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Utilization of Eggshells By-Product as A Mineral Source for Fortification of Bread Strips

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ABSTRACT

Eggshell powder can be used as an attractive source of calcium) Ca (in human diet .Therefore, this work was done to compare different kinds of eggshells) white chicken) WC ,(brown chicken) BC ,(duck and quail .(The proximate chemical composition and mineral content of different eggshells were determined .In addition ,the influence of eggshell powders supplementation 10 ,5) and 15% (on minerals content, physical and sensory properties of bread strips was studied .The obtained results indicated that ,the content of ash was 96.67 95.99 ,96.18 ,and % 93.42 for WC ,BC ,duck and quail eggshells, respectively .The duck eggshell contained the highest calcium content followed by quail ,WC and BC eggshells .Meanwhile , quail eggshells exhibited the highest magnesium) Mg (content followed by BC ,WC and duck eggshells .Addition of eggshell powders led to a noticeable increase of Ca ,Mg contents and water absorption ratio in the supplemented bread strips .Moreover , minor changes in sensory properties of bread strips were recorded by judges .The obtained data revealed that ,we can recommend the possibility of using eggshell powders as dietary calcium supplement to fortify bread at home up to %10 level .Also ,the lack of information on the using of eggshell suggests that there is a promising area to be discovered.

Keywords: Minerals, eggshells, bread strips.

INTRODUCTION

Agro-industrial by-products such as, the bird's eggshells are a renewable resource. In many countries of the world, egg products companies and some food manufacturers that use egg in their products for example, baked products, mayonnaise and so on, produce tons of waste eggshells, which their final destiny is an environmental impact challenge. The annual production of egg produced in Egypt during the year of 2016 was 510000 ton (M.A.L.R., 2016). The role of eggshell (the external layer of a hard-shelled egg) in egg is to protect and provide nutrients to the enclosed embryo. It was used, on a very low scale, as a food additive by humans for a long period (Solomon, *et al*. 1994).

Eggshell represents approximately eleven percentage of the whole egg weight and is a rich source of mineral salts, mainly calcium carbonate, which corresponds to about 94 percentage, moreover it contains about one percentage magnesium carbonate, one percentage calcium phosphate and four percentage organic substances, although these percentages can differ depending on source of eggshell (Thapon and Bourgeois, 1994). Therefore, the proximate amount of eggshells produced in Egypt during the year of 2016 is 56100 ton.

Burley and Vadhera (1989) studied the chemical composition of eggshell and stated that, the content of moisture, protein, lipids and inorganic salts were 1.66, 6.40, 0.03 and 91.1 %, respectively. Moreover, Shaafsma *et al*. (2000) evaluated the minerals content in commercially available Solvakian eggshell powder and 401±7 (mg Ca /g) was found and concluded it can be used as a calcium source in human nutrition.

Broadus (1996) reported that, the calcium is main minerals needed for human body health in many physiological processes and for keeping bone tissue density during the human life. Calcium carbonate salt, which is the main salt in eggshell, is the most commonly used calcium (Ca) salt because 40% of the compound is well absorbed (Karkkainen *et al*. 1997). The percentage of calcium absorption from eggshell is greater than that absorbed from dried milk solution (Oguido *et al*. 1995). The possibility of rats to absorb and utilize calcium from diet fortified with different calcium sources including, calcium citrate, calcium lactate, oyster-shell meal and eggshell meal, were studied by (Bao *et al*. 1998). They reported that, all tested calcium sources exposed a very high absorbability and utilizability. A study by Dutch researchers reported that, the eggshell calcium (supported with the vitamin D and magnesium) has a good effect on the density of bone minerals. Where, after one year, the group supplemented with eggshell showed noticeable increases in the density of bone in their hip bones. Additionally, Japanese studies recognized the best combination of eggshell calcium and vitamin D_3 for the building of bone. Accordingly, any source of egg (goose, chicken, duck and so on) can be used, but it is better to use bio or certified organic eggs.

Calcium deficiency in the diet is a main problem. Calcium intake from dairy products is a suitable way to realize calcium requirements. Nevertheless, people don't usually consume them in the amounts established by clinical guidelines. Supplementation with tablets is expensive and sometimes includes problems of adherence to treatment. Chicken eggshell is a source of calcium carbonate, which is found at home and can be used as calcium supplementation (Brun *et al*. 2013).

Egg products industries in Egypt produce great amount of shells, which are a rich source of mineral salts, mainly calcium carbonate, and their final destiny is an environmental impact challenge. The lack of information on these subjects suggests that there is a promising area to be explored. Therefore, this work was planned to prepare and evaluate calcium carbonate from different kinds of eggshells, because it has a potential application in the development of a novel option of functional foods. In this context, the main objectives of this work were to compare between the chemical composition and minerals content of eggshell powders from WC, BC, duck and quail. In addition,

supplementation of bread strips with eggshell as calcium source at home.

MATERIALS AND METHODS

Materials:

Freshly white and brown chicken eggshells were obtained from Ritaj sweets factory, Baltim, Kafr-Elsheikh Governorate, Egypt. While, duck and quail eggshells were obtained from homes. All eggshells were stored at 4˚C in polyethylene bags till needed. Wheat flour (72% extraction), sugar, milk, salt, baking powder and butter were purchased from local market, Baltim, Kafr-Elsheikh Governorate, Egypt. All chemicals of study were obtained from El- Gomhoria Company for chemicals and drugs, Tanta, Egypt.

Methods:

Eggshell powder preparation:

Eggshell powders were prepared according to Hassan (2015) with a slight modification. Eggshells were washed twice in a warm water and shell membrane was removed. Eggshells were boiled in water for 45 minutes to destroy the harmful bacteria, dried in an air oven at 80˚C for two hours. The dried eggshells were broken to small pieces, and milled into a fine powder in a food brown grinder. The powders were sifted in a 50 mech sieve and collected fine powdered eggshells were stored in polyethylene bags in a dry place, like the kitchen cupboard, till needed.

Proximate chemical composition of different kinds of eggshell powders:

Moisture, ether extract, crude protein, ash and crude fiber contents of eggshell powders were determined using the methods outlined in the A.O.A.C. (2005). Total carbohydrates were calculated by difference.

Determination of minerals content of eggshell powders and bread strips:

Minerals were determined according to (Chapman and Pratt, 1978). After wet ashing, the magnesium (Mg), zinc (Zn) and manganese (Mn) contents were determined using the atomic absorption spectrophotometer (Zeiss FMD3). Calcium (Ca), sodium (Na) and potassium (K) were determined using a flame photometer.

The preparation of bread strips:

Dough was prepared using the method described by Strenhagen and Hosney (1994). Eggshell powders were replaced with the wheat flour (72 % extraction) at different levels 5, 10 and 15%. Then, all dried ingredients were mixed well for 20 min. The dough prepared with wheat flour and eggshell mixtures were baked at 275˚C for 30 minutes. After baking, bread strips were allowed to cool at room temperature before analysis. The control was prepared with the same contents without eggshell powders.

Sensory evaluation of prepared bread strips:

Bread strips containing different eggshell powders and control bread strips were sensory tested in Food Technology Department, Faculty of Agriculture, Kaferelsheikh University, Egypt. For their color, appearance, odor, texture, taste and overall acceptability on a 1 to 10 hedonic scale as described by Meilgaard *et al*. (2007).

Statistical analysis:

All results were examined to analysis of variance by one-way ANOVA using Sigma Stat (v.3.5. Systat Software Inc.). The significant difference between the means of treatments was determined at the $P \leq 0.05$ level by Duncan's new multiple range test (Steel and Torrie, 1981).

RESULTS AND DISCUSSION

Proximate chemical composition of different kinds of eggshell powders:

The raw eggshells from different sources were chemically analyzed for their contents of moisture; protein; ether extract; ash and crude fiber. Total carbohydrates were calculated by difference. Data illustrated in Table (1), showed the proximate chemical composition of different types of eggshell powders used in this study.

It is clear from the table that, white chicken eggshell powder contained the highest values in ash and protein compared to other eggshells, where the content of ash was 96.67, 96.18, 95.99 and 93.42 % for WC, BC, duck and quail eggshells powders, respectively. Moreover, a slight difference between brown and white eggshells in the ash content was found. Form the same Table, it could be noticed that, the content of protein in white and duck (3.17 and 2.95%) eggshell was higher than brown one (2.69%). These results differ from those of Walton *et al*. (1973); Burley and Vadhera (1989) and Hassan (2015). They reported 91.1, 91.4, 90.2 and 7.56, 6.4, 5.4 % for ash and protein, respectively. Burley and Vadhera (1989) and Hassan (2015) reported that, the differences may be related with the differences of eggshell sources and nutrition of birds.

Table 1. Proximate chemical composition of different kinds of eggshell powders (% on dry weight basis).

Components (g/100g)	Eggshell powders			
	White chicken	Brown chicken	Duck	Quail
Moisture	0.95±0.12^{ab}	1.09±0.26^{a}	0.76±0.15^{b}	1.02±0.16^{a}
Crude protein	3.17±0.32^{a}	2.69±0.21^{b}	2.95±0.29^{b}	3.54±0.12^{a}
Fat	0.06±0.02^{a}	0.06±0.01^{a}	0.05±0.02^{a}	0.04±0.01^{a}
Ash	96.67±0.4^{a}	96.18±0.71^{a}	95.99±0.16^{a}	93.42±1.66^{b}
Crude fiber	0.002±0.00^{b}	0.003±0.00^{a}	0.002±0.00^{b}	0.003±0.00^{a}
*Carbohydrates	0.098±0.0^{b}	1.06±0.01^{b}	1.0±0.00^{b}	2.99±0.01^{a}

- **Values followed by different letter in row are significantly different at p ≤ 0.05.**
- **Each value is an average of three determinations.**

*** Total carbohydrates were calculated by subtracting protein, ash and ether extract from the total mass of 100.**

Minerals content of different kinds of eggshell powders:

Minerals content of white and brown chicken, duck and quail eggshell powders were analysed and the results are presented in Table (2). The obtained results revealed that the four-different eggshells used in this work may provide a significant amount of minerals to meet the human mineral requirements (Recommended Dietary Allowance). Inorganic elements detected in studied eggshell powders included primarily Ca, K, Mn, M

Table 2. Minerals content (mg/g) of white chicken, brown chicken, duck and quail eggshell powders.

Minerals (mg/g)	Eggshell powders			
	White chicken	Brown chicken	Duck	Quail
Ca	113	108	171	116
K	0.456	0.366	0.261	0.639
Mn	0.0112	0.0030	0.0028	0.0032
Mg	3.800	5.000	1.885	11.160
Na	1.694	1.894	2.092	2.076
Zn	ND*	ND	ND	ND

ND*: Not detected

It is clear from the results in Table (2) that minerals content in eggshell powders varied due to the source of eggshell. Calcium was the highest content among the other elements and it was ordered from the highest to lowest as follows: 171, 116, 113 and 108 mg/g for duck, quail, white and brown eggshells, respectively. Walton *et al.* (1973) reported that, the minerals content of eggshell was 36.4% calcium, 0.002% iron, 0.097% potassium, 0.398% magnesium, and 0.116% phosphorus. While, 385 and 225.35 mg Ca/g eggshell were reported by Schaafsma *et al.* (2000) and Siulapwa *et al.* (2014), respectively. Furthermore, Hassan (2015) stated that the chicken eggshell powder had 35080, 262, 13.06, 145.1, 4.1 and 149.9 mg/100g for Ca, Mg, Fe, Zn, Cu and Mn, respectively. At the end, it is noticed in the Table (2) that, the least minerals constituent in eggshell powders were manganese, potassium, sodium and magnesium.

Sensory evaluation of bread strips:

The produced bread strips control and supplemented by different kinds of eggshell powders were estimated for organoleptic characteristics by 20 trained judges (Table 3). The average scores for color, taste, odor, texture and overall acceptability of un-supplemented bread strips (control) were 8.2, 7.9, 7.9, 8.4 and 8.1, respectively. The results in this Table (3) also revealed that, no significant differences were detected between control sample and bread strips which supplemented with 5, 10 and 15%, of different kinds of eggshell powders, in sensory properties. Salem *et al.* (2012) studied the influence of eggshell powder addition 10 and 20% as a source of calcium fortification on sensory properties of butter cake. They reported that, no statistically significant differences were detected between unfortified cake and cake fortified with 10% and 20% eggshell for color and overall acceptability, whereas, significant differences in texture, odor, taste and appearance were found.

Table 3. Sensory evaluation of bread strips fortified with different kinds of eggshell powders.

Samples	Sensory properties				
	Color	Taste	Odor	Texture	Overall acceptability
Control	8.2 ± 1.5^{ab}	7.9 ± 1.5^{a}	7.9 ± 1.4^{a}	8.4 ± 1.8^{a}	8.1 ± 1.1^{ab}
White eggshell 5%	9.2 ± 1.1^{a}	8.4 ± 1.7^{a}	8.6 ± 1.4^{a}	9.0 ± 1.1^{a}	9.1 ± 1.3^{a}
White eggshell 10%	8.6 ± 1.0^{ab}	8.1 ± 1.5^{a}	8.5 ± 2.0^{a}	8.7 ± 1.2^{a}	8.6 ± 1.1^{ab}
White eggshell 15%	8.2 ± 1.3^{ab}	7.6 ± 1.7^{a}	8.2 ± 1.4^{a}	8.1 ± 1.5^{a}	8.4 ± 1.4^{ab}
Brown eggshell 5%	8.7 ± 1.3^{ab}	7.6 ± 1.9^{a}	7.4 ± 2.0^{a}	7.8 ± 1.6^{a}	8.2 ± 1.9^{ab}
Brown eggshell 10%	8.3 ± 1.6^{ab}	7.8 ± 1.7^{a}	8.1 ± 1.5^{a}	8.5 ± 1.4^{a}	8.2 ± 1.5^{ab}
Brown eggshell 15%	8.6 ± 1.6^{ab}	7.8 ± 1.6^{a}	7.8 ± 1.2^{a}	8.3 ± 1.5^{a}	8.3 ± 1.4^{ab}
Duck eggshell 5%	8.2 ± 1.6^{ab}	8 ± 1.70^{a}	8.2 ± 1.6^{a}	8.2 ± 1.6^{a}	8.3 ± 1.6^{ab}
Duck eggshell 10%	7.3 ± 1.8^{b}	7.6 ± 1.8^{a}	8.0 ± 1.6^{a}	7.9 ± 1.7^{a}	7.3 ± 1.6^{b}

- **Values followed by different letter in row are significantly different at $p \leq 0.05$.**
- **Each value is an average of three determinations.**

Brun *et al*. (2013) found that the best way to use the eggshell of chicken as calcium dietary source is powdered to add to pizza, bread or spaghetti as there were small changes in texture and no changes in flavor. The sensory evaluation also indicated similarity of crispiness, flavor and taste profiles until 10 % levels of the same calcium source. On the other hand, in case of using a higher level, a stronger fishy smell was observed (Swiatkiewicz *et al*., 2015).

The influence of addition (10 and 20%) eggshell powder on dough rheology of cake compared to control were studied by (Salem *et al*., 2012). They reported that water absorption was increased by increasing of eggshell powder addition. While, dough stability, dough development time and time to breakdown were decreased. Moreover, the effect of added eggshell powder on amylograph properties (begin of gelatinization, gelatinization temperature and gelatinization maximum) of flour .were also studied. The results showed that the eggshell powder addition decreased the beginning of gelatinization comparing to control while gelatinization temperature and gelatinization maximum were increased.

Hassan (2015) studied the chemical composition of biscuits fortified with eggshell powders at different levels (3, 6 and 9%) compared to the control (wheat flour 72%) and they found that the ash content was significantly increased with increasing of addition whereas, protein and lipids contents were slightly decreased.

Effect of fortification of bread strips by eggshell powders on minerals content (mg/g).

Mineral content (mg/g) of control and supplemented bread strips with 5, 10 and 15% eggshell powders are reported in Table (4). The Ca content increased in all supplemented samples by increasing the percentage of eggshell powders added compared to control, in additions some variations in Mg, Na and Mn contents were recorded. These results are in the line with Salem *et al*. (2012) and Hassan (2015), who used the eggshell powders for fortifying butter cake and biscuits. In the same Table, the results exhibited that, the highest increase in calcium content was noted in samples supplemented by duck eggshells. This is due to the highest calcium content of duck eggshell as mentioned above. This may be led to an increase in calcium to phosphorus ratio in the fortified bread strips which favor the probable increase in calcium utilization in humans (Makai and Chudacek, 1991).

Table 4. Minerals content (mg/g) of bread strips fortified with different kinds of eggshell powders (on dry weight basis).

Eggshell powders	Minerals (mg/g)			
	Ca	Mg	Na	Mn
Control	0.245	0.525	1.624	0.0046
White eggshell 5%	28.535	1.295	1.409	0.0054
White eggshell 10%	30.780	1.325	0.823	0.0060
White eggshell 15%	32.900	0.775	0.834	0.0039
Brown eggshell 5%	14.570	1.035	0.861	0.0047
Brown eggshell 10%	15.105	0.640	0.972	0.0043
Brown eggshell 15%	22.030	0.850	1.267	0.0039
Duck eggshell 5%	34.375	1.190	1.329	0.0058
Duck eggshell 10%	38.325	1.390	1.283	0.0056

Effect of fortification of bread strips by different eggshell powders on water absorption ratio:

The effect of eggshell powders supplementation (5, 10 and 15%, chicken and duck eggshells) on the water absorption ratio of produced bread strips was studied and the data are shown in Table (5). Comparing by control, water absorption ratio was increased by increasing eggshell powders addition. This is may be due to the fact that, eggshell powder is hydrophilic filler that can absorb more water (Shuhadah and Supri, 2009). Significant differences were recorded between bread strips supplemented with different kinds of eggshell powders, where bread strips supplemented by white chicken eggshell powders showed the highest increase in the absorption of water (from 2.1 to 2.87 %), while the samples supplemented by duck eggshell powders showed the lowest increase from 0.85 to 1.17% (Table 5).

Table 5. Water absorption ratio (%) of bread strips (on dry weight).

Samples	% Absorption
Control	0.68 ± 0.0^{f}
White eggshell 5%	2.10 ± 0.1^{c}
White eggshell 10%	2.47 ± 0.1^{b}
White eggshell 15%	2.87 ± 0.1^{a}
Brown eggshell 5%	2.10 ± 0.2^{c}
Brown eggshell 10%	2.10 ± 0.0^{c}
Brown eggshell 15%	1.30 ± 0.1^{d}
Duck eggshell 5%	0.85 ± 0.0^{e}
Duck eggshell 10%	1.17 ± 0.1^{d}

Values followed by different letter in row are significantly different at $p \leq 0.05$.
Each value is an average of three determinations.

Water absorption is one of the most important properties of functional properties of crisps, where crisps which absorb more water are very acceptable for consumers. High water absorption of bread decreases the break stress of bread crumb (Zghal *et al.* 2001).

CONCLUSION

It can be concluded that, different kinds of eggshells (white chicken and brown chicken and duck) can used in human nutrition as an inexpensive source of dietary calcium. Addition of different eggshell powders led to a noticeable increase of calcium content in the supplemented bread strips product. Minor slight changes in sensory properties of supplemented bread crisps were recorded. Finally, we can recommend the possibility of using eggshell powders as dietary calcium supplement to fortify bread at home up to 10% level.

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استخدام قشورالبيض كمصدر للمعادن لتدعيم شرائح الخبز

مصطفى على و وليد زكريا بدوى

قسم تكنولوجيا الأغذية ـ كلية الزراعة – جامعة كفرالشيخ

مسحوق قشر البيض يمكن أن يستخدم كمصدر مهم للكالسيوم (كا) في النظام الغذائي البشري. لذلك، تم هذا العمل بمقارنة أنواع مختلفة من قشر البيض (الدجاج الأبيض والدجاج البني والبط والسمان .(تم تقدير التركيب الكيميائي والمحتوى المعدني لقشور البيض المختلفة. وبالإضافة إلى ذلك، تم دراسة تأثير نسب استبدال مساحيق قشر البيض (5 و 10 و 15٪) على محتوى المعادن والخصائص الفيزيائية والحسية لمنتجات الخبز (شرائح الخبز) . أشارت النتائج المتحصل عليها إلى أن محتوى الرماد كان 96,67 ، 96,18 ، 95,99 و 93,42٪ للقشر الأبيض ، البني ، البط والسمان على التوالي. احتوى قشر بيض البط على أعلى نسبة من الكالسيوم يليه قشر بيض السمان ثم الدجاج. بينما، احتوى قشر بيض السمان أعلى محتوى للمغنيسيوم (مغ) يليه قشر بيض الدجاج وقشر بيض البط. إضافة مساحيق قشر البيض أدت إلى زيادة ملحوظة في محتوي الكالسيوم ، المغنيسيوم ونسبة امتصاص الماء في شرائح الخبز المستبدلة. وعلاوة على ذلك، سجل المحكمين تغييرات طفيفة في الخواص الحسية لشرائح الخبز . والبيانات المتحصل عليها كشفت أنه يمكن أن نوصي بإمكانية استخدام مساحيق قشر البيض كنسبة استبدال للكالسيوم لتدعيم الخبز تصل إلى مستوى 10٪. أيضا، عدم وجود معلومات عن استخدام قشر البيض يشير إلى أن هناك منطقة واعدة لاكتشافها.