REDUCING FAT-UPTAKE IN FRIED CHICKEN USING EDIBLE COATING AND SWEET POTATO STARCH BATTER

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Abstract
Protein-based edible coatings with various concentrations (5, 10, and 15%) of chicken protein were prepared from chicken protein isolates using isoelectric solubilization/precipitation. Two batters were used in this study. A new batter containing sweet potato starch (SPS) was prepared and a commercial batter was also used as a control. Then, chicken breast samples were coated, battered with either commercial batter or the SPS-based batter, breaded, and deep-fried in canola oil at 177 ◦C for 3 min. Samples with SPS-based batter and coated with 15% protein resulted in the highest reduction in fat uptake and lowest moisture loss. Coated samples had lower L* and b* values in comparison to the commercial battered samples. Coated samples were less hard than the uncoated samples. The results of this study suggest that chicken protein-based edible coating in combination with SPS in the batter will result in lower fat uptake and improve physicochemical quality attributes of the deep-fat fried chicken.

Keywords: Edible coating; Isoelectric solubilization and precipitation; fat-uptake; fried chicken; sweet potato starch

1. Introduction

Deep-fried foods are popular worldwide, as evidenced by the multi-billion-dollar market and growth of nationally recognized fast-food chains (Kassama, 2003). Fried chicken, even though palatable in its tenderness and crunchy crust can cause serious health consequences due to its fat content. The fat content is derived from oil absorption during frying.

Because of the various properties that are involved in oil absorption, many methods have been used to reduce oil absorption. They include formulation of the batter and the use of edible coatings. An edible coating is a thin layer of edible material applied to the food surface in addition to a protective coating. Proteins from chicken can form edible coatings for various uses, including as an edible coating (Adegoke, Adrah, Nowlin, & Tahergorabi, 2022). The assorted use of these films is due to the mechanical and viscoelastic properties of the protein isolates, such as water holding capabilities and protein types in the gel. Isoelectric solubilization and precipitation (ISP) is a technique used to isolate specific proteins from unwanted materials (skin, bone, etc.). During ISP with chicken, sarcoplasmic proteins are mostly lost. Therefore, the ISP-recovered proteins contain mainly myofibrillar proteins (Tahergorabi, Sivanandan, & Jaczynski, 2012a). Starches function as binding, texturizing, and stabilizing agents in batter systems for fried food. The food industry uses modified resistant corn starch in batter, which changes its amylose content. However, corn starch granules' have assorted sizes and shapes, meaning that batters including this ingredient are more susceptible to damage during processing resulting in a loss of gelatinization and increased retrogradation (Fiszman & Salvador, 2003; Parada & Aguilera, 2011). These factors affect the structural transformation and its performance during frying, resulting in an undesired sensory product. The use of sweet potato starch (SPS) in the batter provides many benefits in processing, packaging, and

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increasing nutritional content (Bhosale, Biswas, Sahoo, Chatli, Sharma1, & Sikka, 2011). Sweet potato is inexpensive, readily available, and rich in fiber, minerals, and bioactive compounds (Issa, Ibrahim, & Tahergorabi, 2016). Therefore, the main objective of this study was to reduce the fat uptake in deep-fried chicken breast with chicken protein-based edible coating and replacement of corn starch with SPS in the batter. In addition, the effect of these treatments was examined through physicochemical tests- moisture content, fat, texture, color, pH, sensory analysis, and frying yield.

2. Methodology

2.1. Brine Washing of Minced Chicken

The fresh chicken breast was purchased from a local grocery, ground uniformly using a meat grinder, and washed according to the method described by Tongnuanchan et al. (2011). This process was done to help remove fat from the ground meat.

2.2. Protein Isolation

Protein was isolated from the washed ground chicken according to the method described by Tahergorabi et al., (2012b). This protein was used in the preparation of the edible coating.

2.3. Edible Coating Preparation

Chicken protein isolate was formulated with water to form edible coating concentrations: 5, 10, and 15% (w/w) protein. Glycerol was also added as a plasticizer at 0.4% (w/w) of the protein. The pH of the mixture was adjusted to solubilize the proteins. It was afterward homogenized at 13,000 rpm for 1 min using a laboratory homogenizer (Homogenizer, OMNI International, Kennesaw, GA, USA). The pH was finally re-adjusted to approximately 7± 0.05. The edible coatings were kept refrigerated (4^{o}C) for up to 12 hours before use.

2.4. Preparation of Batters and breadcrumbs

A batter containing SPS was formulated based on Sahin, Sumnu, and Altunakar (2005), with some modifications. The batter contained 48.75% (w/w) wheat flour (King Arthur Flour Company, Inc., Vermont, USA), 48.75% SPS (New Honda Inter International Inc., Taichung, Taiwan), 1.0% HPMC (Methocel E15 Premium LV Hydroxypropyl Methylcellulose, Midland, USA), 1.0% salt (Morton, Chicago, USA), 0.5% baking powder (Rumford, Terre Haute, USA), and deionized water. A commercial batter (Louisiana Chicken Batter Mix, Baton Rouge, LA, USA) was also used as a control. Plain breadcrumbs (Progresso, breadcrumbs, MN, USA) were used for breading.

2.5. Chicken preparation for frying

Fresh chicken breast samples were cut into pieces of 10 ± 1 g. Using a hand-held prong, chicken pieces were dipped in an edible coating containing either 5, 10, or 15 % (w/w) protein after predusting, if the coating was required. The samples were gently shaken to get rid of the excess coating. They were accordingly dipped either in a batter containing SPS or commercial batter and breaded, thereafter. A summary of the various treatments was presented in Table 1.

2.6. Frying process

The chicken breast samples were fried at 177° C in canola oil (Wesson Pure, Conagra, Chicago, IL) using the Presto® Dual ProFry/1800W (National Presto Industries Inc., WI., U.S.) for 3 minutes.

2.7. Color, texture, and pH measurements

Color measurements were taken using a Minolta Chroma Meter CR-400 colorimeter (Minolta Camera Co. Ltd., Japan). The textural properties were measured utilizing a puncture probe (2 mm. dia., 25 mm long) with the texture analyzer (Model TA-XT2, Texture Technologies Corp., Scarsdale, NY). A calibrated hand-held pH meter (OMNI International, Kennesaw, GA, USA) was used to measure the pH.

2.8. Frying yield, fat, and moisture contents

Frying yield was calculated according to Ananey-Obiri et al., (2020). The lipid content was determined quantitatively by the Soxhlet extraction method (AOAC, 2010). The average moisture content of fried chicken strips was analyzed according to AOAC (2000).

2.9. Sensory evaluation

A sensory evaluation was conducted after IRB (Institutional Review Board) approval was obtained for the survey. 100 untrained panelists evaluated the appearance, texture, odor, and color on a 9-point hedonic scale based on the degree of preference. Choices ranged from 1-dislike extremely to 9-like extremely.

2.10. Statistical analysis
In this study, a one-way analysis of variance (ANOVA) was used to compare sample results. All experiments were completed in triplicate. For every experiment, the mean and variance were obtained using SAS Statistical Package (Version 16.0, SAS Institute, Cary, North Carolina, USA). The data were reported as mean±SD.

3. Results and discussion

3.1. Fat, and moisture contents, texture, and color
Table 2 shows the fat and moisture contents of the deep-fried samples. Samples coated with 15% protein and batter containing SPS had the lowest fat content and the lowest fat uptake. This is due to the formation of a complex network (film) by the edible coating during frying. These networks are formed due to the gelation of the myofibrillar proteins induced by heat. The brine washing of the muscle in this study might have enhanced the gel-forming ability of the chicken protein during heating, as reported by Sun and Holley (2011). The difference in fat-uptake between these SPS battered samples and commercial battered samples could be explained by the differences in amylose content of the two different starches in the batter. The disintegration of the hydrogen bonds during the gelatinization of starches causes the starch granules to lose their structure. This leads to penetration of the oil into the starch granules and swelling. As a result, a void space is created since the amylose content leaches out of the granules. Bertoft, (2017) showed that the amylose content of potato leaches out less easily than corn starch. Since the amylose content (25%) in corn starch is higher than the sweet potato (23 %) starches more space will be created in the corn starch than in the SPS. Also, lipid molecules can be entrapped by amylose (Le-Bail, Hesso, and Le-Bail, 2018). The relatively larger void created in corn starch than in SPS due to the difference in amylose content could have led to more oil being trapped in commercial battered fried samples due to the presence of corn starch in the batter. Adrah, Ananey-Obiri, and Tahergorabi (2021) observed the same behavior in chicken drumsticks coated with protein and an SPS batter. Moisture content increased among the edible coated samples from 43-61%. On average, samples coated with edible coating retained more water than the controls. The coating could form barriers that prevent moisture loss and reduce fat absorption (Singthong & Thongkaew, 2009). Table 3 displays the texture results. The commercial batter had the highest force of mastication and was significantly different ($p < 0.05$) from the other treatments. In general, the coated samples were softer compared to the control samples. The softness of the coated samples may be due to their juiciness and mostly high moisture content (Izadi et al., 2015) and the formation of a softer crust in fried samples due to the edible coating. A similar trend was noticed by Adrah et al. (2021). Table 4 depicts the color values. The L* values ranged from 39.5-56.3, indicating a diverse range of darkness to lightness. In general, the coated samples and battered with SPS had lower L* and b* values but were not significantly different in terms of a* values. Low amylose content in SPS can create larger granules and affect the color of its products negatively. Even though the edible coating was white, the order of processing i.e., pre-dusting, edible coating, battering determined the final color of the sample, hence the dark and reddish-colored sample.

3.2. Frying yield
The frying yield of the SPS battered samples were indicated in Table 5. Control samples had the lowest frying yield. The highest frying yield was recorded for samples coated with 15% protein and battered with SPS. However, there was no significant difference between the coated samples. Frying yield and cooking loss have an inverse relationship. This means the coated samples had lower cooking loss than the control samples or even commercial battered samples. Ananey-Obiri, Matthews, and Tahergorabi, (2020) reported that coated chicken drumsticks had a higher frying yield than the uncoated samples.

3.3. pH values
Figure 1 depicts the pH values of the samples. The highest pH was recorded for SPS battered samples, while the pH decreased after dipping in the edible coating at 10 and 15% concentrations. Even though the pH was adjusted to 7 after ISP processing, the impact is noticeable.

3.4. Sensory evaluation
Figure 2 displays the results of sensory evaluation. A score of 7 was used as the acceptable level of the sensory scores. The sample with the highest attribute scores was the SPS-battered sample with no edible

coating. Although the sensory scores for the coated and battered samples were lower than the samples without coating, the scores were in the acceptable range.

Conclusions

The results of this study showed that the application of chicken protein-based coating and a batter containing SPS significantly reduced the fat uptake and fat contents of the deep-fried chicken breast samples. However, increasing the protein concentration has no significant effect on fat uptake reduction. Chicken protein coating and the SPS-based batter also resulted in higher frying yield and moisture content as well as texture and sensory scores.

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Table 1. *Treatments used to Prepare the Deep-Fried Chicken Samples*

Treatments	Commercial Batter	Sweet Potato Starch Batter	Chicken Protein Based Edible Coating	Breading
CN	No	No	No	No
CB	Yes	No	No	Yes
SP	No	Yes	No	Yes
SP 5%	No	Yes	5%	Yes
SP 10%	No	Yes	10%	Yes
SP 15%	No	Yes	15%	Yes

CN- control with no breading, no coating, and no battering; CB- commercial batter; SP- sweet potato starch batter with no coating; SP 5%- sweet potato starch batter with battering, 5% coating, and breading; SP 10%- sweet potato starch batter with battering, 5% coating, and breading; SP 15%- sweet potato starch batter with battering, 5% coating, and breading

Table 2. *Fat and Moisture contents of Fried Chicken Samples with Edible Coating and Two Batters*

Treatments	Fat content	Fat-uptake	Moisture content
CN	8.83 ± 0.01^{a}	5.03 ± 0.99^{a}	47.35 ± 3.31^{c}
CB	7.51 ± 0.44^{a}	3.76 ± 0.44^{a}	50.02 ± 1.78^{a}
SP	5.74 ± 0.66^{bac}	1.94 ± 0.66^{bac}	56.96 ± 1.22^{ba}
SP 5%	5.17 ± 2.48^{bc}	1.37 ± 2.48^{bc}	43.22 ± 2.02^{c}
SP 10%	4.98 ± 1.26^{bc}	1.18 ± 1.26^{bc}	55.20 ± 1.12^{ba}
SP 15%	3.79 ± 0.67^{c}	0.00 ± 0.67^{c}	61.18 ± 4.20^{a}

The data are presented as mean values ± standard deviation. Different letters within the same row indicate significant differences (Tukey's Test, $p<0.05$) between mean values.

Table 3. *Texture Analysis of Fried Chicken Samples with Edible Coating and Two Batters*

(N)	Treatments					
Puncture Force	CN	CB	SP	SP 5%	SP 10%	SP 15%
	12.61 ± 3.52^{b}	105.64 ± 9.95^{a}	3.7 ± 0.23^{b}	3.45 ± 0.35^{b}	3.14 ± 0.14^{b}	3.05 ± 0.02^{b}

The data are presented as mean values ± standard deviation. Different letters within the same row indicate significant differences (Tukey's Test, p<0.05) between mean values.

Table 4. *Color Properties of Fried Chicken Samples with Edible Coating and Two Batters*

Treatments	L*	a*	b*
CN	56.32 ± 2.33^{a}	$5.52 \pm .59^{dc}$	18.78 ± 1.47^{a}
CB	57.94 ± 1.05^{a}	9.51 ± 0.43^{ba}	24.91 ± 0.54^{a}
CB	52.38 ± 7.09^{a}	8.79 ± 2.10^{ba}	22.14 ± 6.56^{a}
SP	45.33 ± 2.30^{c}	10.58 ± 0.42^{a}	10.85 ± 0.23^{b}
SP 5%	39.53 ± 3.73^{d}	2.85 ± 0.23^{d}	1.83 ± 0.39^{c}
SP 10%	52.49 ± 1.07^{b}	6.62 ± 0.64^{bc}	6.37 ± 0.33^{cb}
SP 15%	42.32 ± 1.48^{d}	7.16 ± 1.49^{bc}	5.29 ± 0.82^{cb}

The data are presented as mean values ± standard deviation. Different letters within the same row indicate significant differences (Tukey's Test, p<0.05) between mean values.

Table 5. *Frying Yield of Fried Chicken Samples with Edible Coating and Two Batters*

(%)	Treatments					
	CN	CB	SP	SP 5%	SP 10%	SP 15%
Frying yield	57.73 ± 0.66^{b}	81.55 ± 0.19^{a}	82.04 ± 0.41^{a}	84.67 ± 0.19^{a}	84.58 ± 0.06^{a}	87.17 ± 0.40^{a}

The data are presented as mean values ± standard deviation. Different letters within the same row indicate significant differences (Tukey's Test, p<0.05) between mean values.

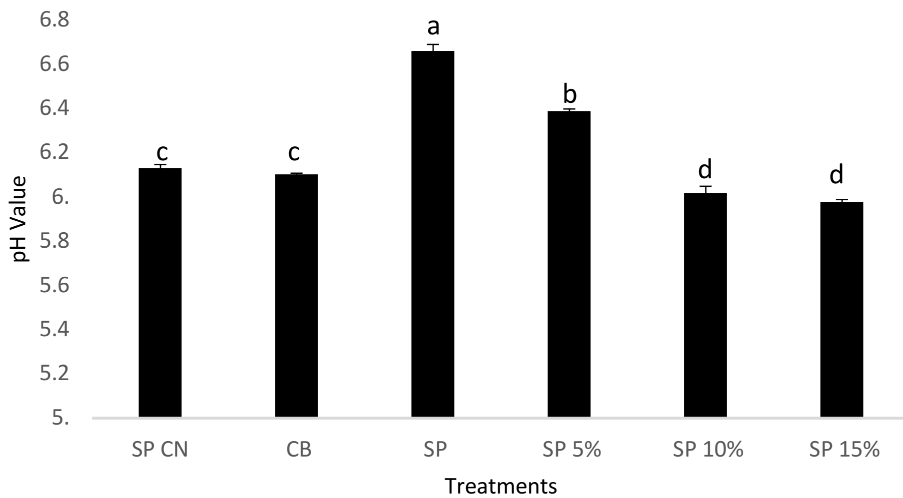

Figure 1. pH values of deep-fat fried chicken breast samples coated with different concertation of edible coating and sweet potato starch batter. Data are given as mean values ± standard deviation. The letters on the top of the data bars indicate significant differences (Tukey's Test, $p<0.05$) between mean values.

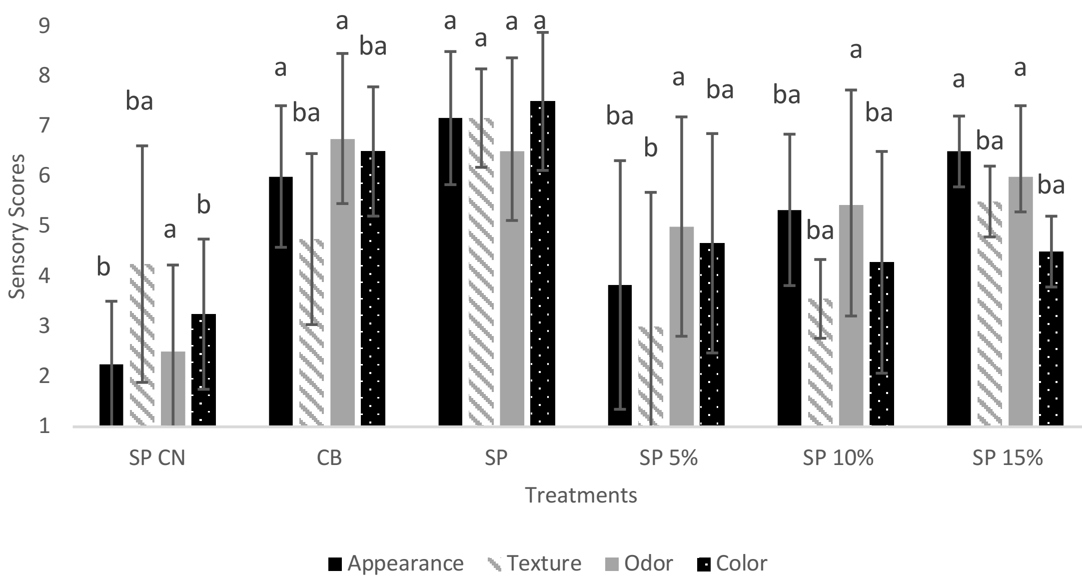

Figure 2. Sensory scores of deep-fat fried chicken breast samples coated with different concertation of edible coating and sweet potato starch batter. Data are given as mean values. The letters on the top of the data bars indicate significant differences (Tukey's Test, $p<0.05$) between mean values.