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Development of biscuit type cookie with partial replacement of fat by inulin

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Abstract: Cookies are bakery products rich in fat and sugars. Lipids have in general important nutritional and technology factors, but excessive intake can bring health risks. The reduced caloric value and lipid content is a common demand among biscuits consumers, which come to own up to 60% fat. This study aimed at developing formulations of cookies with partial replacement (Standard-0%, R1-25%, R2-50% and R3-75%) of fat by inulin as well as evaluating physical, physicochemical and sensory characteristics. Through the present study, it was observed that the partial replacement of fat by inulin in the production of cookies was effective in reducing the percentage of total lipids in the final product, with maximum reduction of 86% in formulation R3, without changing the parameters for moisture, crude fiber and instrumental color. Once insulin was increased, the size of the cookies after baking decreased, therefore increasing the crispness of the cookies made from the formulation with the highest level of replacement, represented by R3, which negatively impacted the sensory evaluation of flavor and purchase intention for the product, while formulation R2, with 50% fat replacement by inulin, presented similar results to the standard product, being the formulation with the greatest sensory acceptance and physical characteristics. Therefore formulation R2 was been good in nutritional and sensorial performance, and then it is best formulation.

Keywords: Cookie, Inulin, Fat Replacement

1. Introduction

Biscuits type cookies are cereal based, and have high sugar and fat levels. Due to consumers demand about healthier products, such products have been increasingly required reformulation and seen as the main target of recent researches [1].

Studies have shown that there is a high correlation between the excess of fat in diets and the risk of cardiovascular diseases [2]. According to the American Heart Association [3], saturated fat is the main alimentary cause of plasmatic cholesterol levels increase. Vegetal hydrogenated fat has high levels of trans-fatty acids, which affects the factors of cardiovascular risks, once it causes an increase in cholesterolemia, elevating the LDL-cholesterol (LDL-c) and reducing the HDL-cholesterol (HDL-c), similarly to how saturated fats work [4]. This made consumers more worried about their eating habits, leading them to reduce their ingestion of lipids.[2].

Despite such problems, fat and sugar are not easily replaced, especially regarding this sort of product. Cookies in general are soft with more favored texture characteristics due to its elevated fat level [5]. Fat is present in relatively high levels, usually between 30 and 60% of the formulations, and plays an important role, lubricating the bulk, reducing beating time, raising volume, improving color, and favoring an elaboration of a soft and highly accepted product [6]. Fat also provides flavor and the taste sensation in the mouth, contributes to appearance, palatability and texture. Sucrose is one of the most important ingredients of bakery, providing volume, texture and sweetness [7].

According to Miraglio [8], the substitutes of fat are food ingredients that can replace totally or partially the lipids in the product and still provide the food with similar organoleptic properties [9]. In general, they play two roles: to reduce total lipid content and to reduce total calories [10] five terms are used to describe ingredients to be used in

order to reduce total lipid content:

- ("fat replacer") – general term that describe any ingredient used instead of fat;
- ("fat substitute") – synthetic compound developed to replace fat without any mass change, usually chemical structures similar to fat, but more resilient against hydrolysis by digestive enzymes;
- ("fat mimetic") – compound utilized to imitate the characteristics of fat that needs high rate of water, but resist to the hydrolysis by the digestive enzymes;
- ("low-calorie fat") – synthetic triglycerides combined with non-conventional fatty acids on the glycerol chain, resulting in a reduced caloric value;
- ("fat extender") – fat system that contains a proportion of standard fats or oils combined with other ingredients.

Inulin is considered to be a fat substitute carbohydrate, or a dietetic fiber, and posses the capacity of jellification when exposed to water, it is also used as food additive, with functional probiotic properties [11]. Inulin is present as a reserve carbohydrate found in roots and tubers of plants such as the Jerusalem artichoke(*helianthus tuberosus),* chicory(*cichorium intybus),* dhalia(*dhalia sp.),* yacon (*smallanthus sochifolius)* [12]. It is formed by an heterogeneous mixture of fructose polymers. The fructose units are usually linked by β1-2 bounds, and present one molecule of glucose at the initial section of each linear fructose chain, and this one is attached by a α1- β2 bond, such as in the molecule of sucrose. However, its characteristic functions allow it to be appliedto different sorts of food formulations, which has increased scientific investigation on identification, extraction, and application of inulin present in different sorts of plants [13], [14]. This carbohydrate is capable of reducing water concentration during starch jellification, leading to a lower blood sugar rate. The use of inulin is promising, once it does not change nor appearance or taste, besides, it raises both softness and moisture, allowing inulin to be applied to products with high contents of starch, such as cakes and biscuits [15].

Despite the absence of evidence about toxicity or digestive diseases associated to inulin consumption, the acceptable diary ingestion (ADI) is 40 grams, according to research carried out in western USA and Europe, the average per capita daily ingestion is from1 to 10 grams [16].

The objective of this present work was to elaborate biscuits type cookies with reduced fat percentage, through partially replacing fat by inulin, and to evaluate their physical and chemical characteristics and acceptance through sensorial analysis.

2. Materials and Methods

The ingredients used to produce the cookies were: wheat flour, starch, inverted sugar syrup, sugar, hydrogenated vegetal fat, salt, soy lecithin, ammonium bicarbonate, and vanilla essence, all items were acquired on local stores in the city of Maringa/PR. The inulin applied was kindly provided by Metachem Industrial e Comercial Ltda.

The base formulation to develop the cookies was proposed by Protzek [17], with some modifications. Four samples were developed, listed on table 1, with partial replacement of fat by inulin: first sample with no inulin (Standard), 25% (R1), 50% (R2), and 75% of the fat by inulin (R3).

Table 1. *Formulation of the cookies*

Ingredients (%)	Standard	R1[1]	R2[2]	R3[3]
Wheat Flour	36,2	36,2	36,2	36,2
Starch	7,2	7,2	7,2	7,2
Inverted Sugar Syrup	7,2	7,2	7,2	7,2
Sugar	21,7	21,7	21,7	21,7
Vegetal Hydrogenated Fat	18,1	13,6	9,1	4,6
Sodium Chloride	0,7	0,7	0,7	0,7
Soy Lechitin	0,7	0,7	0,7	0,7
(NH_4HCO_3)	0,4	0,4	0,4	0,4
Water	7,2	10,6	14	17,4
Vanilla Essence	0,6	0,6	0,6	0,6
Inulin	0,0	1,1	2,2	3,3

[1]R1: Biscuit with 25% fat reduction; [2]R2: Biscuit with 50% fat reduction; [3]R3: Biscuit with 75% fat reduction.

Ashes, total lipids, and crude fiber of the cookies were determined according to the Analytical Standards of Institute Adolfo Lutz [18].

The cookies physical evaluation was carried out through setting their mass, diameter, and thickness before and after baking. The cookies were measured through a caliper rule, and weighted on a digital semi-analytical scale, determining next the expansion factor for the samples. (JUNG e PALHANO, 2011). All analyses were conducted in three replicates.

In order to analyze the experimental texture a Stable Micro Systems Texture Analyzer TAXT2i (Texture Technologies Corp, England) was used as described by Oliveira [19].

The cookies coloration was determined through the CIELab System, using a digital Hunter Lab MiniScan EZ colorimeter.

The sensory analysis for the elaborated product was carried out at the laboratory of sensory analysis of the State University of Maringa. Fifty untrained tasters using a hedonic scale evaluated samples characteristics such as flavor, aroma, color and texture. The samples were codified with three digits numbers and the presentation order was randomized among the tasters (approved by the ethics committee on human research CAAE 18718013.3.0000.0104).

The results were submitted to variance analysis (ANOVA) and Tukey's test 5% probability, using the software Statistica 7.0.

3. Results and Discussion

The proximate composition values are in table 2.

Table 2. *Results of physicochemical analysis on the cookies*

Analysis (%)	Standard	R1[1]	R2[2]	R3[3]
Moisture	6.8[a]±0.00	7.1[a]±0.00	7.0[a]±0.01	6.93[a]±0.01
Ash	1.54[a]±0.25	2.88[a]±0.33	4.10[b]±0.17	4.18[b]±0.18
Lipids	28.0[a]±0.04	14.2[b]±0.04	10.0[c]±0.16	4.0[d]±0.16

*Results are expressed as mean ± standard deviation of three replicates. Means followed by different lowercase letters in the same line are significantly different through Tukey test at the significance level was set to 5 %. [1]R1:25% fat reduced; [2]R2:50% fat reduced; [3]R3:75% fat reduced.

Among the four formulations values obtained to ash and lipids are significantly different (5%). Formulations R2 and R3 presented higher ashes percentage when compared to standard formulation. Moisture values shown certain regularity.

Regarding the lipid content of the samples, the results showed a significant reduction between the formulations. For R1, where the proportion of fat replaced was of 25%, the reduction of total lipids was of 50%, when compared to standard formulation. Formulation R2 obtained even higher reduction, compared with the standard sample it was 65%, and the fat replacement rate was of 50%. The highest reduction was observed for formulation R3, the total lipids reduction was of 86%. For the biscuits type cookies, the lipids reduction in the final product is directly related to the proportion of fat replaced, that means, the higher the percentage of fat replaced, the lower the total lipids in the final product.

The results obtained for moisture and crude fiber showed no significant difference, even with the addition of inulin, which is considered a dietary fiber. Its concentration in concerning the total formulation is very low, since the proportion of replacement was 4 units of fat per 1 unit of inulin [20], making it undetectable by the method of analysis proposed in this paper for any of the formulations.

The results of the physical characteristics evaluation of the cookie biscuits are shown in Table 3. As the percentage of fat replaced by inulin increases, a considerable reduction in the size of the biscuits compared to the standard formulation is noticed, reaching a reduction of 46% to R2 and R3 formulations after baking. A similar result was found by Zoulias et al. [7], in the formulations of biscuits and cookies with sugar replacement and 35% fat replaced by inulin and maltodextrin, showing significantly smaller dimensions than the standard formulation. This dimension reduction can be associated with the ability of elastic recoil presented by maltodextrin and inulin. This characteristic is enhanced while baking the biscuits [7]. Fat reduction showed no significant difference in thickness, expansion and weight of the biscuits.

Table 3. *Values of size, thickness, expansion factor and weight of the cookie before and after baking.*

Sample Parameters		Standard*	R1*[1]	R2*[1]	R3*[1]
Diameter (cm)	Before	5.00±0.15	4.95±0.37	4.95±0.42	4.87±0.20
	After	5.77±0.11	5.77±0.24	2.68±0.36	2.70±0.21
Thickness (cm)	Before	0.72±0.17	0.70±0.40	0.70±0.15	0.71±0.21
	After	0.98±0.15	0.99±0.1	0.99±0.11	1.03±0.05
Weight (g)	Before	16.11[a]±0.85	15.98[a]±1.10	15.98[a]±0.33	15.97[a]±0.65
	After	14.62[a]±0.80	13.91[a]±1.05	13.58[a]±0.11	13.2[a]±0.23

*Results are expressed as mean ± standard deviation of three replicates. Means followed by different lowercase letters in the same line are significantly different by Tukey test at the significance level was set to 5 %. 1R1:25% fat reduced; [2]R2:50% fat reduced; [3]R3:75% fat reduced.

The results for color analysis are shown in Table 4. The parameters analyzed were: L (luminosity) ranging from 0 (black) to 100 (white); coordinate which varies from-a (green) + a (red) and also to assess the coordinate b variation in color between blue (-b) and yellow (+ b). Analyzed like Jung and Palhano [21].

***Table 4**. Color analysis results by the CIELAB system.*

Parameter	Standard	R1[1]	R2[2]	R3[3]
Luminosity L	61.03[a]±2.26	64.00[a]±4.81	63.37[a]±17.02	64.83[a]±8.00
Coordinate a	6.33[a]±0.72	4.90[a]±1.99	5.90[a]±0.73	5.27[a]±8.58
Coordinate b	30.47[a]±1.37	28.53[a]±0.56	38.20[a]±3.13	30.47[a]±1.58

*Means followed by different lowercase letters in the same line are significantly different by Tukey test at the significance level was set to 5 %.

Through color analysis, it is possible to notice that the reduction of fat addition of inulin do not significantly change the cookie color, showing the capability of inulin to mimic the property of fat as a color improver. To Gaines [22] the texture is an important element in the quality of biscuit, directly affecting consumer acceptance and sales. Based on the results presented in Table 5, there is a significant direct relationship between the formulation and the texture of the cookies. The highest compression value is associated with a higher percentage of fat replaced by inulin (R3).

In their study, Forker et al. [23] describe how the incorporation of fat-replacing ingredients contribute to increase the biscuit firmness, which is directly related to the amount and type of substitute used, resembling the results found for R3. Unlike, Zoulias et al [7] found more vigorously biscuits cookies with lower percentages of replacement. Finally, in the formulation with 50% fat replaced by inulin hardness values similar to the standard sample were obtained. This result is similar to what found in this study for R2.

***Table 5.** Results from texture evaluation.*

Texture	Standard	R1[1]	R2[2]	R3[3]
Compression Force (Kgf)	9.27[a]±6.04	12.58[a]±2.41	9.78[a]±29.26	18.55[b]±31.04

*Results are expressed as mean ± standard deviation of three replicates. Means followed by different lowercase letters in the same line are significantly different by Tukey test at the significance level was set to 5 %. [1]R1:25% fat reduced; [2]R2:50% fat reduced; [3]R3:75% fat reduced.

The results of the sensorial analysis are shown in Table 6. The attributes texture and aroma did not present significantly different values. For the parameter color, formulations R2 and R3 differ significantly, contrary to the instrumental analysis pointed. This may be due to an untrained sensory panel. The flavor attribute also pointed out the difference between the sample R3 and the others, indicating that the replacement of 75% of the fat negatively impacted the taste parameter, resulting in scores lower than the others.

***Table 6.** Results of sensory analysis.*

Attributes	Standard*	R1*[1]	R2*[1]	R3*[1]
Color	7.50[a]±1.69	7.68[a]±1.46	7.90[b]±1.25	7.96[b]±0.86
Texture	6.90[a]±1.97	6.80[a]±1.97	6.81[a]±2.07	5.66[a]±2.34
Flavor	7.11[a]±2.40	7.37[a]±2.20	7.69[a]±1.73	6.88[b]±2.34
Aroma	7.38[a]±2.12	7.40[a]±1.90	7.74[a]±1.13	7.40[a]±1.90

*Results are expressed as mean ± standard. Means followed by different lowercase letters in the same line are significantly different by Tukey test at the significance level was set to 5 %. [1]R1:25% fat reduced; [2]R2:50% fat reduced; [3]R3:75% fat reduced.

The results for purchase intention are presented on table 7. It is observed that formulation R2 , with 50% fat replaced, has the greatest acceptance among the samples, and sample R3 having 75% fat replaced presented lower acceptance as shown in the table below.

***Table 7.** Results of purchase intention.*

	Standard	R1	R2	R3
Certainly buy	41.67%	37.5%	41.67%	29.17%
Maybe buy	35.41%	50%	54.17%	37.5%
Would not buy	22.92%	12.5%	4.16%	33.33%

4. Conclusion

The partial replacement of fat by inulin in the production of cookies was effective in reducing the percentage of total lipids in the final product without changing the parameters of moisture, crude fiber and instrumental color. As inulin concentrations were increasing, there was a decrease in the biscuits size after baking and, consequently, an increase in the crispness on the maximum level of replacement formulation represented by R3, while formulation R2, with 50% fat replaced by inulin, presented similar results to the standard sample, being the formulation with better sensory acceptance and better physical characteristics. Therefore, the inulin ingredient can be considered as a fat mimic, efficient and feasible for formulations of biscuits type cookie, with good technological and nutraceutical properties.

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