African Journal of Biotechnology Vol. 10(73), pp. 16589-16593, 21 November, 2011
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB11.1582
ISSN 1684–5315

Full Length Research Paper

Effect of extrusion parameters on some properties of dietary fiber from lemon (*Citrus aurantifolia* Swingle) residues

Méndez-García, S.[1], Martínez-Flores, H.E.[2]* and Morales-Sánchez, E.[3]

[1]Student of Doctorado en Tecnología Avanzada. Centro de Investigación en Ciencia Aplicada y Tecnología Avanzada del IPN. Unidad Querétaro. Calle Cerro Blanco No. 141, Col. Colinas del Cimatario, C.P. 76090. Querétaro, Qro., México.
[2]Facultad de Quimicofarmacobiología. Universidad Michoacana de San Nicolás de Hidalgo. Morelia, Mich., México.
[3]Centro de Investigación en Ciencia Aplicada y Tecnología Avanzada del IPN. Unidad Querétaro. Calle Cerro Blanco No. 141, Col. Colinas del Cimatario, C.P. 76090. Querétaro, Qro., México.

Accepted 7 October, 2011

Approximately 50% of the original whole fruit mass, after citrus processing for juice, consist of the peel, membranes and seeds. Citrus residues consist mainly of insoluble fiber (celluloses) and a small proportion of soluble fiber (hemicelluloses and pectin). For this reason, citrus residues could be considered as a potential high fiber ingredient that is used for food industry. In this study, lemon residues were extruded to modify and increase their soluble fiber fraction. Surface response methodology with six central points and six axial points was used to evaluate the changes in dietary fiber fractions in lemon residues. The independent variables studied were extrusion temperature (from 59.77 to 110.63°C), moisture content of the sample (from 33.18 to 66.82%) and screw speed (from 3.18 to 36.82). The extrusion process increased the soluble fiber from 38.60% in unprocessed lemon residues to 40.00 to 50.01% in extruded samples. The highest content of soluble fiber was 50.00% when operating conditions were high in temperature (100°C), low in moisture content (40%) and low in screw speed (10 rpm). The results of this study indicate that extrusion is a process that has the capability to transform insoluble fiber to soluble fiber in lemon residues.

Key words: Lemon residues, extrusion, dietary fiber.

INTRODUCTION

Fruits and vegetables are good sources of vitamins, minerals, phytochemical compounds and fiber (Palafox-Carlos et al., 2011; Viuda-Martos et al., 2010). The Codex Alimentarius (ALINORM 09/32/26 2009) defines dietary fiber (DF) as carbohydrate polymers with 10 or more monomeric units, which are not hydrolyzed by the endogenous enzymes in the small intestine of humans. DFs decrease intestinal transit time, increase stool bulk, reduce total and low-density lipoprotein (LDL) cholesterol level in blood, decrease postprandial blood glucose and insulin level, and buffer excessive acid in the stomach. Also, DF consumption prevents some health problems such as diverticular disease, cardiovascular disease and colorectal cancer (Martinez-Flores et al., 2008). For this reason, DF becomes the 3rd most sought-after health information in supermarkets in countries like India, Australia, Western Europe and North America (Mehta, 2005). The importance of food fibers has led to the development of a large and potential market for fibre-rich products and ingredients, and nowadays there is a trend to find new sources of DF, such as agronomic by-products that have traditionally been undervalued (Rodriguez et al., 2006). Some sources of fibre have been studied like *Lentinus edodes*, mushroom known

*Corresponding author. E-mail: hedu65@hotmail.com. Tel/Fax: 4433142809, ext. 206.

Abbreviations: DF, Dietary fiber; **LDL,** low-density lipoprotein; **TDF,** total dietary fiber; **IDF,** insoluble dietary fiber; **SDF,** soluble dietary fiber; **CCD,** central composite design.

Table 1. Coded levels for independent variables.

Variable	- α = (-1.682)	-1	0	+	+ α = (+1.682)
X_1	59.77	70	85	100	110.63
X_2	33.18	40	50	60	66.82
X_3	3.18	10	20	30	36.82

X_1 = Temperature (°C); X_2 = Moisture (%); X_3 = Screw speed (rpm).

commercially as Shiitake (Martinez-Flores et al., 2009), apple peel (Henríquez et al., 2010), white-grape by-product (Sánchez-Alonso et al., 2007), coconut fiber (Trinidad et al., 2006), carob fiber (Zunft et al., 2003), and extruded orange pulp (Larrea et al., 2005).

The extraction of juice from citrus fruits, such as oranges, grapefruit and lemons, provide citrus pulp as residue. According to Mirzaei-Aghsaghali and Maheri-Sis (2008), citrus pulp consists of 60 to 65% peels, 30 to 35% segment pulp and 0 to 10% seeds. On average, citrus pulp represents 60% of the fresh weight with a mean dry matter of 19.7%, but the residue can range between 49 and 69% of the initial weight. However, pressing reduces the moisture from 65 to 75%, after which the pulp is dried, but may also be dried without removing the pressed liquor. Dehydration of small particles of peel, pulp and seed, obtained by sieving the wet residue, provides dried citrus meal. In Michoacán, México, the production of this fruit is reported to be between 350 and 405 thousand tons per year. The by-product from the manufacture of lemon is generally used as livestock feed. Therefore, these by-products (lemon residues), mainly consisting of the peel, albedo, flavedo and juice vesicles are underutilized and could be a highly potential source for use as ingredient in food formulation. The application of the heat treatment with shear during the extrusion process of residues lime can cause a partial modification of the structure of insoluble fiber components such as cellulose to obtain compounds with characteristics of soluble fiber. For this reason, the objective of this study is to evaluate the effect of some extrusion parameters on the dietary fiber constituents of lemon by-products.

MATERIALS AND METHODS

Raw materials

Lemon residues of *Citrus aurantifolia var. Swingle* were collected from the Danisco Ingredients S.A. C.V. industry, located in Apatzingán, Michoacán, Mexico. The lemon residues were washed with clean water, drained and placed in a solar dehydrator at a temperature range of 45 to 55°C. The final moisture of dried samples was 8.70%. After seeds were removed manually from dried lemon residues, lemon residues were ground in a hammer mill (Pulvex model 200) and stored at 4°C for later analysis.

Chemical composition

The moisture, ash, protein and fat analysis in lemon residues were realized using the methods of the AACC (2000). Total dietary fiber (TDF), insoluble dietary fiber (IDF) and soluble dietary fiber (SDF) were done with the methodology proposed by Prosky et al. (1998).

Extrusion process

Extrusion experiments were performed using a laboratory single extruder according to the experimental arrangement. The barrel had controlled electric heaters and a 1:1 screw compression ratio. A die with orifice of 6 mm in diameter was used. The extruded samples were dried in a forced-air oven at 60°C for 12 h, milled (0.420 mm) using a hemmer (Pulvex model 200), and stored in polyethylene bags for further analysis.

Experimental arrangement

A central composite design (CCD) was used to evaluate the response of three independent variables: temperature (X_1), moisture (X_2) and screw speed ($X3$), in the process of extruding lemon residues. The CCD used in this study was based on a 3k factorial treatment design with 3k additional combinations called axial points and n_c central points. The coordinates of the axial points of the axes of the codified factor were (± α, 0, 0,..., 0), (0, ± α, 0, 0 . . . , 0) and (0, 0,0, . . . , ± α), and the central points were of the form (0, 0, 0, . . . , 0). Depending on the selection of α in the axial points, the CCD may have different properties, such as orthogonality, rotability and uniformity. The property of rotability applied in this case was achieved by setting $\alpha = (2k)^{1/4}$. In this way, the value of α for a design with three factors was α = 1.682. The outline of the experimental design and their independent variables and variation levels are presented in Table 1. Table 2 shows the complete experimental arrangement that includes eight factorial points, six replicates at the central point, and six axial points. The dependent variables were SDF, IDF, TDF, *L* and color parameters. Treatments were performed randomly. Experimental results of the chemical composition and physicochemical properties values were presented as the mean ± of three measurements. However, all the processes were run in the statistical package Minitab 15.

Colour measurements

Color measurements were performed using a Hunterlab colorimeter (Model D-2.5M Hunter Associates Laboratory, Inc. Reston VA, USA). *L* (luminosity, dark [0] to bright [100]) and *a* (green [-] to red [+]) coordinates were obtained using a D65 illuminant and 10° observer angle as a reference system.

RESULTS AND DISCUSSION

Chemical composition

The chemical analysis results of the lemon residues

Table 2. Description of the independent variables and results of the extruded treatments in samples of lemon residues.

Independent variable			Response variable				
X_1	X_2	X_3	IDF	SDF	TDF	*L**	*a***
70	40	10	47.7	46.9	94.6	58.88	1.29
100	40	10	48.00	50.00	98.00	56.28	1.73
70	60	10	50.00	48.03	98.03	53.74	1.38
100	60	10	52.73	45.22	97.95	50.92	2.12
70	40	30	50.07	40.00	90.07	54.91	1.58
100	40	30	48.00	46.00	94.00	54.69	2.2
70	60	30	52.00	40.52	92.52	54.86	1.22
100	60	30	49.00	48.40	97.40	53.92	1.79
85	50	20	50.00	48.60	98.60	52.43	1.85
85	50	20	49.40	46.70	96.10	53.24	1.54
85	50	20	48.70	45.90	94.60	53.43	1.67
85	50	20	49.50	46.20	95.70	51.3	1.87
85	50	20	48.30	46.40	94.70	54.52	1.57
85	50	20	48.00	46.50	94.50	53.99	1.66
59.77	50	20	50.20	37.70	87.90	53.99	2.28
110.63	50	20	43.90	49.60	93.50	51.49	2.29
85	33.18	20	51.02	41.39	92.41	54.08	1.75
85	66.82	20	53.00	41.00	94.0	54.68	1.93
85	50	3.18	54.70	41.63	96.33	54.97	1.73
85	50	36.82	55.30	43.00	98.30	55.22	1.57
Raw lemon residues			57.01	38.60	95.61	69.6	0.05

X_1 = Temperature (°C); X_2 = Mositure (%); X1 = Screw speed (rpm); IF = Insoluble dietary fiber; SF = Soluble dietary fiber; TDF = Total dietary fiber. * = *L* color parameter, ** = *a* color parameter.

showed that the main chemical component found was the TDF with a total of 95.61%, of which 57.01% corresponded to IDF and 38.60% to SDF. Other minor components were protein, ashes and total carbohydrates.

Effects of the extrusion variables on the composition of the dietary fiber of lemon residues

Table 2 and Figures 1 and 2 show the experimental results for the contents of IDF, SDF and TDF. In general, it was observed that IDF values decreased and SDF values increased when lemon residues were extruded. The value of IDF in unprocessed lemon residues was 57.01%. In samples extruded, the IDF decreased with higher temperatures and lower moisture contents, when the screw speed was 30 rpm (Figure 1). However, the lowest value of IDF (43.90%) was obtained in the individual treatment considering the following conditions: Temperature of 110.63°C, moisture of 50% and screw speed of 20. Probably, under these conditions, the residence time is adequate to assure the solubilization of the fibre components due to the effect of barrel temperature. The same behaviour was evidenced with lower moisture contents and lower screw speeds (10 rpm). These results are in agreement with those of Gourgue et al. (1994) who reported that with extruded lemon rinds, the IDF contents decreased from 47.94 to 33.66% for lemon. In this study, IDF of lemon residues decreased from 57.01 to 43.90-55.30%. Figure 2 shows the SDF as a function of the extrusion temperature, and the moisture content at a screw speed of 10 rpm. The value of SDF in unprocessed lemon residues was 38.60%. In the samples extruded, the highest value for SDF (50.00%) was obtained when the extrusion conditions of temperature were 100°C, the moisture content was 40% and the screw speed was 10 rpm. This was followed by the treatment of 110°C, moisture content of 50% and a screw speed of 20 rpm, when the SDF was 49.60%. This increment in SDF content would be caused by a partial solubilization of IDF as reported by Larrea et al. (2005a, b) that extrusion increased the values for SDF. Gourgue et al. (1994) reported that the SDF content of lemon rinds increased after the extrusion process, from 28.09 to 37.67%. In general, the TDF was maintained in extruded samples as compared to unprocessed lemon residues. However, a redis-tribution of IDF to SDF was appreciated.

Colour measurements

The *L* and *a* color parameters are shown in Table 2. The tendencies show that intensity of lightness of

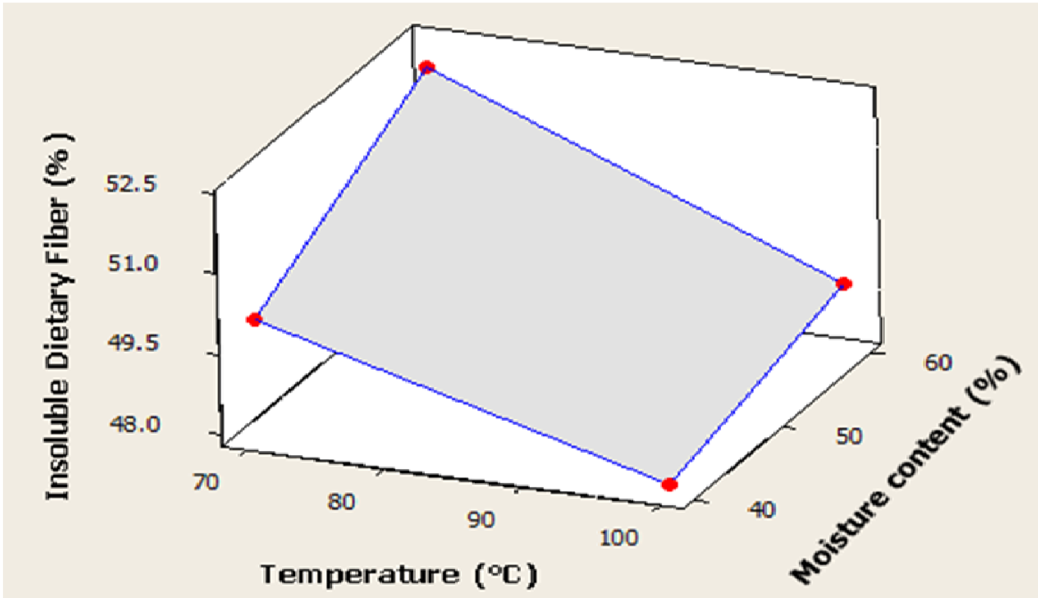

Figure 1. Effects of extrusion temperature and moisture content on the insoluble dietary fiber of the lemon residues. The screw speed was 30 rpm.

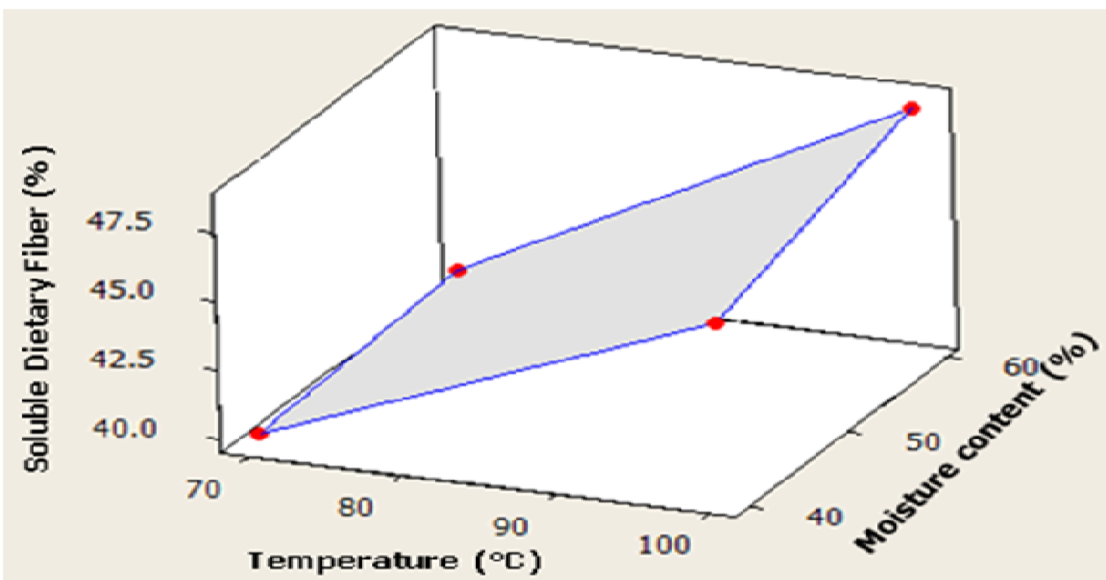

Figure 2. Effects of extrusion temperature and moisture content on the soluble dietary fiber of the lemon residues. The screw speed was 30 rpm.

unprocessed lemon residues decreased as compared to the extruded products from 69.6 to 50.92-58.88. The most intense changes were observed in treatments 4 (temperature of 100°C, moisture 60% and rpm 10) and 16 (temperature of 110.63°C, moisture 50% and rpm 20), having 50.92 and 51.49 *L* values, respectively. In treatment 16, we found the highest extrusion processing temperature, and in treatment 4 we found the second highest temperature of the experimental arrangement combined with the longer residence time (screw speed of 10 rpm). According to Martinez-Flores et al. (1998), the lightness reduction in extruded samples was probably due to the intensification of the Maillard reaction, which occurred between reducing sugars and proteins, causing the products to change from light brown colours to dark colours. Also, a change in *a* value was observed. The results showed that a value of unprocessed lemon residues increased as compared to the extruded products from 0.05 to 1.22-2.29. The most important change occurred in the same number 16 treatment which had the highest *a* value (2.29). It is important to note that the negative values of *a* parameter are related to green colour, while the positive values of *a* parameter are related to red colour. This means that extrusion process begins to change the green traditional colour of lemon residues.

Conclusions

The extrusion conditions increased soluble dietary fiber efficiently and decreased insoluble dietary fiber, particularly when the least temperature of 110°C and the lower screw speeds of 10 and 20 rpm were used to combine the moisture content samples of 40 and 50%.

ACKNOWLEDGMENT

Susana Méndez García is grateful for the Doctorate scholarship granted her by CONACYT, Mexico.

REFERENCES

AACC (2000). American Association of Cereal Chemists. Approved Methods. 10th edition. Ed. by the American Association of Cereal Chemists. Minneapolis, MN, USA.

ALINORM 09/32/26 (2009). Report of the 30th session of the Codex committee on nutrition and foods for special dietary uses 3–7. Appendix II. 46 p. Cape Town, South Africa.

Gourgue CM, Champ M, Guillon F, Delort-Laval J (1994). Effect of extrusion- cooking on the hipoglycaemic properties of citrus fibre: An in vitro study. J. Sci. Food Agric. 64(4): 493–499.

Henríquez C, Speisky H, Chiffelle I, Valenzuela T, Araya M, Simpson R, Almonacid S (2010). Development of an Ingredient Containing Apple Peel, as a Source of Polyphenols and Dietary Fiber. J. Food Sci. 75(6): H172–H181.

Larrea MA, Chang YK, Martinez BF (2005a). Effect of some operational extrusion parameters on the constituents of orange pulp. Food Chem. 89(2): 301-308.

Larrea MA, Chang YK, Martinez-Bustos F (2005b). Some functional properties of extruded orange pulp and its effect on the quality of cookies. LWT – Food Sci. Technol. 38(3): 213-220.

Martinez-Flores HE, Chang YK, Martínez-Bustos F, Sanchez-Sinencio F (2008). Extrusion-cooking of cassava starch with different fiber sources: effect of fibers on expansion and physicochemical properties. In: Advances in Extrusion Technology. Chang YK and Wang SS Editors. Technomic Publishing Co. Inc. Lancaster, PA, USA. pp. 271-278

Martinez-Flores HE, Maya-Cortés DC, Figueroa Cárdenas JD, Garnica-Romo MG, Ponce-Saavedra J (2009). Chemical composition and physicochemical properties of shitake mushroom and high fiber products. CyTA J. Food 7(1): 7-14.

Mehta RS (2005). Dietary fiber benefits. Cereal Foods World, 50(1): 66–71.

Mirzaei-Aghsaghali A, Maheri-Sis N (2008). Nutritive Value of Some Agro-Industrial By-products for Ruminants - A Review. World J Zool. 3(2): 40-46.

Palafox-Carlos H, Ayala-Zavala J.F., González-Aguilar G. (2011). The role of dietary fiber in the bioaccesibility and bioavailability of fruit and vegetable antioxidants. J. Food Sci. 76(1): R6-R15.

Prosky L, Asp NG, Schweizer T, Furda I, Devries JW (1988). Determination of insoluble, soluble, and total dietary fiber in food and products: Interlaboratory study. J. Assoc. Offic. Anal. Chem. 71(5): 1017-1023.

Rodríguez R, Jiménez A, Fernández-Bolaños J, Guillén R, Heredia A (2006). Dietary fibre from vegetable products as source of functional ingredients. Trends Food Sci. Technol. 17(1): 3–15.

Sánchez-Alonso I, Solas MT, Borderías AJ (2007). Physical study of minced fish muscle with a white-grape by-product added as an ingredient. J. Food Sci. 72(2): E94–E101.

Trinidad TP, Mallillin AC, Valdez DH, Loyola AS, Askali-Mercado FC, Castillo JC, Encabo RR, Masa DB, Maglaya AS, Chua MT (2006). Dietary fiber from coconut flour: a functional food. Inn. Food Sci. Emer. Technol. 7(4): 302–17.

Viuda-Martos M, López-Marcos MC, Fernández-López J, Sendra E, López-Vargas JH, Pérez-Alvarez JA (2010). Role of Fiber in Cardiovascular Diseases: A Review. Compr. Rev. Food Sci. Food Saf. 9(2): 240-258.

Zunft HJF, Luder W, Harde A, Haber B, Graubaum HJ, Koebnick C, Grunwald J (2003). Carob pulp preparation rich in insoluble fibre lowers total and LDL cholesterol in hypercholesterolemic patients. Eur. J. Nutr. 42(5): 235–242.