Evaluation of production and gamma radiation effects in pasta enriched with brown flaxseed bagasse (*Linumusitatissimum* L.)

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ABSTRACT

Brazil is the third largest producer of pasta, with an annual turnover of more than one million tons. Pasta is a power source, low cost, convenient to make, can be eaten in all seasons, appeals to everyone, presents variations of shape and color which makes this product so popular. The aim of the study was to evaluate the feasibility of producing an enriched pasta using bagasse obtained from flaxseed oil extraction and study the effects of gamma radiation on the same. Seven preparations of noodles were produced, two of which were irradiated with 20kGy (20 and 40% of crushed flaxseed meal), two were produced with flour from crushed flaxseed irradiated to 10 kGy at the proportions of 20 and 40%, two did not receive a dose (proportions of 20 and 40%) and a control formulation. The irradiations were performed in the multipurpose irradiator of the Institute of Energy and Nuclear Research – IPEN. The following analyzes were performed: determination of moisture, acidity, pH, ether extract, ash, protein, fiber, texture and cooking test, at the Laboratory of Radiobiology and Environmental Center for Nuclear Energy in Agriculture - CENA / USP. The values of moisture and acidity obtained for the different types of noodles showed high efficiency in drying and high quality in the formulations. The formulations P80:20, P80:20FT e P60:40 also showed high quality in relation to the increase in the amount of mass and loss of soluble solids. There was also an increase in the amount of fibers, reducing the caloric value.

Key words: flaxseed, chemical composition, wheat flour, food quality, radiation, pasta.

1. INTRODUCTION

Flaxseed is an oilseed with more than 200 known species, with its grain color varying from light yellow to brown. Its botanical name *Linumusitatissimum* L., means "most usable". There are reports of flaxseed consumption in Europe and Asia since 5000 to 8000 a.C. [1]. The consumption decreased with time but in the last years the flaxseed has become popular due to its functional role to good health, which has stimulated the national production of this raw material worldwide, as a whole grain, ground or in the form of oil. Regarding the nutrient composition, flaxseed presents 28% of dietary fiber, 41% of lipids and 21% of protein, 3% ash, and the oil contains vitamins A, B, D and E, minerals and amino acids. Flaxseed has shelf life of over 12 months being with 9 to 10% of water[2]. Its lipid composition has a low concentration of saturated fatty acids (9%), moderate amounts of monounsaturated (18%) and high content of polyunsaturated fatty acids (73%), especially the alpha linoleic acid; this makes flaxseed the main source of this fatty acid, five times more abundant in walnuts and canola oil. The amino acid profile of a protein fraction resembles soy[3]. According to Cunnane[4], the heating of flaxseed for cooking does not affect the bioavailability of fatty acids.

Pasta is considered an energy source, in other words, much of its nutritional value is derived from carbohydrates. The carbohydrate from the pasta is called complex, however due to being made with refined flour causes it to be a source of readily available energy. The more brown flour is aggregated to the pasta, larger will be the size of the molecule therefore slower will be the digestion process, resulting prolonged repletion. The fibers also function in the gastrointestinal tract; since they serve as substrates for the micro flora naturally present in the large intestine; moreover the fibers regulate the speed of digestion and absorption of nutrients. It was proven that spaghetti fortified with flaxseed remains with their levels of lipids and conjugated dienes stable even after cooked and stored [5]. There were no changes in fatty acid or peroxide values in whole and ground flaxseed when heated for 60 minutes at 100° to 350°C[6].

Food irradiation is a physical technique of preservation and aims to eliminate the infestation by insects, fungi and microbial contamination. At low doses (0.2 - 1kGy) is effective in controlling insects and in doses around 5kGy eliminates spores and fungi. The effect of radiation on the quality of pasta needs to be investigated at doses above 10 kGy.

The target of this study was to evaluate the production and the effects of gamma radiation on pasta enriched with bagasse of brown flaxseed (*Linumusitatissimum*L.).

2. MATERIALS AND METHODS

Production of flour from bagasse of flaxseed

The brown flaxseed was acquired at the cereal market in São Paulo, stored in dark plastic boxes at a temperature of approximately 28 ° C in the Laboratory of Radiobiology and Environmental Center for Nuclear Energy in Agriculture in the city of Piracicaba, was mechanically pressed at the Faculty of Technology of the State of São Paulo in Piracicaba. After oil extraction, the remaining residue was dried on paper towel and crushed in a grinder of grains 'Hamilton Bleach'. The resulting flour from this process was stored in aluminized plastic bags without restriction as the temperature and the samples were irradiated with 20 kGy at the Institute for Nuclear and Energy Research at the University of São Paulo under a dose rate of 4.16 kGy / h.

Pasta Development

The raw materials used were eggs, special wheat flour and flaxseed bagasse flour. The steps taken to produce the pasta were: mixing of the ingredients; homogenization, kneading, rolling, sectioning, drying and packaging.

Seven experimental formulations were tested, being one of pure wheat and six mixes the flour with FBF (flaxseed bagasse flour) as shown in Table 1.

Table 1. Formulations used for preparing the pasta "talharim" type with different mixtures of wheat flour and flour from flaxseed bagasse.

Ingredients (proportion)				
Formula	Wheat Flour	Flaxseed F.B.	Treated F.B.L	Eggs
P 100	100	0	0	60
P 80:20	80	20	0	60
P 80:20T	80	0	20	60
P 80:20Irr	80	20	0	60
P 60:40	60	40	0	60
P 60:40T	60	0	40	60
P 60:40Irr	60	40	0	60

Flaxseed.F.B. – Flaxseed Bagasse Flour
Treated F.B.F. – Treated Flaxseed Bagasse Flour (10kGy)
P100 – Pasta with100% of Wheat Flour
P80:20- Pasta with 80% of Wheat Flour and 20% of Flaxseed Bagasse Flour
P80:20T – Pasta with 80% of Wheat Flour and 20% Treated Flaxseed Bagasse Flour
P80:20Irr – Irradiated Pasta (20KGy) with 80% of QWheat Flour and 20% of Flaxseed Bagasse Flour
P60:40 – Pasta with 60% of Wheat Flour and 40% of Flaxseed Bagasse Flour
P60:40T- Pasta with 60% of Wheat Flour and 40% of Treated Flaxseed Bagasse Flour
P60:40Irr – Irradiated Pasta (20KGy) with 60% of Wheat Flour and 40% of Flaxseed

Bagasse Flour

The drying process of the pasta was done at a temperature of approximately 28 ° C in cardboard utensil for 24 hours and allotments of pasta were packed in styrofoam trays inside plastic bags and kept in the Laboratory of Radiobiology and Environmental Center for Nuclear Energy in Agriculture in Piracicaba. The two formulations of pasta P 80:20Irr and P 60:40Irr were irradiated at the Institute for Nuclear and Energy Research at the University of São Paulo under a dose rate of 4.16 kGy / h.

The pH, acidity and chemical composition analysis were performed 24 hours after packing the pasta in the Laboratory of Radiobiology and Environment of CENA. The analysis of texture, viscosity and cooking time were carried out at the Laboratory of Food Science in the College of Agriculture Luiz de Queiroz, University of Sao Paulo in Piracicaba.

Physicochemical Reviews

The technological characteristics of the pasta were determined through assessments of chemical composition and baking tests. All procedures were performed in triplicate by AOAC, 1995.

The texture of the pasta was evaluated using the Texturometer T.A.TX plus from Stable Micro Systems. The pasta was cooked in the optimum cooking time (11 minutes) passed by washing with 50 mL of water and placed in 50ml of distilled water for 1 minute, drained and cut with 2 cm in length. Compression was used with 75% penetration rate of 2 mm/s. For adhesion, it was used the same samples from the texture tests.

The cooking test was performed according to the AACC method 16-50 and the parameters evaluated were: cooking time, loss of soluble solids, increased volume and mass.

3. RESULTS AND DISCUSSION

Analysis of pasta obtained

By utilizing brown flaxseed, the color of the pasta on three proportions of P60:40 were very dark however, on P80:20 proportions the color was agreeable.

The determination of the moisture content in pasta was made with the purpose of controlling the efficiency of the drying process, when this level is below 13% the product is negligible of microbiological problems. Pasta showed moisture content between 7.3 and 8.8%; theoretically, on this range the pasta is free of microbiological problems. To complement the humidity test, the acidity test of products was performed, since there was the possibility of residual moisture inside, even if the average humidity is within normal parameters. Then, to assess the efficiency of drying the resulting quality of the pasta both tests conducted and the results are in Table 2.

Table 2. Indexes of acidity, pH and moisture of pasta (talharim type) with different mixtures of wheat flour and flaxseed bagasse flour.

Formula	Acidity (gAA/kg)	pH	Moisture %
P 100	$3,8^{A}$	$6,4^{D}$	$8,2^{F}$
P 80:20	$4,1^{B}$	$6,7^{D}$	$8,8^{F}$
P 80:20T	$4,4^{B}$	$6,7^{D}$	$7,6^{E}$
P 80:20Irr	$3,1^{A}$	$6,4^{D}$	$8,4^{F}$
P 60:40	$6,6^{C}$	$6,6^{D}$	$7,3^{E}$
P 60:40T	$6,6^{C}$	$6,6^{D}$	$7,5^{E}$
P 60:40Irr	$3,5^{A}$	$6,3^{D}$	$7,4^{E}$

Different capital letters in the same column means significant difference.($p<0,01$). SAS/Tukey.

The amount of alcohol acidity should not be over 5%, but it was found that as the wheat flour was substituted to flaxseed bagasse flour in proportions of P 60-40, there is the propensity of increase in acidity. Even so, the values found were within the acceptable range. The acidity of irradiated pastas are smaller than all others. The baking tests provide information about how the product is presented during cooking, its texture and adhesiveness. The results of the baking tests are shown in Table 3.

Table 3. Pasta cooking tests ('talharim' type) with different mixtures of wheat flour and flaxseed bagasse flour.

Formula	Mass Increase %	Volume increase %	Soluble Solids %	Cooking Time *(min)
P 100	216^{A}	263^{D}	$4,3^{G}$	11
P 80:20	230^{A}	275^{D}	$3,1^{G}$	11
P 80:20T	195^{B}	225^{E}	$3,8^{G}$	11
P 80:20Irr	136^{C}	175^{F}	$19,8^{H}$	11
P 60:40	217^{A}	275^{D}	$4,3^{G}$	11
P 60:40T	201^{A}	275^{D}	$10,9^{I}$	11
P 60:40Irr	124^{C}	150^{F}	$18,8^{H}$	11

* "al dente" pasta cooking point.

Different capital letters in the same column means significant difference.($p<0,01$). SAS/Tukey.

Each shape and thickness of pasta has a cooking time. Eleven minutes was the perfect time to let the pasta "al dente" and for that kind of pasta is considered normal. According to the literature, it is expected that the values for mass increase be around 200%, then in accordance with the data in Table 3, only the irradiated pasta has a smaller factor than mentioned, directly affecting the quality of the final product. The same was observed on volume increase, which is expected between 250 and 300%. For soluble solids the values were below 10% for all types of pasta, except irradiated. Values for soluble solids above 10% indicate that the pasta is low quality and the lower the loss of soluble solids, the better the quality of pasta [7]. According to Table 3 and the Hummel patterns, irradiated pasta showed poor quality but the remainder proves to be of high quality.

The high loss of soluble solids, low increases of mass and volume in irradiated foods [8] can be seen in Table 3, which prevents its production, and have submitted an unwanted aroma. The values of Table 3 shows that P 80:20 and P60:40T have less mass and volume increase and a greater quantity of soluble solids which leads the interpretation that the irradiation of flaxseed flour is responsible for poor quality of the final product.

Texture and Adhesiveness

The values of texture and adhesiveness are shown in Table 4 and by the results; it is possible to observe that the addition of flaxseed bagasse flour leaves the pasta more brittle, regardless of the proportion placed and the treatment of the flour. By the results of adhesiveness it is observed that the two types of irradiated pasta, P60:40Irr and P80:20Irr, have higher values of adhesion, indicating a probable breakdown of starch by radiation. It is also observed that the higher the addition of flaxseed, the greater the adhesiveness.

Table 4 - Texture and Adhesiveness of pasta ('talharim' type) with different mixtures of wheat flour and flaxseed bagasse flour.

Formula	Texture (g/mm)	Adhesiveness(g/s)
P 100	8601^{A}	$-16,6^{E}$
P 80:20	5392^{C}	$-22,9^{E,F}$
P 80:20T	6581^{B}	$-19,1^{E}$
P 80:20Irr	5384^{C}	$-34,6^{F}$
P 60:40	6262^{B}	$-26,5^{F}$
P 60:40T	4841^{D}	$-29,1^{G}$
P 60:40Irr	6768^{B}	$-61,8^{H}$

Different capital letters in the same column means significant difference.($p<0,01$). SAS/Tukey.

Chemical Composition

ANVISA, the National Agency for Sanitary Surveillance of Brazil[9]states that fresh pasta moisture should not exceed 35% and dry matter should not exceed 13%. This characterizes that all types of 'talharim' pasta produced are pasta with levels of moisture of dry matter. The lower the moisture lesser the growth of bacteria. Table 5 shows the chemical composition of the pasta in the analysis.

Table 5. Chemical Composition of the pasta ('talharim' type) with different mixtures of wheat flour and flaxseed bagasse flour

Formula	Fib. %	Prot. %	Lipids%	Moist%	Ashes%	Available Carbohydrates%	Energy(kcal)
P 100	5,99	11,64	3,65	8,24	0,68	69,8	334,65
P 80:20	13,39	11,81	7,89	7,19	1,06	58,66	299,32
P 80:20T	11,59	11,85	7,08	7,62	1,12	60,74	307,71
P 80:20Irr	12,92	12,45	5,45	8,42	1,22	59,54	285,34
P 60:40	20,81	13,09	9,34	7,31	1,4	48,05	245,39
P 60:40T	22,13	13,44	8,2	7,46	1,6	47,17	227,74
P 60:40Irr	22,18	12,43	8,46	7,41	1,49	48,03	229,26
PUSDA	3,20	13,04	1,51	9,90	0,9	74,67	371,00

From the results obtained, the ash content will be greater, the larger the addition of flaxseed bagasse flour.

Because it is pasta with eggs it is important to consider that all kinds of pasta will contain the portion of proteins found on the eggs and in the pasta with the addition of bagasse it will also be found the portion of proteins on the flaxseed. However, values for the respective protein formulations should be in the range between 11 and 12.1%.

It is called Total Fibers, the sum of Soluble and Insoluble Fibers. The average values of Total Fibers are given in Table 5. Based on these results it is observed that the fibers increase was proportional to the percentage of flaxseed bagasse flour used and the fibers found in the proportions of 20 and 40% remained at the same level, regardless of the treatment received. The relevance of fiber increase is in the addition of flaxseed and not in the given treatment.

The average values of Lipids on Table 5 show that the amount of fatty acid was proportional to the amount of flaxseed bagasse flour. The decrease of lipids in the formulations that were irradiated may indicate a breakdown of fatty acids by radiation.

Available Carbohydrates are calculated by the sum of the fiber, protein, lipid, ash and moisture, subtracting the result from 100%. Shown in Table 5 are the values of available carbohydrates calculated as mentioned.

The last line of Table 5 presents the calculations of P USDA (United States Department of Agriculture - Table of Food Composition[10]) for pasta without eggs. We note that the results in USDA Table are very close to the P100 (pasta with only wheat flour).

The last column of Table 5 presents the values of Energy in kcal/100g. The plots included in the calculation of energy are: protein (P), carbohydrate (C), lipids (L) and fibers (F) according to the equation: Energy (kcal/100g) = 4.P + 4.(C) + 9.L .

The Energy values in kcal for a 100g portion are in the last column of Table 5. Based on the results of Table 5 it is showed that the kinds of pasta with the addition of flaxseed bagasse have fewer calories than pasta with wheat flour. The further addition of flaxseed, fewer calories are found in the pasta i.e. the higher the proportion of fibers in the pasta, fewer calories.

Greater the addition of flaxseed bagasse flour, lower the amount of carbohydrates. It may also be noted that the higher content of protein, ash, and lipids was presented by the addition of 40% flaxseed bagasse flour.

From the nutritional point of view, Table 5 indicates that the pasta with the addition of brown flaxseed bagasse flour have less carbs, more fiber and fewer calories than the pasta with wheat flour; which makes them viable for production.

4. CONCLUSION

O use of flaxseed bagasse brought great benefit for the pasta, proving its viability for commercial production. However, irradiation of pasta did not granted any additional advantage.

All formulations produced showed humidity below 7% and are within the standards of quality of dried pasta; which is essential for the no microbiological proliferation. The addition of crushed flaxseed altered fiber, ash, available carbohydrates and lipids.

The physicochemical quality of the pasta on both concentrations irradiated (P80:20Irr and P60:40Irr), were low and in the proportion P60:40T was average. The P80:20T, P80:20 and P60:40 are of high quality and good for production.

The chemical composition of the control formulation P100 was similar to the values presented by USDA Table.

The dose of 20 kGy caused no significant changes except the cooking tests and acidity.

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