, antibodies face recognition problems for compounds with similar chemical structure. The cross-reactivity assay indicates the low cross-reaction rate of antibodies revealing desirable specificity of the detection method (STEEL CJ., *et al,* 2012). Some commercial test kits also demonstrate high cross.

The number of yeasts and molds, as well as Enterobacteriaceae, was measured during the entire shelf life of the products. The yeasts and molds in the tortilla samples showed a decreasing tendency with the addition of chickpea flour (PICO, 2015). They had the same path, in some cases statistically insignificant, with the short-term storage. This decrease during storage was due to the low moisture content of the tortilla samples. This conclusion was also supported by Pearson's correlation between humidity and microbiological content, as all correlations are positive.

The snacks obtained and developed are gluten-free products, according to the determined analyses, the amount of gluten is <20 mg/kg. These products are also intended for people with gluten intolerance.

From a sensory point of view, all samples were rated positively (scored on the positive steps). The preferred samples are TCN1 and TCL1, samples that have a 50% corn flour - 50% chickpea flour mix and 50% corn flour - 50% lentil flour mix.

CHAPTER V. CONCLUSIONS AND RECOMMENDATIONS

Studies on the 7 prototypes of tortilla chips obtained from mixing corn flour with chickpea flour and red lentil flour in proportions of 20%, 50%, 80%, 100% were carried out in order to highlight the advantages and/or disadvantages of the flour mixtures. The reference sample being tortilla chips made from 100% corn flour. The differences reported between the current study and previous studies may be due to the different variety of corn used in tortilla chips.

The use of chickpeas in salty snacks has shown promising results in terms of starch and dietary fibre content. Another reason for the increasing use of chickpea flour is its nutritional value and lack of gluten, making it a handy alternative for gluten-free products.

Slightly higher protein contents were observed for tortillas with added 50% chickpea flour (TCN1) and 100% lentil flour (TCL3) i.e. 13.97% and 22.79%. Red lentil flour tortilla chips have a significant amount of high quality protein, increasing from 4.25% over the control sample, to 22.32% and 22.79% for the cornmeal sample with 80% added red lentil flour and 100% red lentil flour respectively. The flour mixtures used behaved differently in the manufacturing technology requiring changes in technological parameters. The amount of water added and the time of the mixing process were correlated according to the texture of the dough and the way of cutting the triangular shape by the knife die used to cut the triangular shape.

ORIGINALITY AND INNOVATIVE CONTRIBUTIONS OF THE THESIS

The elements of originality of the present PhD thesis are:

- ✓ Direct correlation between quality parameters and technological processes of corn, chickpea and lentil flours, organoleptic and sensory characteristics of the final products obtained.
- ✓ The manufacturing technology used differs from the standard totilla chips technology, using a non-heat treated corn flour in the study.
- ✓ Corn, chickpea and lentil flours were obtained by blending different grain sizes following grinding processes. In the classical technology for obtaining tortilla chips, heat-treated corn flour is used through the nixtamalization process.

- ✓ Possibility of manufacturing on industrial production line with optimization of process parameters so that designed and developed products can be produced at industrial level.
- ✓ Optimizing blends of cornmeal, chickpea and lentil flour to produce salty tortilla chip snacks that are popular and accepted by consumers.

Identification of bioactive components with a functional role in the mixtures obtained and monitoring their efficacy in the finished product by quantifying and optimizing them.