Defence Science Journal, Vol. 67, No. 5, September 2017, pp. 518-522, DOI : 10.14429/dsj.67.11870

Glycemic Index Lowering Effect of Chicken Solids on Corn Starch

Shefali Bhardwaj*, V.K. Shiby, and M.C. Pandey

Freeze Drying and Animal Products Technology Division, Defence Food Research Laboratory, Mysuru - 570011, India
**E-mail: bhardwaj_shefali@yahoo.co.in*

ABSTRACT

Glycemic index lowering effect of chicken solids was studied using a model system approach. Experimental samples were prepared by adding chicken powder at varying levels (10 mg, 20 mg, 30 mg, 40 mg) to 50 mg of corn starch as carbohydrate base. The chicken powder had a proximate protein content of 81.1 per cent, fat 9.1 per cent, ash 6 per cent and moisture 3.7 per cent. *In vitro* starch digestibility and estimated glycemic index (eGI) of the samples were estimated. It was found that only sample B and C could reduce the eGI of the sample by 22.8 per cent and 21.8 per cent respectively, with an eGI value of 68.05 and 68.9 respectively. Samples containing 30 mg and 40 mg chicken powder did not affect the eGI significantly and values were close to eGI values for the control (corn starch alone). It is concluded that chicken solids exhibit a significant ($p < 0.05$) glycemic index lowering effect at a level of 17 per cent to 29 per cent of the formulation, and not linearly with an increase in protein content.

Keywords: Estimated- glycemic index; *In-vitro* starch digestibility; Chicken solids; Protein; Cornstarch

NOMENCLATURE

eGI	Estimated glycemic index
GI	Glycemic index
AUC	Area under the curve
HBV	High biological value
DM	Diabetes mellitus
C	Percentage of starch hydrolysed at time t in min
t	Time (m)
C_∞	Equilibrium percentage of starch hydrolysed at 180 m
K	Kinetic constant
HI	Hydrolysis index

1. INTRODUCTION

Pre-flight meals for long haul flights should be carbohydrate rich, low glycemic foods and should be able to provide sustained energy release for minimum of 5 h - 6 h. These foods must aid in preventing hypoglycaemia. Designer foods incorporating non vegetarian ingredients have not yet been introduced in pre-flight meals for Indian Armed Forces. The addition of chicken solids to a carbohydrate base can make the food more nutritious in terms of protein content and can also exert a glycemic Index lowering effect, which has not been studied extensively.

Carbohydrate constitutes the major part of Indian diets and is considered to be the predominant factor affecting postprandial blood glucose control[1]. Blood glucose response of a food is commonly assessed using the GI[2].

It is defined as the incremental area under the curve (AUC) for the blood glucose response post prandial relative to AUC of a reference food (white bread or glucose) given in an equivalent carbohydrate amount (50 g or 25 g)[3]. It is a ranking of foods and there are three categories of GI foods- low (GI<55), moderate (GI 55-69) and high (GI>70)[4]. A low GI diet is related to be clinically useful for diabetes and hyperlipidemia but is beneficial for general population too[5]. Excess intake of processed carbohydrates leads to a vicious cycle of transient spikes in blood glucose and insulin, after a meal trigger reactive hypoglycaemia and hunger. Repeated consumption of a diet high in processed carbohydrates leads to excess visceral fat, in turn increasing both, insulin resistance and inflammation predisposing to diabetes, hypertension and cardio vascular diseases[5].

The most beneficial and recommended therapy for type 2 DM is to achieve an optimal blood glucose control post-prandial[6]. This can be achieved either by delaying the absorption of glucose or inhibiting its uptake.

Research has shown other factors like fat, protein, GI[7] and processing[8] to have a significant effect on postprandial glucose levels. Minimally processed foods increase post-prandial glucose to a much lesser extent than the processed foods[8]. Lean protein of high biological value (HBV) reduces post-meal glucose level and also improves satiety. Nilsson[9], *et al.* conducted a study in healthy individuals, and reported a decrease in post-prandial blood glucose area under the curve approximately by 56 per cent, upon addition of whey protein to a pure glucose drink. Thus, HBV protein foods like egg whites, fish, skinless poultry breast meat, and whey protein (or other non-fat dairy protein) when consumed with meals, reduce the post-prandial blood glucose response[10].

Among the therapeutic drugs used in prevention of a high blood glucose level, the inhibitors of α –amylase (breaks down

Received : 20 February 2017, Revised : 18 March 2017
Accepted : 25 April 2017, Online published : 19 September 2017

the long-chain carbohydrates) and α-glucosidase, (a membrane-bound enzyme at the epithelium of the small intestine responsible for the cleavage of glucose from disaccharide) are effective in delaying glucose absorption[11,12]. However, it has been difficult to reach an agreement on the continued intake of these inhibitors accounting to the side-effects like flatulence and diarrhoea[13]. Some investigations related to the delay of glucose absorption by food have been made[14].

The inhibition of α-amylase activity, along with α-glucosidase, is considered to be an effective approach for management of type 2 DM or in lowering blood glucose levels post consumption. Researchers have reported effective anti-diabetic compounds from natural materials[15,16], like polysaccharides from tea leaves[17], hydrolysate from sardine muscle[18], is oflavones from soybean[19], egg albumin[20].

Starch digestibility varies among various carbohydrate foods and has attracted much interest in development of low GI foods and in the treatment of type 2 DM[21]. However, there have been mixed reports on effect of protein on reduction of glycemic index or post prandial blood glucose levels. Gullifor[22], *et al.* reported a decrease in the blood glucose level with a diet consisting of 25 g carbohydrate from potato and 25 g protein from tuna fish added as a protein source. A further reduction in the blood glucose after addition of fat was noticed. The difference between the glycemic responses after addition of protein followed by fat was significantly reduced in comparison with the carbohydrate-only diet. Papadaki[23], *et al.* reported no significant effect of protein alone on the glycemic index and concluded that a high protein-low GI diet has its beneficial impact on GI due to its effect on the satiety, weight loss and fat oxidation. Pineli[24], *et al.* developed low GI quinoa milk and suggested the GI to be lowered due to the protein content. Also, protein is reported to have different effect on blood glucose with or without carbohydrate, i.e. 30 mg protein with carbohydrate affects blood glucose[25] but when consumed alone, 75 g of protein is needed to see an effect on blood glucose[26].

The present study was undertaken with an aim to develop a low GI functional food with animal protein. A model system approach has been employed to assess the level or range within which chicken exhibits GI lowering effect. To our knowledge, no such study has been reported where a level is specified within which the protein exhibits the GI lowering effect.

2. MATERIALS AND METHODS

2.1 Materials

Corn starch and boneless chicken were procured from the local market of Mysore, India. Boneless chicken was washed with potable water twice and care was taken to select the lean protein by manually removing fat before further processing. Lean chicken was cooked, minced and dried in a hot air oven at 60 °C - 65 °C for 5 h - 6 h. The dried chicken was ground to a powder using a domestic mixer. The chicken powder was stored in an airtight container till further use.

2.2 Proximate Composition

Moisture content (gravimetric method), protein (Kjedahl), ash (incineration), fat (soxhlet method) were analysed as per standard procedures of AOAC (1995)[27].

2.3 *In-vitro* Starch Digestibility and estimated-Glycemic Index

Five samples were taken and numbered alphabetically from A to E, where A constituted 50 mg corn starch only, B was a mix of 50 mg corn starch +10 mg chicken powder, C was 50 mg corn starch +20 mg chicken powder, D was 50 mg corn starch+ 30 mg chicken powder and E was 50 mg corn starch+ 40 mg chicken powder.

The eGI of the products were determined according to the methodology described by Goñi[28], *et al.* with a few modifications: glucose released was determined using a GOD-POD glucose kit (Erba Manheim, Transasia Bio-medicals Ltd., Solan (HP), India) and the absorbance was measured in a UV/VIS spectrophotometer (Perkin-Elmer Lambda 40 Uv/vis Spectrometer, Massachusetts, United States) at λ=505 nm. Glucose was converted to starch using a multiplication factor of 0.9. Starch digestion rate was expressed through the percentage of starch released at each time (mg/100g sample) (0 min, 30 min, 60 min, 90 min, 120 min, 150 min, and 180 min). The digestion curves were fitted to Eqn. (1):

$$C = C_{\infty}(1 - e^{-kt}) \tag{1}$$

C is percentage of starch hydrolysed at time t in minutes, C_{∞} is the equilibrium percentage of starch hydrolysed at 180 min, and k is the kinetic constant. Every product has its own C_{∞} and k value.

Hydrolysis curves were built (disregarding the value at time 0), and the area under the curve (AUC) was calculated (AUC) as per Eqn. (2):

$$AUC = C_{\infty}(t_f - t_0) - (C_{\infty}/k)[1 - e^{-k(t_f - t_0)}] \tag{2}$$

The hydrolysis index (HI) for each sample was calculated as the ratio between the AUC of sample and the AUC of white bread. Finally, the GI was calculated according to Eqn. (3):

$$GI = 39.71 + (0.549 \times HI) \tag{3}$$

where GI = Glycemic Index; and HI = Hydrolysis Index (per cent).

2.4 Statistical Analysis

The experimental values were fitted to one phase exponential association equation using Graphpad Prism version 5.03 software. Anova, mean and standard deviation were calculated using MS Excel 2010.

3. RESULTS AND DISCUSSION

The prepared chicken powder was analysed for its proximate composition (Table 1). The rate of starch digestibility can be a determinant of the metabolic response to a meal[29]. Evidences prove that slowly digested and absorbed carbohydrates are recommended in the dietary management of metabolic disorders, such as diabetes[30]. Various factors influence the starch digestibility rates, such as the type of starch, protein, physical arrangement and lipids interactions, antinutrients, enzyme inhibitors, isoflavones[21] and food processing[22]. The rate of starch hydrolysis is specific for every product due to one or more reasons, mentioned earlier.

The presence of protein along with an equal amount

Table 1. Proximate composition of chicken powder

Component	Percentage (per cent)
Protein	81± 0.26
Fat	9.2± 0.10
Ash	6± 0.06
Moisture	3.7 ± 0.15

*Values expressed as mean ± S.D., n=3

of starch in each sample, affected the starch digestibility in comparison to sample A (Fig 1). This decrease in the starch digestibility can be accounted to the presence of peptides present in chicken powder. Peptides have been documented to have an enzyme inhibitory effect on α-amylase and α-glucosidase[20]. These enzymes are essential for breakdown of carbohydrates to glucose in the body. Peptides from sardine muscle[20] hydrolyzed using alkaline protease were reported to have similar inhibitory effect on the enzyme activity. Due to this inhibitory activity, these hydrolysates can be utilised successfully in preparation of physiologically functional food, for diabetics. Novel peptides derived from egg white protein have been documented to have inhibitory action against α –glucosidase activity[31] and anti-diabetic activity peptides from albumin against α -glucosidase and α -amylase have also been reported[22]. It is suggested that the inhibition of α-glucosidase results from multiple interactions of peptides with the enzyme[21]. The eGI for all samples have been shown in Table 2, and followed the order A> E>D>C>B. Samples B (eGI 68.05) and C (eGI 68.9) could reduce the eGI of the sample by 22.8 per cent and 21.8 per cent respectively. Sample D and E could reduce the eGI only by 7.6 per cent and 4.6 per cent respectively. The reason for this decrease is attributed to the peptides interacting with the enzymes in multiple ways structurally. (Table 2, Fig. 2).

4. CONCLUSION

The model system approach was employed to understand the GI lowering effect of chicken solids, as no such studies have been reported till date. This study helps to assess the level at which it can be used in development of functional foods with an objective to lower the post prandial blood glucose or be low GI. We conclude that in the functional food formulation, chicken solids at a level of 17 per cent - 29 per cent has maximum eGI lowering effect, and can be employed in the formulations of pre-flight meals. Such a product has a wide spectrum of consumers including diabetics, sports personnel and weight watchers.

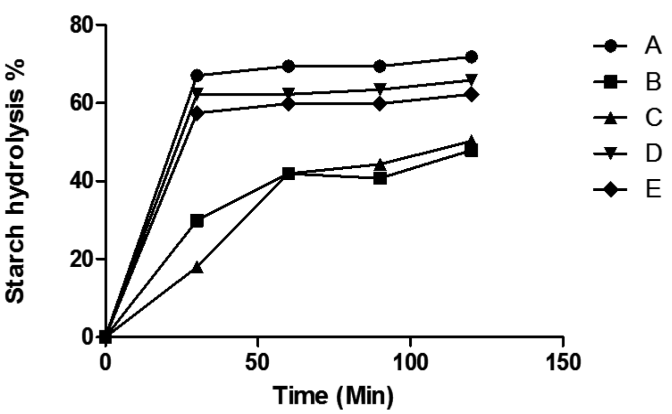

Figure 1. Starch digestibility curve for the samples A to E ; Sample A: 50 mg corn starch alone, Sample B: 50 mg corn starch + 10 mg chicken powder, Sample C: 50 mg corn starch + 20 mg chicken powder, Sample D: 50 mg corn starch + 30 mg chicken powder Sample E: 50 mg corn starch + 40 mg chicken powder.

Table 2. IVSD parameters and eGI of the samples ; Sample A: 50 mg corn starch only or 0 % chicken, Sample B: 50 mg corn starch + 10 mg or 17 % chicken powder, Sample C: 50 mg corn starch + 20 mg or 29% chicken powder, Sample D: 50 mg corn starch+ 30 mg or 38% chicken powder, and Sample E: 50 mg corn starch + 40 mg or 44% chicken powder

Sample	C_∞	k	AUC	HI(%)	*e*GI
A	70.29	0.1015	11960	88.15	88.104
B	46.32	0.0347	7003.8	51.622	68.05
C	60.48	0.0155	7220.3	53.218	68.927
D	60.73	0.0964	10301	75.926	81.393
E	63.87	0.1203	10966	80.823	84.082

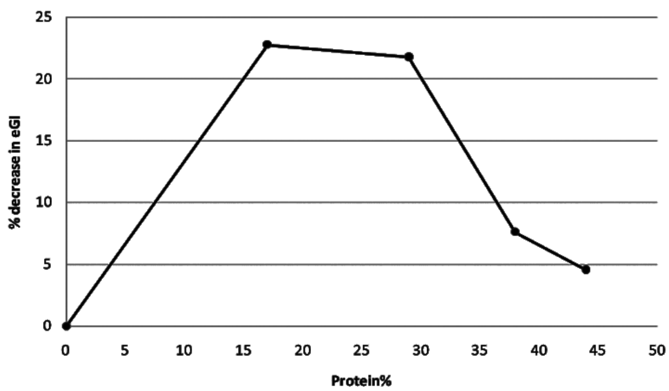

Figure 2. Percentage decrease in eGI values with increase in protein content.

Conflict of Interest : None

REFERENCES

1. American Diabetes Association. Approaches to glycemic treatment. Sec. 7. *In* Standards of Medical Care in Diabetesd 2015. Diabetes Care 2015, 38 (Suppl. 1), S41–S48.
doi: 10.2337/dc15-S010
2. Frei, M.; Siddhuraju, P. & Becker, K. Studies on the in vitro starch digestibility and the glycemic index of six different indigenous rice cultivars from the Philippines. *Food Chemistry*, 2003, **83**, 395–402.
doi: 10.1016/S0308-8146(03)00101-8
3. Brand-Miller, J.C.; Stockmann, K.; Atkinson, F.; Petocz, P. & Denyer, G. Glycemic index, postprandial glycemia, and the shape of the curve in healthy subjects: analysis of a database of more than 1000

foods. *Am J. Clin. Nutr.*, 2009, **89**, 97–105. doi: 10.3945/ajcn.2008.26354

4. Jenkins, D.J.; Wolever, T.M. & Taylor, R.H. Glycemic index of foods: A physiological basis for carbohydrate exchange. *Am J. Clin. Nutr.*,1981, **34**, 362–366.
5. Brand-Miller, J.C.; Hayne, S.; Petocz, P. & Colagiuri, S. Low-glycemic index diets in the management of diabetes: A meta-analysis of randomized controlled trials. *Diabetes Care.*, 2003, **26**, 2261–2267.
6. Stanik, S. & Marcus, R. Insulin secretion improves following dietary control of plasma glucose in severely hyperglycemic obese patients. *Metabolism*. 1980, **29**, 346-350. doi: 10.1016/0026-0495(80)90008-6
7. Bell, K.J.; Smart, C.E.; Steil, G.M.; Brand-Miller, J.C.; King, B. & Wolpert, H.A. Impact of fat, protein, and glycemic index on postprandial glucose control in type 1 diabetes: Implications for intensive diabetes management in the continuous glucose monitoring era. *Diabetes Care,* 2015, **38**, 1008–1015. doi: 10.2337/dc15-0100
8. Jenkins, D.; Kendall, C.; Faulkner, D.; Kemp, T.; Marchie, A.; Nguyen, T.H.; Wong, J.M.; de Souza, R.; Emam, A.; Vidgen, E.; Trautwein, E.A.; Lapsley, K.G.; Josse, R.G.; Leiter, L.A. & Singer, W. Long-term effects of a plant-based dietary portfolio of cholesterol-lowering foods on blood pressure. *Eur J. Clin. Nutr.,* 2008, **62**(6), 781-788. doi:10.1038/sj.ejcn.1602768
9. Nilsson, M.; Holst, J. & Björck, I. Metabolic effects of amino acid mixtures and whey protein in healthy subjects: studies using glucose-equivalent drinks. *Am. J. Clin. Nut.,* 2007, **85**, 996 –1004.
10. Arora, S. & McFarlane, S. The case for low carbohydrate diets in diabetes management. *Nutrition Metabolism,* 2005, **2**, 16-24. doi: 10.1186/1743-7075-2-16
11. Golay, A.; Schneider, H.; Temler, E. & Felber, J.P. Effect of trestatin, an amylase inhibitor, incorporated into bread, on glycemic responses in normal and diabetic patients, *Am. J. Clin. Nutr.*, 1991, **53**, 61-65.
12. Miura, M. & Gomyo, T. Nippon shokuhin kagaku kogaku kaishi, 1996, **43**, 157-163. (in Japanese). doi: 10.1271/bbb.60.2019
13. Toeller, M. Alpha-glucosidase inhibitors in diabetes: efficacy in NIDDM subjects. *Eur. J. Clin. Invest.*,1994, **24**(3), 31-35.
14. Golay, A.; Schneider, H.; Temler, E. & Felber, J.P. Effect of trestatin, an amylase inhibitor, incorporated into bread, on glycemic responses in normal and diabetic patients, *Am. J. Clin. Nutr.*, 1991, **53**, 61-65.
15. Liu, I.M. & Tzeng, T.F. Angelica acutiloba root alleviates advanced glycation end-product-mediated renal injury in streptozotocin-diabetic rats. *J. Food Science*, 2011, **76**(7), H165-H174. doi: 10.1111/j.1750-3841.2011.02310.x
16. Wang, H.; Du, Y.J. & Song, H.C. Alpha-glucosidase and alpha-amylase inhibitoryactivities of guava leaves. *Food Chemistry*, 2010, **123**(1), 6-13. doi: 10.1016/j.foodchem.2010.03.088
17. Xiao, J.; Huo, J.; Jiang, H. & Yang, F. Chemical compositions and bioactivities of crude polysaccharides from tea leaves beyond their useful date. *Int. J. Bio. Macromol.*, 2011, **49**(5), 1143-1151. doi: 10.1016/j.ijbiomac.2011.09.013
18. Matsui, T.; Yoshimoto, C.; Osajima, K.; Oki, T. & Osajima, Y. In vitro survey of alpha-glucosidase inhibitory food components. *Biosc., Biotechnol., Biochem.*, 1996, **60**(12), 2019-2022. doi: 10.1271/bbb.60.2019
19. Niamnuy, C.; Nachaisin, M.; Laohavanich, J. & Devahastin, S. Evaluation of bioactive compounds and bioactivities of soybean dried by different methods and conditions. *Food Chemistry*, 2011, **129**(3), 899-906. doi: 10.1016/j.foodchem.2011.05.042
20. Yu, Z.; Yin, Y.; Zhao, W.; Liu, J. & Chen, F. Anti-diabetic activity peptides from albumin against α -glucosidase and α-amylase. *Food Chemistry*, 2012, **135**, 2078-2085. doi: 10.1016/j.foodchem.2012.06.088
21. Jenkins, D.J.A.; Wolever, T.M.S.; Buckley, G.; Lam, K.Y.; Giudici, S.; Kalmusky, J.; Jenkins, A.L., Patten, R.L.; Bird, J.; Wong, G.S. & Josse, R.G. Low-glycemic-index starchy foods in the diabetic diet. *Am. J. Clin. Nut.*, 1988, **48**, 248-254.
22. Gulliford, M.C.; Bicknell, E.J. & Scarpello, J.H. Differential effect of protein and fat ingestion on blood glucose responses to high- and low-glycemic-index carbohydrates in noninsulin-dependent diabetic subjects. *Am. J. Clin. Nut.,* 1989, **50**, 773-777.
23. Papadaki, A.; Linardakis, M.; Larsen, T.M.; van Baak, M.A.; Lindroos, A.K.; Andreas F.H.; Pfeiffer, J.; Martinez, A.; Handjieva-Darlenska, T.; Holst, M. K.C.; Astrup, A.; Saris, W.H.M. & Kafatos, A. The effect of protein and glycemic index on children's body composition: The DiOGenes randomized study. *Pediatrics*, 2010, **126**(5), e1143-52. doi: 10.1542/peds.2009-3633
24. Pineli, L.d.L.d.O.; Botelho, R.B.A.; Zandonadi, R.P.; Solorzano, J.L.; de Oliveira, G.T.; Reis, C.E.G. & Teixeira, D.D.S. Low glycemic index and increased protein content in a novel quinoa milk. LWT - *Food Sci. Technol.*, 2015. doi: 10.1016/j.lwt.2015.03.094
25. Uthoff, H.; Lehmann, R.; Sprenger, M. & Wiesli, P. Skipping meals or carbohydrate-free meals in order to determine basal insulin requirements in subjects with type 1 diabetes mellitus? *Exp. Clin. Endocrinol Diabetes*, 2010, **118**, 325-327. doi: 10.1055/s-0029-1241199
26. Paterson, M.A.; Smart, C.E.; Lopez, P.E.; McElduff, P.; Attia, J.; Morbey, C. & King, B.R. Influence of pure protein on postprandial blood glucose levels in individuals with type 1 diabetes mellitus. *Diabetic*

Medicine, 2014, **63**, 1-7.

27. AOAC. Official methods of analysis. Ed. 16th. Washington, DC: Association of Official Analytical Chemists, 1995.
28. Goñi, I.; Garcia-Alonso, A. & Saura-Calixto, F.A starch hydrolysis procedure to estimate glycemic index. *Nutrition Research*, 1997, **17**(3), 427-437. doi: 10.1016/S0271-5317(97)00010-9
29. O'Dea, K.; Snow, P. & Nestel, P. Rate of starch hydrolysis in vitro as a predictor of metabolic responses to complex carbohydrates in vivo. *Am. J. Clin. Nutr.,* 1981, **34**, 1991-1993.
30. Jenkins, D.J.A.; Wolever, T.M.S.; Kalmusky, J.; Giudic, S.; Giordano, C.; Wong, S.G.; Bird, J.N.; Patten, R.; Hall, M.; Buckley, G. & Little, J.A. Low glycemic index carbohydrate foods in the management of hyperlipidemia. *Am. J. Clin. Nutr.*, 1985, **42**, 604-60l7.
31. Yu, Z.; Yin, Y.; Zhao, W.; Yu, Y.; Liu, B.; Liu, J. & Chen, F. Novel peptides derived from egg white protein inhibiting alpha-glucosidase. *Food Chemistry*, 2011, **129**, 1376-1382. doi: 10.1016/j.foodchem.2011.05.067

CONTRIBUTORS

Ms S. Bhardwaj received her MSc in Home Science (Food technology). Currently pursuing PhD from Defence Food Research Laboratry, Mysuru, India. She has designed the research plan, organised the study, participated in experiments, coordinated the data analysis, and contributed to the writing of the manuscript.
She has designed the research plan, organised the study, participated in experiments, coordinated the data analysis, andcontributed to the writing of the manuscript

Dr V.K. Shiby received her PhD in Agricultural and Food Engineering. Currently she is working as a Scientist 'D' at DFRL, has a research experience of 15 years in the area of food product development and process modelling. She received *DRDO Laboratory Acientist Award* (2013).
She has participated in the experimental design, organisedthe reported study and contributed to the writing of themanuscript.

Dr M.C. Pandey received his PhD in Agriculture Engineering. Currently he is working as a Scientist 'G' & Project coordinator at DFRL, has a research experience of over 20 years in the area of agriculture and food engineering.
He contributed towards the experimental design, organised thestudy and drafting of the manuscript.