FORMATION OF PEANUT BUTTER-LIKE PRODUCTS FROM GLANDLESS COTTONSEED

Zhongqi He
Huai N. Cheng
USDA-ARS, Southern Regional Research Center
New Orleans, LA
Jibao He
Coordinated Instrument Facility, Tulane University
New Orleans, LA

Abstract

"Glandless" (Gl) cottonseed is a unique cotton variety with only a trace content of toxic gossypol present. The new Gl cottonseed raises the potential of its enhanced utilization as agro-foods for human consumption. In this work, Gl cottonseed kernels were used as the base material to produce protein-oil butter-like formulations. Kernels roasted at two temperatures were first ground with different ratios of cottonseed oil and two other ingredients (i.e., salt and sugar) by a food blender, and then passed through a meat grinder with the 4-mm-hole grinding plate. Based on the results, the textural and microstructural properties of two butter-like products were evaluated. The morphology of the two butters was examined and compared by Scanning Electron Microscopy (SEM) and cryo-SEM. Oil stability test showed no substantial oil separation from the butter products over 7 weeks (49 days) at ambient temperature (22 ^{o}C). This work provided the basic information and parameters for lab cottonseed butter making so that optimization and characterization of cottonseed butter formation can be designed and performed in future research.

Introduction

Plant-based (nut and seed) butters have steadily increased in consumer popularity. Substitutes for peanut-butter have been of particular interest as the severe allergenic character of peanuts is a problem for a significant percentage of the population. Several types of plant-based butters or spreads have been commercialized, including products from almond, cashew, hazelnut, sunflower, sesame, peanut, pistachio, pumpkin seed and soybeans (Dimi , Vujasinovi , et al., 2013, Gorrepati, Balasubramanian, et al., 2015, Shakerardekani, Karim, et al., 2013). Plant-based butters are generally prepared by roasting and grinding with some additives (Shahidi-Noghabi, Naji-Tabasi, et al., 2019, Tanti, Barbut, et al., 2016). Temperatures of roasting and grinding are both vital for formulation of healthy and nutritious plant-based butters (Norazatul Hanim, Chin, et al., 2016).

Because of the presence of toxic gossypol, seed products derived from glanded cottonseed are typically not suitable for human consumption. The discovery of a glandless mutant in the 1950's made it possible for food utilization of cottonseed (Lawhon, Cater, et al., 1970, Lusas and Jividen, 1987). However, there are only few publications in the formulation of cottonseed products such as edible nuts, brownies, cookies and a component in corn tortilla, and these products have not been fully evaluated (Cherry and Berardi, 1982, Plating and Cherry, 1979). Recently, the use of modern genetic modification technologies has enabled several new glandless and low-gossypol cotton lines to be made (Alam, Watanabe, et al., Zhang and Wedegaertner, 2021, Zhang, Wedegaertner, et al., 2016). Exploration of these cottonseeds as food products would greatly enhance the economic impacts of these new cotton lines. Thus, this work attempted to gather the basic information and manufacturing parameters for peanut butter-like products so that relevant experiments on optimization and characterization of cottonseed butter can be designed and performed later. These butter-like products were characterized for selected rheological, textural, and physical properties through both in-house instrumentation and outside collaboration.

Materials and Methods

The Gl cottonseed of NuMex series was provided by Cotton, Inc. (Cary, NC, USA). The selected chemical composition of the Gl kernels is listed in Table 1 together with a comparison of the glanded (Gd) kernels. These seeds were dehulled mechanically by cracking with a 20.32-cm plate mill and then separated with a vibratory shaker. The kernel products were further cleaned by passing the material through a laboratory aspirator to remove the non-kernel material. These Gl kernels were used as the base material (70.0, 75.0, and 80.0%) to produce peanut butter-like spread formulations. Cottonseed oil (11.8, 16.8%, and 21.8%), cane sugar (7.5%), and table salt (0.7%) were the other three ingredients used in the formulation.. The Gl kernels were first roasted in a convection oven (Thermo Scientific Precision Compact Ovens, Waltham, MA) at 140 or 150 ^{o}C for a given time (15 or 30 min). The roasted kernels were ground with Waring Commercial Blender (Model WF2211214, Torrington CT) at a high speed for 3 min, then mixed thoroughly with the three additives by a spatula. The mixture was then passed through a Smokehouse meat grinder with a 4-mm hole plate (Buchanan Dam, TX). The extruded products were then visually examined, collected, and kept at 4 ºC until analysis.

The butter (oil) stability was determined by accelerated oil separation rates (Shahidi-Noghabi, Naji-Tabasi, et al., 2019, Tanti, Barbut, et al., 2016). The tested butter products (5.000 g each) were put into capped 50-mL centrifuge tubes and kept at room temperature (22 ºC). After storage for a given time, the butter tubes were centrifuged at 1258 g for 10 min at 22 °C. Surface oil was removed after centrifugation and the percent loss was calculated below:

Oil separation content (%) = Oil separated after centrifugation (g)/5.000 (g) × 100

For scanning electron microscopy (SEM), oil in the butter products was first removed by hexane extraction to reduce its possible interferences in the SEM imaging process (Norazatul Hanim, Chin, et al., 2016). During analysis, a thin layer of the de-oiled butter sample was gently attached to an 8 mm x 12 mm double-sided sticky carbon tape on an aluminum stud. The butter sample was coated with 3-nm thickness of carbon using Cressington 208HR sputter coater. The samples were observed and imaged with a Hitachi S-4800 Field Emission Scanning Electron Microscope (Hitachi, Japan), operating at 3kV (He, Nam, et al., 2021). For non-deoiled butter samples, the Gatan Alto 2500 cryogenic system and the Hitachi S-4800 field emission SEM were used in acquiring cryogenic SEM images. A 5-ul cream sample was loaded to a sample holding device, a 3-mm diameter cylinder, and formed a crown-like cap on the top of the cylinder. The sample was plunged into a cup of slushed liquid nitrogen and vitrified. A fracture surface of the sample was acquired at -130 ºC, sublimed 5 minutes at -95 ºC, and coated with Pd/Pt alloy at -130 ºC. The fracture surface was observed at 3 kV at -130 ºC.

Table 1. Selected chemical components of Gd and Gl cottonseed kernels. ADF, acid detergent fiber. ADL, acid detergent lignin. Adapted from He, Nam, et al. (2022).

Major component (g kg^{-1})							
	Moisture	Gossypol	Oil	Protein	ADF	ADL	Starch
Gd	67.9	3.75	387	397	100	52.3	12.2
Gl	68.3	0.06	350	421	109	67.8	16.6
Macro element (g kg^{-1})							
	P	Ca	K	Mg	Na	S	Ash
Gd	9.8	2.0	12.0	5.4	0.6	4.5	46.7
Gl	11.5	2.3	12.8	6.1	0.6	4.9	47.9
Trace element (mg kg^{-1})							
	Fe	Zn	Cu	Mn	B	Ni	Al
Gd	104	70.5	18.1	12.9	13.8	1.9	91.6
Gl	111	74.3	19.0	13.3	14.2	2.1	109.8

Results and Discussion

The data in Table 1 indicate that the chemical components of the Gl kernels were basically at the same levels as those of the Gd kernels with the exception of having much less gossypol content in Gl kernels. Indeed, the gossypol content in Gl kernels (60 mg per kg) was lower than the FDA's criteria of 450 ppm gossypol that is allowed for use as food products (He, Nam, et al., 2022).

Preliminary butter making trials were conducted at three levels of Gl kernels (70.0, 75.0, and 80.0%), three levels of oil (11.8, 16.8%, and 21.8%), and fixed levels of sugar (7.5%) and salt (0.7%). Visual examination of the products indicated that the mixture of 75.0% cottonseed kernels and 16.8% oil possessed a more appealing peanut-like appearance and textural characteristics. Thus, this formulation was adopted to produce more cottonseed butter-like samples for its structural and textural evaluation.

The two butter products of optimal formulation with cottonseed kernels roasted at 150 ºC for 15 and 30 min were examined by scanning electronic microcopy (Fig. 1). Differences in the Cryo-SEM images of the two products were observed. The morphology of the butter product with 15-min roasting time (i.e., B15-c) was more like a rough sponge structure filled with many tiny particles. In contrast, the surface of the butter sample with 30-min roasting (B30-c) was smoother, and those tiny particles were distributed more evenly on the surface. The images of the two de-oiled butter samples (B15-d and B30-d) looked more similar to each other. The microstructures of both de-oiled butter products contained spherical, ellipsoidal, and flat particles. Those observations indicated that roasting time seems to have more impact on the oil-related morphology of the cottonseed butter products. In addition, the SEM images also revealed that the morphology of the two butter-like products of cottonseed was not as smooth as that of peanut butter by comparison with the relevant SEM images in the literature (Norazatul Hanim, Chin, et al., 2016, Tanti, Barbut, et al., 2016).

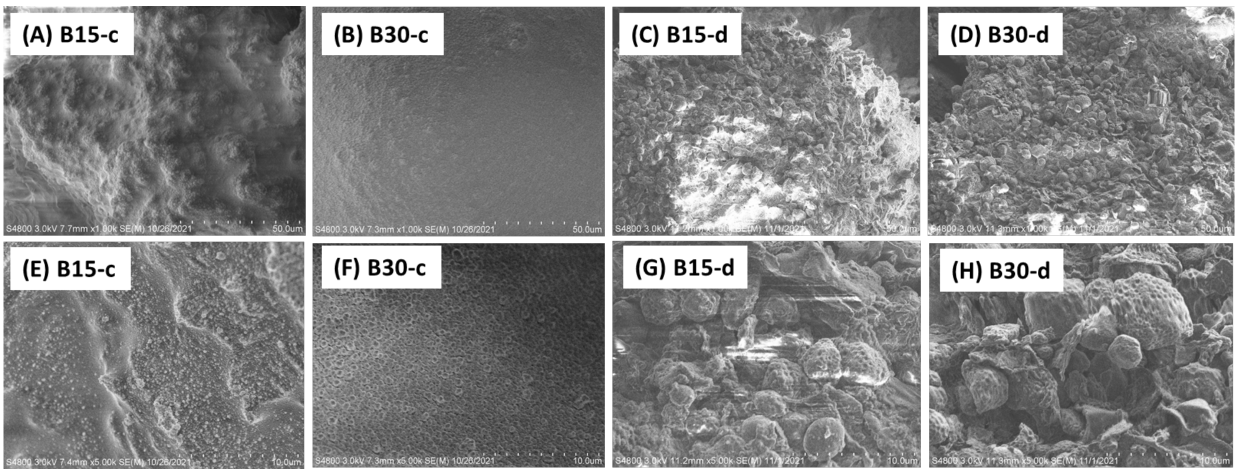

Fig. 1. SEM images of cottonseed butter products with 15- (B15) and 30-min (B30) kernel roasting at 150 ºC. Suffixes "c" and "d" indicate "cryo-SEM" and "de-oiled" samples, respectively. Bar distance is 50 and 10 µm, respectively, for upper and lower rows.

The stability of the cottonseed butter products was evaluated by oil separation during the storage of the butter products at room temperature over 49 days (Fig. 2). Similar to the oil loss of walnut butter (Norazatul Hanim, Chin, et al., 2016), the oil loss of the cottonseed butter fluctuated with storage time, but with a general trend of increasing oil loss with increasing storage times. The longer roasting duration of cottonseed kernels resulted in more oil loss from the butter during storage. The maximal oil loss during the storage was 1.6% and 2.9% of the total butter weight, respectively, for B15 and B30 samples. Even so, the oil loss was less than that of peanut butter (around 5.4%) (Lima, Guraya, et al., 2000) and walnut butter (around 20%) (Norazatul Hanim, Chin, et al., 2016). Thus, stabilizer additives would not be required for formulation of the cottonseed butter under current preparation conditions.

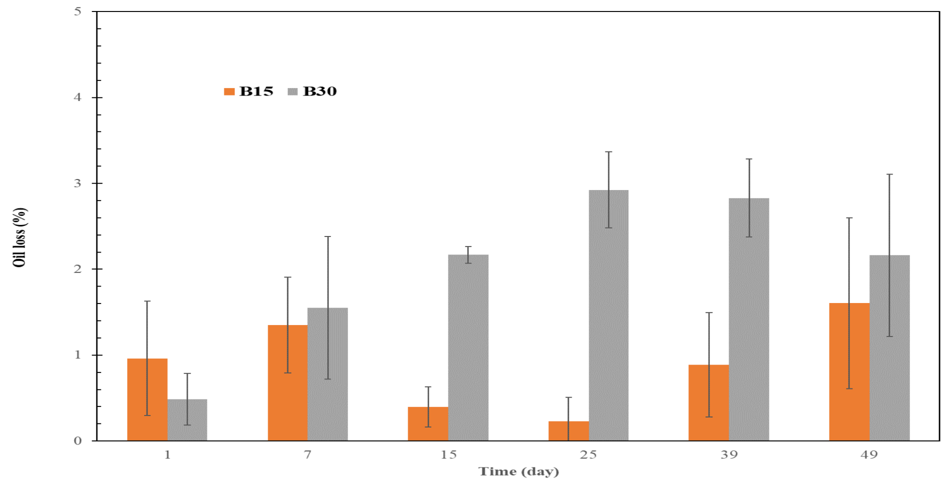

Fig. 2. Changes in the rate of oil separation from the cottonseed butters during 49 days of storage at room temperature (25 °C). B15 and B30, kernels were roasted at 150 ºC for 15 and 30 min, respectively. Data are presented as averages with standard deviation bars (n=3).

Summary

Glandless cottonseed kernels could be used to make peanut butter-like food products. An initial workable formulation included 75.0% roasted cottonseed kernels, 16.8% cottonseed oil, 7.5% sugar and 0.7% salt. Microstructural analysis revealed that the butter product with a longer (30 min) roasting time possessed a smoother surface than the products with a shorter (15 min) time. On the other hand, the butter product with 30-min roasting duration showed a higher oil separation rate (up to 2.9%) than the product with 15-min roasting (1.6%). Nonetheless, the oil separation during storage of both cottonseed products was lower than those of peanut butter and walnut butter as reported in the literature, indicating higher butter stability of the cottonseed products. The evaluation of the textural properties (e. g., hardness and spreadability) of the cottonseed butters is under way.

Acknowledgements

The authors thank Dr. Michael Dowd for cottonseed material and Mr. Stephen Rogers for data collection. This work was supported by the U.S. Department of Agriculture, Agricultural Research Service. Mention of trade names or commercial products is solely for the purpose of providing specific information and does not imply recommendation or endorsement by USDA. USDA is an equal opportunity provider and employer.

References

Alam, M.S., W.O. Watanabe, P.M. Carroll, J.E. Gabel, M.A. Corum, P. Seaton, et al. 2018. Evaluation of genetically-improved (glandless) and genetically-modified low-gossypol cottonseed meal as alternative protein sources in the diet of juvenile southern flounder Paralichthys lethostigma reared in a recirculating aquaculture system. Aquaculture 489: 36-45. doi:https://doi.org/10.1016/j.aquaculture.2018.02.006.

Cherry, J.P. and L.C. Berardi. 1982. Cottonseed. In: I. A. Wolff, editor CRC handbook of Processing and Utilization in Agriculture. Volume II: Part 2- Plant Products. CRC Press, Boca Raton, FL. p. 187-255.

Dimi , E.B., V.B. Vujasinovi , O.F. Rado aj and B.D. Bori . 2013. Sensory Evaluation of commercial fat spread based on oil seeds and walnut. Acta Periodica Technologica 44: 21-30.

Gorrepati, K., S. Balasubramanian and P. Chandra. 2015. Plant based butters. J. Food Sci. Technol. 52: 3965-3976.

He, Z., S. Nam, D.D. Fang, H.N. Cheng and J. He. 2021. Surface and thermal characterization of cotton fibers of phenotypes differing in fiber length. Polymers 13: 994. doi:10.3390/polym13070994.

He, Z., S. Nam, H. Zhang and O.M. Olanya. 2022. Chemical composition and thermogravimetric behaviors of glanded and glandless cottonseed kernels. Molecules 27: 316. doi:10.3390/molecules27010316.

Lawhon, J.T., C.M. Cater and K.F. Mattil. 1970. Preparation of a high-protein low-cost nut-like food product from glandless cottonseed kernels. Food Technol. 24: 701-709.

Lima, I., H. Guraya and E. Champagne. 2000. Improved peanut flour for a reduced-fat peanut butter product. J. Food Sci. 65: 854-861.

Lusas, E. and G. Jividen. 1987. Glandless cottonseed: a review of the first 25 years of processing and utilization research. J. Am. Oil Chem. Soc. 64: 839-854.

Norazatul Hanim, M., N. Chin and Y. Yusof. 2016. Effects of grinding time on rheological, textural and physical properties of natural peanut butter stored at different temperatures. J. Texture Stud. 47: 131-141.

Plating, S.J. and J.P. Cherry. 1979. Protein and amino acid composition of cottonseed flour fermented with selected filamentous fungi. J. Food Sci. 44: 1178-1182.

Shahidi-Noghabi, M., S. Naji-Tabasi and M. Sarraf. 2019. Effect of emulsifier on rheological, textural and microstructure properties of walnut butter. J. Food Measur. Character. 13: 785-792.

Shakerardekani, A., R. Karim, H.M. Ghazali and N.L. Chin. 2013. Development of pistachio (Pistacia vera L.) spread. J. Food Sci. 78: S484-S489.

Tanti, R., S. Barbut and A.G. Marangoni. 2016. Oil stabilization of natural peanut butter using food grade polymers. Food Hydrocolloids 61: 399-408. doi:https://doi.org/10.1016/j.foodhyd.2016.05.034.

Zhang, J. and T. Wedegaertner. 2021. Genetics and Breeding for Glandless Upland Cotton With Improved Yield Potential and Disease Resistance: A Review. Front. Plant Sci.: 2227.

Zhang, J., T. Wedegaertner, O.J. Idowu, R. Flynn, S.E. Hughs and D.C. Jones. 2016. Registration of ‘NuMex COT 15 GLS’glandless cotton. J. Plant Registr. 10: 223-227.