

## Effect of Chicory Inulin Extract as a Fat Replacer on Texture and Sensory Properties of Cookies

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### ABSTRACT

Today inulin mostly supplied by Chicory (*Cichorium intybus* L.). Root yield and their inulin percentage are two major components to increase inulin yield put the quantity and quantity of chicory root depend on variety, cultural and agri-ecological conditions. Inulin is an important ingredient could be used in the food industry as a sugar or as a fat replacer, which offers a unique combination of nutritional properties and important technological benefits. Therefore, the present study is evaluate yield productivity, extract inulin from Nues chicory root variety and to evaluate the effects of inulin as a fat replacer at different levels (10, 20, 30, 40 and 50%) on quality evaluation of cookies. The obtained data indicated that, the highest root and inulin yield was detected from Nues variety. Increasing level of inulin as a fat replacer from 10 to 50 % was effective in reduction the percentage of total lipids and caloric value in all samples of cookies. The reduction in caloric values were ranged from 495.24 to 453 Kcal/ 100g, comparing with control sample (504.68 Kcal/ 100g). Values of diameter, thickness, spread ratio and density were decreased by increasing level of replacing fat ratio while the hardness increased. The sensory evaluation showed that, no significant differences were observed among control and the other total samples of cookies (up to 40% fat replacer). Therefore, the utilization of chicory inulin as a fat replacer is well accepted by consumers and resulting a product with potentially healthier properties.

**Key words:** Chicory root, inulin extract, fat replacer, cookies

### Introduction

Chicory (*Cichorium intybus* L.), a perennial herb of the Asteraceae family is native to the Mediterranean region, mid Asia and northern Africa. Historically, chicory was grown by the ancient Egyptians as a medicinal plant (Munoz, 2004).

Fresh chicory root typically contains, 68% inulin, 14% sucrose, 5% cellulose, 6% protein, 4% ash, and 3% other compounds (by dry weight). Dried chicory root extract contains, approximately 98% inulin and 2% other compounds by weight (Meehye and Shin, 1996). As well as (Massoud *et al.*, 2009) revealed that chicory roots contain a high concentration of total carbohydrates (89.41%). De Leenheer (1996) reported the content of inulin extracted from chicory roots is, also, high (more than 70% on dry substance) and fairly constant from year to year as well as depend on varieties. At present, chicory is the most important source of inulin, which is only grown and processed (Monti *et al.*, 2005). It was observed, in unpublished data, that Neus is one of chicory root varieties contained a higher amount of inulin. Therefore, it cultivated to inulin extraction and utilize in bakery products manufacturing. The differences in inulin content are reflected to the effect of variety and agri-ecological conditions on quality formation of chicory with average range between 20-25 ton ha<sup>-1</sup> root yields (Baert, 1997). On the other hand, (Shoorideh *et al.*, 2016) mentioned that root yield and inulin percentage are two major components to increase inulin yield.

It is worthily too mentioned the compound of 3,5-Di-*O*-caffeoylquinic acid, a chlorogenic acid, is responsible for nearly 70% of the antioxidant activity of chicory (Fraisie *et al.*, 2011), which was up to them the reasons of bitter taste and play a role in the organoleptic properties of chicory (Price *et al.*, 1990 and van Beek *et al.*, 1990). In this case (Massoud *et al.*, 2009) reported that it could

be stated that the removal bitterness of powder chicory roots and dried inulin extracted successfully replace wheat flour with good acceptability form consumer.

Inulin is a natural dietary fiber derived from chicory root, garlic, wheat, bananas, and artichokes, and so it has always been part of the human diet (Niness 1999). Roots of chicory (*Cichorium intybus* L.) are used for the production of inulin and as ingredients in certain roasted products (Wilson *et al.*, 2004; Geel *et al.*, 2005 and Toneli *et al.*, 2007).

Chemically, inulin is a carbohydrate built up from  $\beta$  (2,1)-linked fructosyl residues mostly ending with a glucose residue (Meyer *et al.* 2011). Inulin has been a part of our daily food intake for centuries contributing to nutritional properties and exhibits technological benefits that may be used to formulate innovative healthy foods for today's consumers (Akalin and Erisir 2008 and Shoaib *et al.*, 2016).

The diversity of foods fortified with inulin is great and the concentrations used ranging widely depending on the type of food from 0.75 to 50 percent (González-Herrera *et al.*, 2015). Inulin has become an attractive ingredient in the food industry due to its prebiotic properties as well as unique technological applications for its ability to replace fat in the manufacturing of low-calorie foods (Silva, 1996, Franck, 2000 and Aslam *et al.*, 2015). Inulin cannot be digested by human digestive enzymes due to the presence of  $\beta$ -2-1 fructosyl linkages; however, they can be fermented by the beneficial bacteria in the colon (Mudannayake *et al.*, 2015). When inulin is mixed with the foods, it forms smooth creamy mouthfeel as fat (Niness, 1999 and Franck, 2000).

Much evidence suggests that increases in obesity and overweight were related to the increases in fat and caloric intake (Cutler *et al.*, 2003, Neuhouser *et al.*, 2004 and Philipson and Posner, 2008). Reducing fat in every-day diet has become a public health issue and a concern for most consumers (Barber *et al.*, 2016). Moreover, Akoh, 1998 and Zoulas *et al.* (2002) stated that, high fat intake is associated with increased risk for obesity and some types of cancer, and saturated fat intake is associated with high blood cholesterol and coronary disease.

In bakery products, fats and oils offer various positive functional attributes in baking products. Textural properties of these products are significantly influenced by fats and oils and combined result of their physical, chemical, functional and rheological properties (Devi and Khatkar, 2016). Fat provides the highest energy value of all major food constituents, fat substitution by other ingredients is a great challenge, especially in bakery products, as they can contain high levels of fat (Felisberto *et al.*, 2015). Fat, also, interacts with other ingredients to develop and texture, mouthfeel, overall sensation of lubricity of the product and it adds a rich quality to cookies (O'Brien, 2003 and Zahn *et al.*, 2010).

Cookies are widely accepted and consumed in many developing countries. Cookies and biscuits represent the largest category of snack items among baked foods overall the world (Hooda and Jood, 2005 and Ameer *et al.*, 2008). Cookies, especially, are soft-type biscuits whose textural characteristics are mostly provided by their high fat content.

The objectives of this study were to use inulin which extracted from chicory and as a functional ingredient in cookies production and to evaluate the effect of inulin as a fat replacer on physical and sensory characteristics of cookies.

## Materials and Methods

### Materials

*Cichorium intybs* L. var. Nues was sowing at 15 October during successful season 2015/2016, the experimental field carried out at Giza station, sugar crop Res. Inst., Agric. Res. Center at Giza, Egypt. A complete randomized block design was used with four replications; final plant population after thinning was approximately 10 plants /m<sup>2</sup>. Other agricultural practices were follows as usual in chicory field by NPK (60: 30: 36) Kg/fed. The chicory was harvested after 165 days from sowing.

Wheat flour (72% extraction rate) was obtained from South Cairo Company of milling with chemical composition as follow: protein 10.20%, fat 0.79%, ash 0.50%, crude fiber 0.52%, total carbohydrate 87.99%, iron 1.20mg/100g, zinc 0.71mg/100g, calcium 31.5mg/100g, and potassium content 29.3 mg/100g (on dry weight basis). Other ingredients used in this study were purchased from the local market in Cairo, Egypt.

## Methods

### *Yield and quality parameter*

1. Handing harvest, topping, counted and weighted obtained roots of each plot for used to calculated root fresh weight plant (g) and root yields (Ton /Fedan).
2. Random samples of 10 roots from each plot was taken and washed by water to remaining soil, roots were cutting into small pieces and dried at 70°C for 48 h in an oven for determine drying matte % and used to calculate root dry yield (Ton/Fedan) as follows = root yield x dry matter%.
3. Inulin was determined using HPLC analysis, the chromatographic equipment consists of a Model LC-20AT pump system (Shimadzu, Japan), a 20-IL sample loop, and a LC solution system which acquires data from the refractive index detector (RID 10A, Shimadzu, Tokyo, Japan). The analytical column which is put to use in this case is Shim-pack SCR 101C from Shimadzu (Tokyo, Japan). Inulin was determined according to the methods described by Wang *et al.* (2010) and calculated inulin yield (ton/fed) as follows = root yield x inulin %
4. Moisture, protein, fat, crude fiber and ash content of raw materials and cookies samples were determined according to the methods described in AOAC (2010). Total carbohydrates content was calculated by difference. Caloric value was calculated according to the following equation (FAO/WHO, 1974): Caloric value = 4 (protein% + Carbohydrate %) + 9 (fat %).
5. Minerals content was estimated by Atomic Absorption Spectrophotometer (model 3300, Perkin-Elmer, Beaconsfield, UK) and digestion according to the procedure outlined by AOAC (2010)

### *Preparation of chicory*

The plant of chicory root was washed with tap water to remove remaining soil and other impurities. The roots were cut into small pieces.

### *Removing of the bitter taste*

Chicory roots pieces were soaked in citric acid solution (0.75 %) at a ratio of 1: 10 (roots: water w/v) 24 hrs. according to Massoud *et al.* (2009). The samples were washed, dried at 40°C for 10 hr. in an electric oven (Gasellsaft for Laboratory, D3006, German), then ground using an electrical mill to pass through 100 mesh sieves and stored in polyethylene bags in freezer at -10 °C until used.

### *Extraction of inulin from chicory*

The extraction process was made by adding hot water to the roots powder, in a 1:2 proportion (roots: water) at the average temperature of  $80 \pm 2$  °C for 1 hr., with constant agitation. The liquid inulin extracts obtained was filtered (Leite *et al.*, 2004). The extracted filtrate was then concentrated according to (Amin, 1997). The concentrated extracted was dried firstly by freezing and water portion separation, then the concentrated portion was dried by oven under vacuum at 40°C to reach a complete dryness.

### *Preparation of cookies*

Cookies dough was prepared according to methods of AACC methods (2000) with some modification using the following recipe: Flour 100g, sugar 30g, shortening 40g, sodium bicarbonate 1g, ammonium bicarbonate 0.5g, salt 1g, dextrose solution 14.6 ml and distilled water. Sugar and fat were creamed till smooth for 3 min. Dough water containing dextrose solution, sodium bicarbonate, ammonium bicarbonate, and salt were mixed and then added into the cream and mixed for 5min to obtain homogeneous cream. Finally, flour was also added and kneaded. The inulin was added as a fat replacer with a ratio (10, 20, 30, 40 and 50%). The dough was rolled out to disks with a diameter 5 cm and thickness 4 mm and baked in the oven at 200 °C for a period up to 7 and 10 min. After baking, cookies were left to cool.

### *Determination of water activity*

Water activity ( $a_w$ ) was measured with a rotronic Hygro Lab EA10-SCS (Switzerland)  $a_w$  meter. The measurements were performed in triplicate.

### *Physical characteristics of cookies*

The cookies were evaluated for diameter (mm), thickness (mm), density ( $\text{g/cm}^3$ ) and spread ratio as described by Gaines (1991). Spread ratio was calculated by dividing the average value of diameter by average value of thickness of cookies.

### *Hardness of cookies*

Cookies hardness was determined using a Texture Profile Analyzer (TPA) according to AACC (2000). Texture was determined by universal testing machine (Conetech, B type, Taiwan) provided with software. Hardness was calculated from TPA graphic in Newton (N).

### *Sensory Evaluation of cookies*

Produced cookies were evaluated for their sensory characteristics after baking by ten panelists from the staff of Bread and Pastry Research Dep., Food Technol. Res. Institute., Agr. Res. Center, Giza. The scoring scheme was established by 10 degree for each as mentioned by Sudha *et al.* (2007) as follows: for tested attributes (appearance, taste, texture, color, flavor and overall acceptability).

### *Statistical analysis*

The data were statistically analyzed by the least significant differences value (LSD) at 0.05 probability level as the procedure of Snedecor and Cochran (1980).

## **Results and Discussion**

### **Yield and quality parameters for Nues variety of chicory root:**

Data presented in Table (1) shows the obtained yields of fresh and dry root, and inulin yield of variety Nues. Data in this Table indicate that such variety produced high yields of fresh and dry root as well as inulin yield. These results are in line with those obtained by De Leenheer (1996), Meehye and Shin, (1996), Massoud *et al.* (2009) and Shoorideh *et al.* (2016)

Therefore from yield component of Nues chicory root variety it's clearly economically for the possibility nutritional and therapeutic use of its extracts in industrial food thus it was used as application in cookies produce.

**Table1:** Yield and quality parameters of Nues chicory root variety

Yield parameters	
Yield of fresh root	10.56 Ton/Fed
Yield of dry root	2.76 Ton /Fed
Average root fresh weight/plant	0.254 kg
Inulin yield	2.54 Ton/Fed
Quality parameters	
Inulin %	92.19
Dry matte %	26.1
Moisture content %	73.90

## Chemical analysis of inulin

Data presented in Table (2), show the chemical analysis of the extracted inulin. It was obviously clear that inulin had a high concentration of total carbohydrates and low level of protein, fat, ash and crude fiber. Moreover, minerals content of inulin was 0.31mg zinc (Zn)/100g, 0.89 mg iron (Fe)/100g, 34.75mg calcium (Ca)/100g, and 31.59 mg potassium (K)/100g.

These results are in agreement with those reported by Mudannayake *et al.* (2015) who reported, the inulin (which was extracted from commercial chicory) contained a protein content of 0.43%, fat 0.33% and total carbohydrate 97.56%. It was, also, reported that inulin (which was extracted from commercial chicory) had a protein amount of 1.58% and ash of 1.19% (Bouaziz *et al.*, 2014). The differences in the composition and minerals content may be due to chicory variety, the cultivar of chicory and methods of inulin extraction.

**Table 2:** Chemical analysis of inulin extracted from Nues chicory root Variety.

Constituents (%)	Inulin
Moisture	4.82
Protein*	0.57
Fat*	0.52
Ash*	0.63
Crude fiber*	0.81
Total carbohydrate*	97.47
Minerals (mg/100g)*	
Zinc (Zn)	0.31
Iron (Fe)	0.89
Calcium (Ca)	34.75
Potassium (K)	31.59

\*On dry weight basis

## Chemical analysis of produced cookies

Data in Table (3) showed that, the chemical analysis of cookies manufactured by inulin as a fat replacer at levels of 10, 20, 30, 40 and 50%, in relative to the control sample. The results showed that, all total cookies samples had lower moisture content, ranged from 3.82 to 3.24%, than the control (3.94%). Such decrease in moisture may be due to the levels of substitution of inulin. According to Bertagnolli *et al.* (2014), cookies with low moisture content will have longer shelf life conditions. Control cookies samples, also, had the highest value of protein, fat, fiber and the lowest value of total carbohydrate.

There was a slight reduction in protein by replacing fat with inulin as a fat replacer in cookies. The fat was decreased as the percentage of the fat replacer increased. The fat content in the cookies were 22.24, 20.40, 18.01, 16.76, 14.63 and 12.04% in the samples contained fat replacement levels of 10, 20, 30, 40 and 50%, respectively. Crude fiber and ash contents, also, were slightly increased as a result of increasing fat replacement level. The crude fiber content of the resultant cookies ranged from 0.47 to 0.56%, while ash content ranged from 1.18 to 1.24%. All cookies formulated with the different levels of fat replacer under investigation were found to have higher values of total carbohydrate than the control cookies. This may be due to the high amount of carbohydrates in inulin as reported by Mudannayake *et al.* (2015).

As a result of the aforementioned changes in the chemical analysis of cookies associated with the use of the tested fat replacer, the caloric values, of cookies produced using inulin as a fat replacer were lower than the control cookies. Replacing 10, 20, 30, 40 and 50% of fat with inulin resulted in reductions of 1.78, 4.23, 5.50, 7.63 and 10.42% in caloric value of cookies, respectively. These results agreed with those obtained by Drewnowski *et al.* (1998) reported that reducing the fat content in cookies would reduce total calories. Decreasing the amount of fat added to cookies is a good way to obtain a healthier and lower-calorie product. Moreover, the results showed that all samples of

produced cookies had slight higher values of minerals (Fe, Zn, and Ca) and a slight reduction in (K) in replaced fat (by inulin) sampled in relative to the control sample

**Table 3:** Chemical analysis of cookies prepared by different amount by the extracted inulin as a fat replacer.

Constituents (%)	Cookies samples					
	Control	10%	20%	30%	40%	50%
Moisture content	3.94	3.82	3.75	3.49	3.38	3.24
Protein*	7.98	7.96	7.92	7.90	7.87	7.83
Fat*	22.24	20.40	18.01	16.76	14.63	12.04
Ash*	1.18	1.18	1.19	1.20	1.21	1.24
Crude fiber*	0.45	0.47	0.49	0.52	0.54	0.56
Total carbohydrate*	68.15	69.99	72.39	73.62	75.75	78.33
Total energy (kcal/100g)	504.68	495.24	483.33	476.92	466.15	453
Caloric reduction compared to the control	-	1.87	4.23	5.50	7.63	10.24
Minerals (mg/100g)*						
Fe	0.87	0.88	0.90	0.92	0.94	0.94
Zn	0.71	0.74	0.76	0.76	0.78	0.91
Ca	71.50	72.15	72.76	73.47	74.13	74.80
K	43.06	42.32	41.51	40.78	40.03	39.27

\*On dry weight basis

### Physical properties of produced cookies

Fat is one of the principal ingredients that affect cookies texture. Substitution of fat with other ingredients had a greater impact on textural attributes of cookies than the replacement of sugar or flour as reported by Campbell *et al.* (1994).

Data in the Table (4) showed the effect of using the crude extracted inulin as fat a replacer at levels of 10, 20, 30, 40 and 50% on physical properties of cookies. The results showed that, the values of diameter and thickness in all samples of cookies result in a slight decrease as increasing the inulin amount as a fat replacer. The changes in diameter and thickness were reflected, also, in the spread ratio of cookies. The spread was 8.45 for control cookies and a slight decrease with increasing inulin ratio as a fat replacer was detected. Similar results were observed by (Sudha *et al.*, 2007, Pareyt and Delcour 2008, and Pareyt *et al.*, 2009) who found that, where an increase in fat level in biscuits was generally associated with higher spread rate due to the increased mobility in the system when fat melts and lubrication of the structure by coating the matrix during baking and gave soft structure doughs. Hence, fat reduction in the formulation made flour components more accessible to the water.

**Table 4:** Physical properties of cookies with inulin as a fat replacer.

Samples	Diameter (D) (mm)	Thickness (T) (mm)	Spread ratio D/ T	Density (g/cm <sup>3</sup> )	Hardness (N)	Water activity (a <sub>w</sub> )
Control	55.80	6.60	8.45	0.60	23.90	0.258
10%	54.90	6.60	8.32	0.59	24.65	0.249
20%	53.70	6.55	8.19	0.58	25.98	0.241
30%	52.80	6.53	8.09	0.56	28.90	0.238
40%	52.10	6.52	7.99	0.56	31.30	0.237
50%	51.50	6.50	7.92	0.54	36.60	0.230

The density of the cookies, decrease gradually from 0.59 to 0.54 g/cm<sup>3</sup>. According to hardness data showed that, the hardness of the cookies were increased by increasing substitution with inulin as a fat replacer from 10 to 50% compared to the control sample. These results agreed with Zoulias *et al.*, (2002) and Żbikowska and Rutkowska (2008) who reported that high values of shear force (which

indicated hardness) is an unpleasant attribute for such type of product. The hardness, also, increased as percentage replaced fat increased. It was referred that this increase to the structure was less aerated and had more compact crumb in high fat replacer formula (Rodríguez-García *et al.*, 2013).

In addition, the water activity ( $a_w$ ) of the cookies ranged from 0.249 to 0.230. They were much lower than the limit of water activity for spoilage by bacteria, yeasts and molds, approximately 0.90, 0.85-0.88, and 0.80, respectively; the rate of chemical reaction in food decreases much more slowly with reduced moisture content, and enzymatic activity in foods may be significant at water activities as low as 0.30 as reported by Inglett *et al.* (2014).

### Sensory evaluation of cookies

Flavor, texture and appearance are the main quality attributes of cookies. Fat is a very important ingredient of cookies because it contributes to the texture and pleasing mouthfeel and additionally positively impacts flavour intensity and perception (Zoulias *et al.*, 2002). Sensory evaluations for the cookies attributes substituted with different level of inulin as a fat replacer are illustrated in Table (5).

Data in Table (5) showed that, the appearance and color of cookies were not significantly affected when replacing up to 40% of fat with inulin without any adverse effect. Texture and taste decreased significantly with increasing the high level of substitution, but there are no significant differences between control cookies and cookies with fat replacement levels up to 30%. Regarding the flavor, it was found that replacing up to 50% of fat in cookies did not significantly influence the flavor of cookies. With respect to overall acceptance confirmed lower of cookies in the case when 50% of fat replaced with inulin. Moreover, Zoulias *et al.* (2002) reported that the organoleptic limit for the fat replacement in cookie formulation was 50% because of the decreasing of the overall quality. On the other hand, Drewnowski *et al.* (1998) reported that the acceptability rating of sensory panels in the perception of fat in cookies are relatively unaffected by a 25% reduction of fat.

**Table 5:** Sensory evaluation of cookies with inulin as a fat replacer

Samples	Appearance (10)	Color (10)	Texture (10)	Taste (10)	Flavor (10)	Overall acceptance (10)
Control	9.50 <sup>a</sup> ±0.11	9.50 <sup>a</sup> ±0.05	9.60 <sup>a</sup> ±0.08	9.50 <sup>a</sup> ±0.11	9.40 <sup>a</sup> ±0.10	9.47 <sup>a</sup> ±0.05
10%	9.47 <sup>a</sup> ±0.03	9.48 <sup>a</sup> ±0.11	9.56 <sup>a</sup> ±0.03	9.45 <sup>ab</sup> ±0.08	9.30 <sup>a</sup> ±0.11	9.34 <sup>ab</sup> ±0.09
20%	9.41 <sup>a</sup> ±0.05	9.45 <sup>a</sup> ±0.02	9.48 <sup>ab</sup> ±0.03	9.39 <sup>ab</sup> ±0.04	9.30 <sup>a</sup> ±0.11	9.34 <sup>ab</sup> ±0.09
30%	9.38 <sup>a</sup> ±0.04	9.37 <sup>ab</sup> ±0.08	9.48 <sup>ab</sup> ±0.01	9.33 <sup>ab</sup> ±0.06	9.30 <sup>a</sup> ±0.05	9.30 <sup>abc</sup> ±0.01
40%	9.30 <sup>ab</sup> ±0.02	9.30 <sup>ab</sup> ±0.05	9.34 <sup>b</sup> ±0.02	9.19 <sup>bc</sup> ±0.06	9.26 <sup>a</sup> ±0.08	9.30 <sup>abc</sup> ±0.01
50%	9.15 <sup>b</sup> ±0.04	9.00 <sup>b</sup> ±0.23	9.24 <sup>bc</sup> ±0.02	9.00 <sup>c</sup> ±0.01	9.22 <sup>a</sup> ±0.05	9.11 <sup>c</sup> ±0.05

\*Values are means of ten replicates ± SD, number in the same column followed by the same latter are not significant at 0.05 level.

### Conclusion

From the above evaluation, it could be concluded that chicory is a good source for effectively inulin extraction as a fat replacer to formulate cookies in order to reducing caloric values, and to be suitable for all people who need to reduce fat. Additionally, such products could be considered to be beneficial to health when consuming.

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