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WASTE VALORISATION OF CHICKEN EGG SHELLS AND DEVELOPMENT OF FORMULATED BISCUITS WITH EGG SHELL WASTE AS A SOURCE OF DIETARY CALCIUM

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Abstract: *The increased consumption of chicken eggs results in a tremendous volume of egg shell waste, which has an environmental impact. In the node of waste valorisation, egg shells can be utilized as a source of calcium supplementation in various food products. The purpose of this work was to make wheat biscuits supplemented with (1) egg shell powder and (2) calcium chloride extracted from egg shell. The supplemented biscuits were analysed for sensory and proximate analysis. The calcium content in both sources tends to increase, but much higher in calcium chloride formulated biscuits. From sensory scores, biscuits with egg shell powder in 15% and 20% concentrations have more sandy texture and taste, up to 10% concentration is more acceptable. Whereas biscuits with calcium chloride in all concentrations (0.5, 1, 1.5, 2) does not marks any undesirable sensory properties. Conclusively, fortifying biscuits with either egg shell powder or extracted calcium chloride might be an excellent source of calcium without any significant impact on the quality of biscuits.*

Keywords*: waste valorisation, chicken egg shells, calcium supplementation, fortified product.*

1. Introduction

Chicken eggshells are by products of chicken farms, hatcheries, household kitchens, and food processing plants that use eggs in their products. Egg consumption has increased over the years due to cost effectiveness and increased dietary acceptance, which ultimately leads to increase in eggshell waste and the disposals poses serious environmental and health risks [1], The cost of disposal, accessibility of disposal locations, odour, insects, and abrasiveness are further constraints associated with the disposal of the egg shells [2]. As a novel method of waste valorisation, the egg shells waste can be converted into valuable products for the consumption of humans, which could alleviate its environmental impact [3]. Egg shells are excellent source of calcium which has the capability to be utilised by humans [4]. Eggshell calcium is regarded as the finest natural source of calcium, and it has been shown to boost bone mineral density in elderly adults struggling with osteoporosis [5]. Calcium is one of the essential nutrients that is required for metabolic functions, and plays a pivotal role in sustaining bone and teeth health and other normal body functions. Eggshells are the largest source of calcium with an approximate calcium content of 38% [6]. Dairy products are an excellent source of calcium to meet the daily calcium requirement. The recommended intake of calcium ranges from 1200 to 1400 mg/day, which is difficult to meet for those with lactose intolerance. Hence alternate source of calcium is much needed. Chicken egg shells can be the best replacement, ideal

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source of calcium supplementation, which is more easily accessible and cost effective. Egg shells calcium can also be used as a cheap alternative for expensive calcium supplements [4]. [7] Claimed that half of an eggshell might provide individuals with the daily recommended amount of calcium. With an approach to waste valorisation and to provide inexpensive calcium source the current study aims at evaluating the characterization of biscuits supplemented with egg shells powder and Ca Cl_2 extracted from egg shells.

2. Materials and methods

Materials: Commercially available wheat flour (72% extraction), chicken eggs shells and all other necessary baking ingredients sugar, shortening agent, milk powder, baking powder, salt, eggs.

Preparation of eggshell powder: Collected chicken eggshells were demembraned, rinsed with distilled water, boiled in hot water for 10mins to kill pathogens then dried, and made in to fine powder. Powder was dried in oven and autoclaved.

Extraction of Calcium Chloride from Eggshells: Eggshells powder were mixed with a hydrochloric acid solution, left for 3 hr and stirred occasionally until no gas bubbles were observed. The mixture was centrifuged at 3500 rpm for 10 min at 4 °C. The supernatant was removed and heated to 110–115 °C until dried to yield crystals of calcium chloride [8].

Formulation and Preparation of formulated Biscuits: (1) The powdered eggshell was added to wheat flour at various concentrations 0, 5, 10, 15, and 20% as shown in (table 1). (2) The extracted Ca Cl_2 was added to wheat flour at 0, 0.5, 1, 1.5, and 2% as shown in (table 2). Biscuit were prepared according to the creamery method, all the ingredients were blended and the dough is rested for a while. Dough was sheeted using a wooden roller pin and the biscuits were cut into circular shape, and then baked at 220˚C for 15 min in the oven. The biscuits were allowed to cool for 30 minutes, packed, and stored in airtight container for further analysis.

Chemical Analysis: Chemical analysis of wheat flour, egg shell powder and formulated biscuits were determined according the procedures as described by Association of Official Analytical Chemist [9] for moisture, protein, fat, crude fibre, and ash contents Moisture content were determined by using gravimetric method, protein by Kjeldahl method, fat by Soxhlet extraction method, ash by dry ashing method and fibre by enzymatic gravimetric method. All the analyses were carried out in triplicates.

Determination of Mineral Composition: Minerals including iron, calcium, zinc, phosphorus, magnesium were determined using the method described by Association of Official Analytical Chemists [10]. Calcium, magnesium, iron and Zinc were determined using Atomic Absorption Spectrophotometer (Perkin Elmer Model 3300). Sodium and Potassium were determined using the standard flame emission photometer (Jenway Model PFP7).

Sensory analysis of formulated biscuits: Sensory properties of the formulated biscuits were evaluated by twenty five trained panellists. The panellists evaluated biscuits for its colour, odour, taste, texture, flavour, and overall acceptability. Each sensory attribute was rated on a 9 point hedonic scale: extremely liked – 9, very much liked – 8, moderately liked – 7, slightly liked – 6, neither liked nor disliked – 5, slightly disliked – 4, moderately disliked – 3, very much disliked – 2 and extremely disliked – 1 [11].

Table1.

Treatment used in formulation of blend of wheat flour and egg shell powder (%)

Treatment	Wheat flour (g)	Egg shell powder (g)	Sugar (g)	Shortening (g)	Egg (g)	Milk powder (g)	Salt (g)	Baking powder (g)	Vanilla essence (drops)
T0	100	0	60	20	40	5	1	.5	2
T1	95	5	60	20	40	5	1	.5	2
T2	90	10	60	20	40	5	1	.5	2
T3	85	15	60	20	40	5	1	.5	2
T4	80	20	60	20	40	5	1	.5	2

T0 – control biscuits with 100% wheat flour and 0% egg shell powder; T1 – biscuits with 95% wheat flour and 5% egg shell powder; T2 – biscuits with 90% wheat flour and 10% egg shell powder; T3 – biscuits with 85% wheat flour and 15% egg shell powder; T4 – biscuits with 80% wheat flour and 20% egg shell powder.

Table2.

Treatment used in formulation of blend of wheat flour and $CaCl_2$.

Treatment	Wheat flour (g)	Extracted $CaCl_2$ (g)	Sugar (g)	Shortening (g)	Egg (g)	Milk powder (g)	Salt (g)	Baking powder (g)	Vanilla essence (drops)
T0	100	0	60	20	40	5	1	.5	2
T1	99.5	0.5	60	20	40	5	1	.5	2
T2	99	1	60	20	40	5	1	.5	2
T3	98.5	1.5	60	20	40	5	1	.5	2
T4	98	2	60	20	40	5	1	.5	2

T0 – control biscuits with 100% wheat flour and 0% $CaCl_2$; T1 – biscuits with 99.5% wheat flour and 0.5% $CaCl_2$; T2 – biscuits with 99% wheat flour and 1% $CaCl_2$; T3 – biscuits with 98.5% wheat flour and 1.5% $CaCl_2$; T4 – biscuits with 98% wheat flour and 2% $CaCl_2$.

3. Results and discussion

Proximate analysis of wheat flour and eggshell powder: The proximate analysis of commercially available wheat flour and eggshell powder is reported in Table 3. The wheat flour has the highest amount of protein (11.14%) and least amount of ash value (0.84%). These results are consistent with the findings of [12] and [13]. The ash content of egg shell powder records highest (93.26%) and has the lowest fat content (0.03%). The chemical compositions of eggshells were consistent with the analysis by [14].

Table3.

Proximate analysis of wheat and egg shell powder.

components	Wheat (%)	Egg shell powder (%)
Moisture	11.58^a	0.78^b
Protein	11.14^a	2.43^b
Fat	2.01^a	0.03^b
Fibre	0.41^a	nd^b
Ash	0.84^b	93.26^a

[a]indicates the highest value across the same row; nd defines not detected.

Mineral composition of the wheat flour and eggshell powder: The analysed composition of mineral content of wheat and egg shell powder is shown in table 4. The obtained data shows the egg shell powder is mainly composed of calcium (354.17 mg/100g), followed by magnesium. It to be noted the iron content is comparatively higher in egg shell (10.02 mg/100g) than in wheat flour (0.89 mg/100g). [15] Reported values for egg shell powder were similar to the current findings. According to [16] the calcium content in egg shell powder is about (382 mg g^{-1}) which is in closer range.

Table 4.

Mineral composition of wheat flour and egg shell powder.

Minerals (mg/100g)	Wheat flour	Egg shell powder
Ca	52.64[b]	354.17[a]
Mg	78.41[b]	275.14[a]
P	120.14[a]	116.24[b]
Na	43.13[b]	78.24[a]
K	198.74[a]	64.98[b]
Zn	0.66[b]	0.76[a]
Fe	0.89[b]	10.02[a]

[a]indicates the highest value across the same row.

Impact of egg shell powder on the proximate analysis of biscuits: The proximate analysis of the formulated biscuit supplemented with egg shell powder is shown in Table 5. Significant increase in moisture content was observed. Ash content increase with increase in concentration of shell powder, biscuits with 20% shell powder marks higher value (8.03%), which indicates higher mineral content in biscuits. No such significant effects were observed in fat, but a slight depletion in protein and fibre were observed. [17] Reported biscuits supplemented with egg shell powder shows higher ash content.

Table 5.

Proximate analysis of formulated biscuits (wheat flour + egg shells powder).

Treatment	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	Fibre (%)
T0	3.98[e]	6.84[a]	0.45[e]	28.85[a]	0.18[a]
T1	4.83[d]	6.67[b]	2.32[d]	28.77[a]	0.16[b]
T2	5.67[c]	6.03[c]	4.37[c]	27.83[b]	0.15[c]
T3	6.64[b]	5.86[d]	6.97[b]	27.04[c]	0.13[d]
T4	7.09[a]	5.22[e]	8.03[a]	26.93[d]	0.13[d]

[a]indicates the highest value across the same column; [a-e] different letter superscripts in the same column indicate statistical difference of P<0.05; T0 – control biscuits with 100% wheat flour and 0% egg shell powder; T1 – biscuits with 95% wheat flour and 5% egg shell powder; T2 – biscuits with 90% wheat flour and 10% egg shell powder; T3 – biscuits with 85% wheat flour and 15% egg shell powder; T4 – biscuits with 80% wheat flour and 20% egg shell powder.

Impact of egg shell powder on the mineral composition of formulated biscuits: Mineral composition of formulated biscuits is shown in table 6. Biscuits supplemented with egg shell powder increased the minerals content; it is observed that the concentration of calcium, magnesium, sodium, zinc and iron increased significantly, while with reduction of phosphorus and potassium contents. The level of calcium increases predominantly, the values of calcium obtained in this research are in consideration with the recommended daily allowance (RDA) of 1000 to 1300 mg/day. Studies by [14], [18], and [19] discovered a substantial rise in the calcium content of baked goods when eggshell was added.

Table 6.

Mineral composition of formulated biscuits (mg/100g)

Treatment	Ca	Mg	P	Na	K	Zn	Fe
T0	48.14[e]	18.74[e]	78.21[a]	68.12[e]	180.53[a]	0.06[a]	0.27[a]
T1	974[d]	22.08[d]	76.54[b]	113.76[d]	179.22[a]	0.18[b]	0.35[b]
T2	1853[c]	29.34[c]	69.02[c]	149.12[c]	167.59[b]	0.34[c]	0.59[c]
T3	2569[b]	38.69[b]	68.87[c]	158.23[b]	147.84[c]	0.58[d]	0.73[d]
T4	3947[a]	44.12[a]	59.71[d]	169.77[a]	139.02[d]	0.67[e]	0.95[e]

[a]indicates the highest value across the same column; [a-e] different letter superscripts in the same column indicate statistical difference of P<0.05

Impact of $CaCl_2$ on the proximate analysis of biscuits: Proximate analysis of Ca supplemented biscuits was shown in table 7. When calcium chloride was supplemented the moisture content remains in the range as with control T0. Protein, ash, fat and fibre content does not show any significant impact. The most significant effect was observed in the level of calcium, which increased from 48.14 in T0 control to 1243, 2547, 3698, 4729 mg/100g in T1, T2, T3 and T4, respectively.

Table7.

Proximate analysis of $CaCl_2$supplemented biscuits (wheat flour + $CaCl_2$).

Treatment	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	Fibre (%)	Calcium (mg/100g)
T0	3.98^{d}	6.84^{b}	0.45^{b}	28.85^{a}	0.18^{a}	48.14^{e}
T1	4.03^{d}	6.91^{a}	0.45^{b}	28.86^{a}	0.18^{a}	1243^{d}
T2	4.11^{c}	6.79^{c}	0.48^{ab}	28.83^{a}	0.17^{a}	2547^{c}
T3	4.47^{b}	6.80^{bc}	0.51^{a}	28.85^{a}	0.15^{a}	3698^{b}
T4	4.61^{a}	6.77^{c}	0.52^{a}	28.85^{a}	0.15^{a}	4729^{a}

^{a}indicates the highest value across the same column; $^{a-e}$ different letter superscripts in the same column indicate statistical difference of P<0.05; T0 – control biscuits with 100% wheat flour and 0% $CaCl_2$; T1 – biscuits with 99.5% wheat flour and 0.5% $CaCl_2$; T2 – biscuits with 99% wheat flour and 1% $CaCl_2$; T3 – biscuits with 98.5% wheat flour and 1.5% $CaCl_2$; T4 – biscuits with 98% wheat flour and 2% $CaCl_2$.

Sensory analysis of egg shell supplemented biscuits: Sensory score of biscuits supplemented with egg shell powder is shown in figure 1. Sensory analysis of biscuits supplemented with egg shell powder (T1 and T2) showed similar characteristics as control (T0), where as the biscuits containing 15% and 20% egg shells powder, has significant variation in taste, texture and flavour.

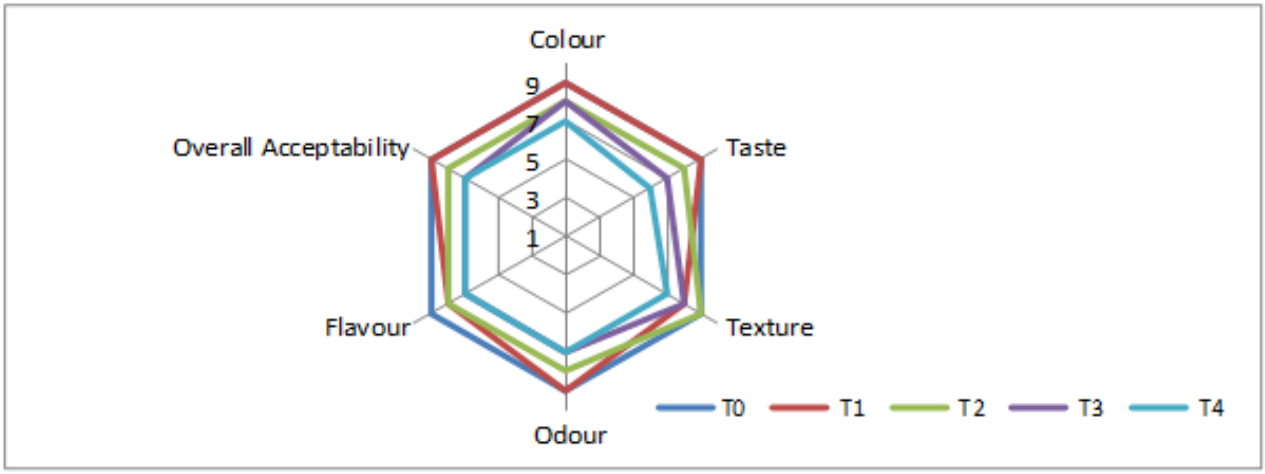

Fig.1. Sensory score of biscuits supplemented with egg shell powder.

Sensory analysis of $CaCl_2$ supplemented biscuits: Sensory score of biscuits supplemented with $CaCl_2$ is shown in figure 2. Sensory analysis of biscuits supplemented with $CaCl_2$ at all concentrations (0.5, 1, 1.5, and 2) showed similarity with control T0. These are no such significant changes in the colour, texture, taste, odour, flavour.

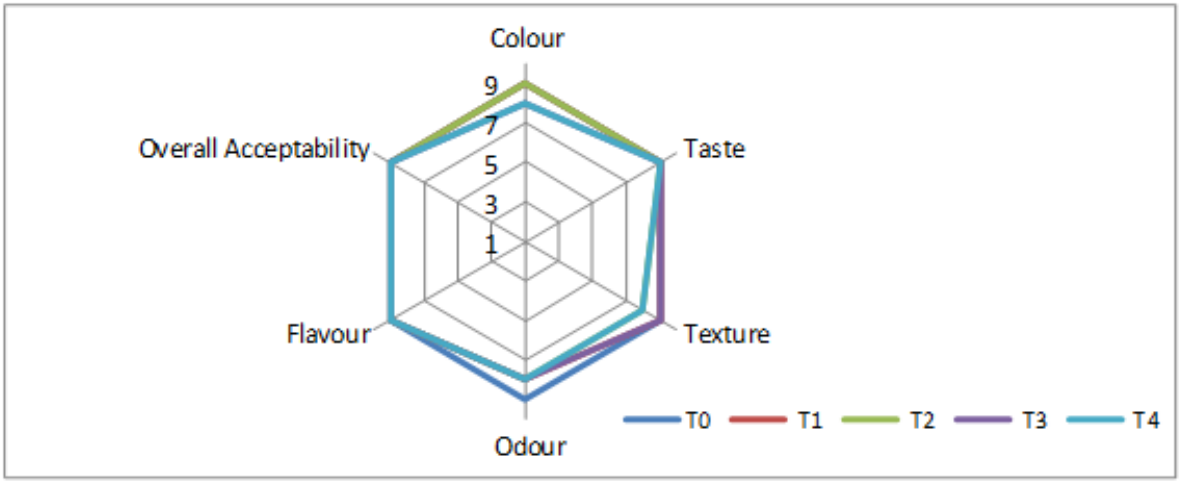

Fig.2. Sensory score of biscuits supplemented with $CaCl_2$.

It to be noted the biscuits containing higher amount of egg shell powder has sandy taste and flavour. Comparing the texture sample T4 had more hardness. With increase in the concentration the colour of the biscuits darkened, Studies by [20] reported that the darkening of biscuits may arise due the reaction between the reducing sugars and the amino acids. Overall acceptability is higher up to 10% supplementation.

4. Conclusion

This study highlighted that both egg shell powder and calcium chloride extracted from egg shell increases the calcium content in the biscuits. On comparison the moisture content in the biscuits supplemented with egg shell powder is higher than biscuit with CaCl2, which may reduce the shelf life of the product. Even though egg shell powder increases the mineral profile other than calcium it may possess the risk of recontamination during storage. Furthermore, the eggshell powder does not have any undesirable sensory attributes up to 10% supplementation and which meets the daily calcium intake up to 1300mg/day. Biscuits containing $CaCl_2$tend to have more calcium as the concentration of $CaCl_2$increases. These findings suggest that both powder and extract can be utilized as a calcium supplement, with the extract being more desirable. Valorization of egg shells reduces waste while also functioning as an inexpensive source of calcium to alleviate calcium deficiency.

5. References

[1]. AJALA E., ELETTA O., AJALA M., OYENIYI S., Characterization and evaluation of chicken eggshell for use as a bioresource, *Arid Zone Journal of Engineering, Technology and Environment*, 14: 26–40, (2018)
[2]. PHIL G. &ZHIHONI M., High Value Products from Hatchery Waste. *RIRDC Publication*, (2009)
[3]. WAHEED, M., YOUSAF, M., SHEHZAD, A., INAM-UR-RAHEEM, M., KHAN, M.K.I., KHAN, M.R., AHMED, N., AADIL, R.M., Channeling eggshell waste to valuable and utilizable products: A comprehensive review. *Trends in Food Science and Technology*, 10: 78–90, (2020)
[4]. WAHEED M., BUTT M.S., SHEHZAD A., ADZAHAN N.M., SHABBIR M.A., SULERIA H.A.R., AADIL, R.M., Eggshell calcium: A cheap alternative to expensive supplements. *Trends in Food Science and Technology*, 91: 219–230, (2019)
[5]. SCHAAFSMA Z., VAN DOORMAL J.J., MUSKIET F.A., HOFSTEDE G.J., PAKAN L. & VANDER V.E., Positive Effects of a Chicken Egg Shell Powder Enriched Vitamin-Mineral Supplement on Femoral Neck Bone Mineral

Density in Healthy Late Post-Menopausal Dutch Women. *Br. J. Nutr*. 87:267-275, (2002)
[6]. RAY, S., BARMAN, A. K., ROY, P. K., & SINGH, B. K., Chicken eggshell powder as dietary calcium source in chocolate cakes. *The Pharma Innovation*, *6*(9, Part A), 1, (2017)
[7]. MILBRADT B.G., MULLER A.L.H., DA SILVA J.S., LUNARDI J.R., MILANI L.I.G., DE MORAES FLORES E.M., CALLEGARO M.D.G.K., EMANUELLI T., Eggshell as calcium source for humans: Mineral composition and microbiological analysis. *Ciencia Rural*, 45: 560–567, (2015)
[8]. THAKUR, R.J., SHAIKH, H., GAT, Y., ROJI B., Effect of calcium chloride extracted from eggshell in maintaining quality of selected fresh-cut fruits. *Int J Recycl Org Waste Agricult* 8 (Suppl 1), 27–36, (2019) https://doi.org/10.1007/s40093-019-0260-z
[9]. AOAC. Association of Official Chemists. Official Methods of Analysis, (15th edition). Arlington, VA. Association of Official Analytical Chemists, USA (2000)
[10]. AOAC. Official methods of analysis, 15th ed. Washington DC: Association of Official Analytical Chemists (2005)
[11]. WICHCHUKIT, S. AND O'MAHONY, M., The 9-point hedonic scale and hedonic ranking in food science: some reappraisals and alternatives. *J. Sci. Food Agric*., 95: 2167-2178, (2015) https://doi.org/10.1002/jsfa.6993
[12]. ALI M.A., HALIM M.A. Bread made from wheat flour and white sesame flour in presences of natural improver. *Pakistan Journal of Nutrition*, 12: 353–355, (2013)
[13]. DAVID, O., ARTHUR, E., KWADWO, S. O., BADU, E., & SAKYI, P., Proximate composition and some functional properties of soft wheat flour. *International Journal of Innovative Research in Science, Engineering and Technology*, *4*(2), 753-758, (2015)
[14]. ALI M., BADAWY W.Z., Utilization of eggshells by product as a mineral source for fortification of bread strips. *Journal of Food and Dairy Sciences*, 8: 455–459, (2017)
[15]. AL-AWWAL, N.Y. AND ALI, U.L., Proximate analyses of different samples of egg shells obtained from sokoto market in Nigeria. *International Journal of Science and Research*, 4(3), pp.564–566, 2015
[16]. BRUN L.R., LUPO M., DELORENZI D.A., DI LORETO V.E., RIGALLI A., Chicken eggshell as suitable calcium source at home. *International Journal of Food Sciences and Nutrition*, 64: 740–743, (2013)
[17]. HASSAN, N.M., Chicken Eggshell Powder as Dietary Calcium Source in Biscuits, (2015)
[18]. ARNOLD, M., RAJAGUKGUK, Y. V., SIDOR, A., KULCZYŃSKI, B., BRZOZOWSKA, A., SULIBURSKA, J., WAWRZYNIAK, N., & GRAMZA-MICHAŁOWSKA, A., Innovative Application of Chicken Eggshell Calcium to Improve the Functional Value of Gingerbread. *International Journal of Environmental Research and Public Health*, *19*(7), 4195, (2022) https://doi.org/10.3390/ijerph19074195
[19]. ZEREK, E., ERSOY, N., & ERSOY, G., Determination of some nutritional and quality properties of eggshell powder added cookies. *Journal of Food Measurement and Characterization*, *16*(5), 3315–3320, (2022) https://doi.org/10.1007/s11694-022-01419-w
[20]. LEE, KYONG-AE & BRENNAND, CHARLOTTE., Physico-chemical, textural and sensory properties of a fried cookie system containing soy protein isolate. *International Journal of Food Science & Technology*. 40. 501 – 508, (2005)