Available online freely at www.isisn.org

Bioscience Research

Print ISSN: 1811-9506 Online ISSN: 2218-3973

Journal by Innovative Scientific Information & Services Network

RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2020 17(2):1443-1450. **OPEN ACCESS**

Technical variables affecting to orange-flesh sweet Potato-Shrimp snack production

Minh Phuoc Nguyen

Faculty of Biotechnology, Ho Chi Minh City Open University, Ho Chi Minh City, **Vietnam**

***Correspondence: minh.np@ou.edu.vn** **Received 28-04-2020, Revised: 20-06-2020, Accepted: 24-06-2020 e-Published: 29-06-2020**

Ready-to-eat snack is highly preferred due to its convenience, wide availability, appearance, taste and texture. The major ingredient in snack formula is starch originated from corn, wheat, potato and rice. Orange-fleshed sweet potato is a rich source of starch, dietary fibre and beta-caroten In our research, we attempted to produce an instant snack prepared from orange-fleshed sweet potato starch combined with shrimp meat and beta-glucan as fibre supplementation. Technical variables of extrusion process such as kinds of fibre agents (guar gum, galactooligosaccharide, psyllium, beta-glucan, wheat bran, chitosan), fibre ratios (2, 4, 6, 8, 10%, 12%, 14%), screw speed (160, 180, 200, 220, 240, 260, 280 rpm), feed rate (12, 15, 18, 21, 24, 27, 30%), feed moisture content (13, 16, 19, 22, 25, 28, 31%), extrusion temperature (100, 105, 110, 115, 120, 125, 130ºC) were thoroughly investigated. Expansion ratio, bulk density (g/l), hardness (g), water absorption index, water solubility index, antioxidant activity (DPPH, %) and overall acceptance were evaluated on the orange-flesh sweet potato-shrimp snack. From this study, the optimal extrusion conditions were recorded at beta-glucan 8%, screw speed 220 rpm, feed rate 24%, feed moisture content 19%, extrusion temperature 120ºC because these conditions provided a good quality orange-flesh sweet potato-shrimp snack.

Keywords: Snack, orange-fleshed sweet potato starch, shrimp meat, beta-glucan, screw speed, feed rate, feed moisture content, extrusion temperature

INTRODUCTION

Extrusion technology has been widely proven in food industry with numerous benefits such as the desired physical shape, minimized anti-nutritional content, increased stability, enhanced digestibility, and palatability of nutrients (Mishra et al., 2012). The ingredients undergo mixing, shearing, shaping, cooking, drying and texturization (David et al., 2017). Extrusion is preferable to other food-processing techniques in terms of continuous process with high productivity and significant nutrient retention (Sing et al., 2007).

Orange-fleshed sweet potato flour is a nutritious food, low in fat and protein; but rich in carbohydrates, antioxidants, minerals, vitamins and pleasant sensory characteristics (Teow et al. 2007; Ukom et al., 2009; Rose and Vasanthakaalam, 2011; Sebben et al., 2017; Satheeshand Solomon, 2019). Shrimp meat is an excellent source of protein, minerals, poly unsaturated fatty acids. Adding fiber to food can provide alternative ways to fill in the gap between the current fiber consumption and recommended intake levels (Yao and Andrew, 2017). Orange-fleshed sweet potato could be mixed with high protein and lipid containing ingredients to produce nutritionally adequate products (Amagloh and Coad, 2014).

Some notable studies mentioned to the snack production via extrusion. The effect of extrusion conditions, including feed rate, feed moisture content, screw speed, and barrel temperature on the physicochemical properties (density, expansion, water absorption index, and water solubility index) and sensory characteristics (hardness and crispness) of an expanded rice snack was investigated (Qing et al., 2005). The effects of orange sweet potato flour addition to tapioca starch on the expansion, oil absorption, bulk density, water absorption index (WAI), water solubility index (WSI), hardness and colour of fried extruded fish crackers were investigated (Noorakmar et al., 2012). Various blending ratios of sorghum, broken rice and green gram flours, operational variables of extrusion such as barrel temperature and screw speed were optimized for physical and sensory properties of sorghum based extruded products (Vijaya et al., 2016). Corn snacks supplemented with chickpea, defatted soy flour and guar gum were prepared through extrusion processing (Faiz et al., 2016). Ranendra and Ratankumar (2014) examined the expanded products with fish flour, rice and corn flour by applying a twin-screw extruder with various temperature, screw speed, total moisture and fish flour content to establish their effect on the expansion ratio, bulk density, porosity and water solubility index of the extrudates adopting response surface methodology. Effect of Hom Nil rice flour moisture content, barrel temperature and screw speed of a single screw extruder on snack properties was investigated (Sangnark et al., 2015). The effects of extrusion temperature, screw speed and feed moisture on physicochemical and sensory properties of shrimp -corn snack were investigated using response surface methodology (Osman et al., 2017). Orange-fleshed sweet potato and bambara groundnut were extruded to create snack (Buzo et al., 2017). Ricardo et al., (2018) evaluated the effect of the extrusion temperature, feed moisture and concentration of orange bagasse on the physicochemical and sensory properties of directly expanded extruded products. Ready-to-eat healthy mushroom-rice snacks were developed and processed (Hataichanok et al., 2018). Cátia et al. (2019) explored the production of an expanded snack entirely based on pea- and oat-rich fractions using the extrusion technology. Naseer et al. (2019) prepared the extruded snacks from whole wheat flour enriched with crude lycopene, tomato powder and saffron extract. Emanet a. (2019) prepared snack from extruding broken rice, sweet potato flour and sweet lupine flour.

Extruded snack products are nornally prepared from cereal flour to be low in protein and low biological value (Ainsworth et al., 2007). To produce a nutritious snack, cereals are usually enriched with protein rich food stuff. Consumers are increasing demand of more nutritious snacks that are low in fat but rich in protein, fiber, minerals and vitamins (Brennan et al., 2013). Objective of our study focused on some major technical parameters of extrusion conditions such as kinds of fibre agents, fibre ratios, screw speed, feed rate, feed moisture content, extrusion temperature to the physicochemical, phytochemical and overall acceptance of the orange-fleshed sweet potato-shrimp snack.

MATERIALS AND METHODS

Material

Orange-fleshed sweet potato flourwere purchased from Rainbow Trading Co. Ltd, Vietnam.The dried shrimp meat was ground to a fine particles size by grinder. Orange-fleshed sweet potato flour was mixed with the shrimp powder and other ingredients ready for extrusion.

Researching method

Orange-fleshed sweet potato flour was mixed thoroughly with shrimp powder (10%), sugar (2.7%) and salt (0.3%) to create a mixture. This mixture was then blended with different fiber agents (guar gum, galacto oligosaccharide, psyllium, beta-glucan, wheat bran, chitosan), fiber ratios (2, 4, 6, 8, 10%), screw speed (200, 220, 240, 260, 280 rpm), feed rate (15, 18, 21, 24, 27%), feed moisture content (16, 19, 22, 25, 28%), extrusion temperature (105, 110, 115, 120, 125^{o}C). The blend was added into feed hopper and extruded using die diameter of 2.5 mm and product was collected at the die end. The quality of extrudate was evaluated on expansion ratio, bulk density (g/l), hardness (g), water absorption index, water solubility index, antioxidant activity (DPPH, %) and overall acceptance.

Physicochemical, phytochemical and sensory analysis

Expansion ratio of extrudatewas calculated by dividing the square of extrudate diameter by the square of die diameter. Bulk density (g/L) of extrudate was calculated as the ratio of the weight of the extrudate to the volume of extrudate. Hardness (g) of extrudate was estimated by texture analyzer. About 5 g of ground extrudates were dispersed in 50 ml of distilled water. After stirring for 15 min using magnetic stirrer dispersions were rinsed and centrifuged at 4000×g for 5 min. The supernatant was decanted into a evaporating dish of known weight. Water absorption index or WAI was the weight of gel obtained after removal of the supernatant per unit weight oforiginal dry solids. Water solubility index or SWI was the weight of dry solids in the supernatant expressed as a percentage of the original weight of sample. The antioxidant activity or DPPH (%) of snack was evaluated with the stable free radical 2, 2-diphenyl-1-picryl hydrazyl using the procedure proposed by Huang et al. (2005).Overall acceptance of snack was evaluated by a group of panelists using 9 poin-Hedonic scale.

Statistical analysis

The experiments were run in triplicate with three different lots of samples. The data were presented as mean±standard deviation. Statistical analysis was performed by the Statgraphics Centurion version XVI.

RESULTS AND DISCUSSION

Effect of fibre agents on the physicochemical, phytochemical and sensory attributes of the extrudated orange-fleshed sweet potato-shrimp snack

Different fibre agents (guar gum, galactooligosaccharide, psyllium, beta-glucan, wheat bran, chitosan) were examined on the physicochemical, phytochemical and sensory attributes of the extrudated orange-fleshed sweet potato-shrimp snack (see Table 1). It's obviously realized that beta-glucan gave the best quality of snack so this fibre agent was selected for the next experiments. In similar reports, Silva et al., (2013) verified the efficacy of guar gum supplementation on pasta quality properties. Results showed that the added guar gum changed the overall quality of both raw and cooked pasta. In one report, corn snack supplemented with 15% soy and 15% chickpea flour got the highest acceptance (Faiz et al., 2016). Naseer et al., (2019) proved that hardness of snacks containing crude lycopene and tomato powder was higher than the control. Total phenolic content (TPC) of the formulations with added tomato powder increased significantly. Extrusion significantly reduced the TPC, DPPH scavenging activity of snacks.

Effect of beta-glucan ratio on the physicochemical, phytochemical and sensory attributes of the extrudated orange-fleshed sweet potato-shrimp snack

Expansion is the most important physical property of the snack food. Water absorptivity index can be used as an index of gelatinization (Qing et al., 2005). The change in hardness of the product may be observed due to the starch gelatinization and texture of the final product. In our research, different beta-glucan ratios (2, 4, 6, 8, 10, 12, 14%) were examined on the physicochemical, phytochemical and sensory attributes of the extrudated orange-fleshed sweet potato-shrimp snack (see table 2). It's obviously realized that 8% beta-glucan gave the best quality of snack so this ratio was selected for the next experiments.In similar reports, Yang et al. (2018) proved that when the polydextrose content in corn mixture increased from 0 to 10%, the bulk density of the fried extrudate increased, while expansion ratio and crispness
decreased.

Effect of the screw speed on the physicochemical, phytochemical and sensory attributes of the extrudated orange-fleshed sweet potato-shrimp snack

In our research, different screw speed (160, 180, 200, 220, 240, 260, 280 rpm) were examined on the physicochemical, phytochemical and sensory attributes of the extrudated orange-fleshed sweet potato-shrimp snack (see table 3). It's obviously realized that screw speed at 220 rpm gave the best quality of snack so this value was selected for the next experiments.In similar reports, Guha et al., (1997) reported that an increase in screw speeds at 200-300 rpm reduced the bulk density of extrudates from rice flour. Increasing screw speed resulted in an increase in expansion ratio and a decrease in bulk density of the products which added corn flour (Liu et al., 2000). According to Qing et al., (2005), screw speed had no significant effect on the physicochemical properties and sensory characteristics of the extrudate of the expanded rice snack. Increase in water absorptivity index was inversely proportional to screw speed (Yagci and Gogus, 2008). Pansawat et al., (2008) found that an increased screw speed from 150 to 250 rpm decreased the radial expansion of rice-based snack containing fish powder, while increased screw speed over 250 rpm increased the radial expansion. According to Sangnark et al., (2015),

Table 1: Effect of fibre agents on the physicochemical, phytochemical and sensory attributes of the extrudated orange-fleshed sweet potato-shrimp snack

Fibres	Expansion ratio	Bulk densit (g/L)	Hardness (g)	WAI	WSI	DPPH (%)	Overall acceptance
Control	120.83±0.02^{c}	54.18±0.03^{f}	495.740.00^{d}	201.07±0.02^{d}	10.76±0.03^{e}	34.65±0.02^{d}	4.65±0.01^{d}
Guar gum	124.42±0.00^{bc}	59.83±0.02^{e}	516.32±0.00^{cd}	219.34±0.03^{cd}	12.37±0.02^{d}	37.25±0.00^{cd}	5.31±0.02^{cd}
Galactooligos accharide	126.19±0.03^{bc}	65.34±0.00^{d}	548.69±0.02^{c}	226.38±0.00^{c}	12.84±0.02^{cd}	39.42±0.03^{c}	5.78±0.00^{c}
Psyllium	133.67±0.02^{ab}	69.91±0.03^{c}	601.54±0.01^{bc}	247.05±0.00^{bc}	13.48±0.03^{c}	42.65±0.00^{bc}	5.95±0.03^{bc}
Beta-glucan	139.60±0.01^{a}	78.42±0.00^{a}	677.23±0.03^{a}	297.31±0.02^{a}	15.65±0.01^{a}	50.79±0.02^{a}	6.11±0.01^{a}
Wheat bran	128.76±0.00^{b}	72.06±0.02^{b}	631.49±0.01^{ab}	281.35±0.03^{ab}	15.03±0.02^{ab}	47.63±0.01^{ab}	6.07±0.02^{ab}
Chitosan	127.43±0.02^{b}	70.85±0.00^{bc}	617.27±0.03^{b}	265.70±0.02^{b}	14.37±0.00^{b}	45.04±0.03^{b}	6.03±0.00^{b}

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant ($\alpha = 5\%$).

Table 2: Effect of beta-glucan ratio (%) on the physicochemical, phytochemical and sensory attributes of the extrudated orange-fleshed sweet potato-shrimp snack

Fibre ratio (%)	Expansion ratio	Bulk density (g/L)	Hardness (g)	WAI	WSI	DPPH (%)	Overall acceptance
2.0	139.60±0.01^{c}	78.42±0.00^{d}	677.23±0.03^{d}	297.31±0.02^{d}	15.65±0.01^{d}	50.79±0.02^{a}	6.11±0.01^{d}
4.0	141.13±0.02^{bc}	80.15±0.03^{cd}	706.42±0.01^{cd}	311.34±0.00^{cd}	15.97±0.03^{cd}	49.53±0.01^{ab}	6.45±0.00^{cd}
6.0	143.06±0.01^{b}	82.79±0.01^{bc}	741.69±0.00^{c}	329.60±0.02^{bc}	16.23±0.01^{c}	49.02±0.02^{b}	6.97±0.03^{c}
8.0	147.20±0.03^{a}	86.54±0.02^{a}	753.47±0.00^{bc}	347.55±0.01^{a}	17.80±0.02^{a}	48.76±0.03^{bc}	7.63±0.01^{a}
10.0	145.07±0.02^{ab}	84.69±0.01^{ab}	768.22±0.02^{b}	338.50±0.03^{ab}	17.34±0.00^{ab}	48.50±0.02^{c}	7.41±0.02^{ab}
12.0	143.63±0.01^{b}	83.45±0.00^{b}	780.19±0.03^{ab}	334.47±0.02^{b}	16.95±0.01^{b}	48.04±0.03^{cd}	7.26±0.00^{b}
14.0	140.31±0.00^{bc}	80.77±0.03^{c}	782.06±0.02^{a}	320.71±0.01^{c}	16.61±0.02^{bc}	47.62±0.01^{d}	7.10±0.03^{bc}

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant ($\alpha = 5\%$).

Table 3: Effect of screw speed (rpm) on the physicochemical, phytochemical and sensory attributes of the extrudated orange-fleshed sweet potato-shrimp snack

Screw speed (rpm)	Expansion ratio	Bulk Density (g/L)	Hardness (g)	WAI	WSI	DPPH (%)	Overall acceptance
160	147.20±0.03^{d}	86.54±0.02^{cd}	753.47±0.00^{d}	347.55±0.01^{d}	17.80±0.02^{d}	48.76±0.03^{a}	7.63±0.01^{bc}
180	149.8±0.01^{cd}	88.65±0.00^{c}	759.12±0.03^{cd}	351.05±0.02^{c}	18.34±0.01^{cd}	46.53±0.02^{ab}	7.81±0.01^{b}
200	152.27±0.02^{c}	89.76±0.01^{bc}	788.65±0.02^{c}	356.46±0.03^{b}	18.86±0.02^{c}	44.77±0.01^{b}	7.85±0.02^{ab}
220	197.55±0.00^{a}	94.25±0.03^{a}	826.53±0.01^{a}	362.17±0.00^{a}	20.37±0.03^{a}	43.01±0.00^{bc}	7.93±0.03^{a}
240	190.11±0.03^{ab}	92.48±0.02^{ab}	813.70±0.01^{ab}	358.70±0.02^{ab}	20.05±0.01^{ab}	42.86±0.03^{c}	7.46±0.01^{c}
260	173.46±0.02^{b}	90.35±0.01^{b}	804.33±0.00^{b}	354.47±0.01^{bc}	19.64±0.02^{b}	42.71±0.01^{cd}	7.15±0.02^{cd}
280	166.34±0.01^{bc}	84.13±0.02^{d}	793.88±0.03^{bc}	349.10±0.00^{cd}	19.14±0.03^{bc}	42.57±0.02^{d}	7.01±0.01^{d}

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant ($\alpha = 5\%$)

Table 4: Effect of feed rate (%) on the physicochemical, phytochemical and sensory attributes of the extrudated orange-fleshed sweet potato-shrimp snack

Feed rate (%)	Expansion ratio	Bulk density (g/L)	Hardness (g)	WAI	WSI	DPPH (%)	Overall acceptance
12	197.55±0.00^{d}	94.25±0.03^{cd}	826.53±0.01^{d}	362.17±0.00^{cd}	20.37±0.03^{d}	43.01±0.00^{d}	7.93±0.03^{d}
15	203.41±0.02^{cd}	96.02±0.01^{c}	829.60±0.02^{cd}	367.53±0.01^{c}	20.75±0.02^{cd}	43.67±0.03^{cd}	8.02±0.02^{c}
18	204.93±0.00^{c}	97.84±0.01^{bc}	833.17±0.00^{c}	371.15±0.00^{bc}	20.96±0.01^{c}	44.15±0.02^{c}	8.09±0.00^{b}
21	207.65±0.03^{b}	99.01±0.02^{b}	845.89±0.03^{bc}	386.30±0.00^{b}	21.23±0.02^{bc}	44.80±0.01^{bc}	8.13±0.01^{ab}
24	213.79±0.01^{a}	103.16±0.00^{a}	878.60±0.02^{a}	397.68±0.03^{a}	22.07±0.00^{a}	45.24±0.02^{b}	8.19±0.02^{a}
27	208.36±0.00^{ab}	101.31±0.03^{ab}	869.33±0.01^{ab}	390.55±0.00^{ab}	21.86±0.01^{ab}	45.79±0.02^{ab}	8.10±0.00^{b}
30	205.0±0.03^{bc}	90.17±0.01^{d}	852.46 ±0.02^{b}	347.23 ±0.01^{d}	21.53 ±0.00^{b}	46.00 ±0.01^{a}	8.06 ±0.03^{bc}

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant ($\alpha = 5\%$).

Increasing screw speed caused an increase in expansion ratio and a decrease in density and hardness of extrudate. The maximum value of expansion ratio and minimum bulk density was at 150 rpm (Vijaya et al., 2016). Orange-fleshed sweet potato and bambara groundnut were extruded at screw speed of 30 rpm (Buzo et al., 2017). Ready-to-eat healthy mushroom-rice snacks were developed and processed. The optimum extrusion was recorded at screw speed of 425 rpm (Hataichanok et al.,2018).

Effect of the feed rate on the physicochemical, phytochemical and sensory attributes of the extrudated orange-fleshed sweet potato-shrimp snack

In our research, different feed rate (12, 15, 18, 21, 24, 27, 30%) were examined on the physicochemical, phytochemical and sensory attributes of the extrudated orange-fleshed sweet potato-shrimp snack (see table 4). It's clearly shown that feed rate at 24% gave the best quality of snack so this value was selected for the next experiments.According to Qing et al., (2005), increasing feed rate resulted in extrudates with a higher expansion, lower water solubility index, and higher hardness of the expanded rice snack. Orange-fleshed sweet potato and bambara groundnut were extruded at a feed rate of 10.15 kg/hr (Buzo et al., 2017).

Effect of the feed moisture content on the physicochemical, phytochemical and sensory attributes of the extrudated orange-fleshed sweet potato-shrimp snack

The moisture content had a significant influence on the gelatinization process. Starch-based ingredients were extruded at lower moistures than vegetable proteins (Gbenyi et al., 2016). During the extrusion process, the starch was partially hydrated and subjected to increasing shear while it was mechanically conveyed and heated (David et al., 2017). The elastic swell and bubble growth contributed to the hardness modification of starch. The water played a key role as a plasticizer to the starch-based material reducing its viscosity and the mechanical energy dissipation in the extruder therefore the product became dense and bubble growth was compressed (Vijaya et al., 2016). Lower moisture content caused the increased viscosity and more mechanical damage. High moisture extrudates had larger pore sizes and thicker cell walls (David et al., 2017). In our research, different feed moisture content (13, 16, 19, 22, 25, 28, 31%)were examined on the physicochemical, phytochemical and sensory attributes of the extrudated orange-fleshed sweet potato-shrimp snack (see table 5). It's clearly shown that feed moisture content at 19% gave the best quality of snack so this value was selected for the next experiments. The hardness of extrudate increased as the feed moisture content increased it might due to the reduced expansion caused by the increase in moisture content (Badrie and Mellowes, 1991). According to Qing et al., (2005), increasing feed moisture content resulted in extrudates with a higher density, lower expansion, higher water absorption index, lower water solubility index, higher hardness and lower crispness of the expanded rice snack. The increase in the feed moisture decreased the expansion ratio of the extrudate (Mahesh et al., 2012). Ranendra and Ratankumar (2014) proved that the fish-based expanded snacks obtained at 14–18% moisture had the best expansion ratio, bulk density, porosity and water solubility index characteristics. According to Sangnark et al., (2015), the 15% moisture content of rice flour caused the optimum properties of extrudate. According to David et al., (2017), the expansion ratio of the extrudates was found to generally increase as the feed moisture was increased from 15 to 25% while the bulk density of extrudates generally decreased as the feed moisture was increased from 15 to 25%. Ricardo et al., (2018) reported that the highest expansion index was obtained at a feed moisture content of 146.4 g/kg. Ready-to-eat healthy mushroom-rice snacks were developed and processed. The optimum extrusion was recorded at 13.5% of feed moisture (Hataichanok et al., 2018).

Effects of extrusion temperature (100, 105, 110, 115, 120, 125, 130^{o}C) on the physicochemical, phytochemical and sensory attributes of the extrudated orange-fleshed sweet potato-shrimp snack

In our research, different extrusion temperature (100, 105, 110, 115, 120, 125, 130^{o}C) were examined on the physicochemical, phytochemical and sensory attributes of the extrudated orange-fleshed sweet potato-shrimp snack (see table 6).

Table 5: Effect of feed moisture content (%) on the physicochemical, phytochemical and sensory attributes of the extrudated orange-fleshed sweet potato-shrimp snack

Feed moisture content (%)	Expansion ratio	Bulk density (g/L)	Hardness (g)	WAI	WSI	DPPH (%)	Overall acceptance
13	213.79±0.01^{c}	103.16±0.00^{b}	878.60±0.02^{bc}	397.68±0.03^{b}	22.07±0.00^{b}	45.24±0.02^{a}	8.19±0.02^{b}
16	225.57±0.02^{b}	107.35±0.03^{ab}	891.24±0.03^{ab}	401.05±0.02^{ab}	22.64±0.01^{ab}	45.01±0.02^{ab}	8.31±0.01^{ab}
19	234.13±0.00^{a}	109.11±0.02^{a}	904.12±0.02^{a}	406.74±0.03^{a}	22.97±0.02^{a}	44.64±0.01^{b}	8.52±0.02^{a}
22	229.40±0.03^{ab}	96.34±0.01^{bc}	897.64±0.03^{b}	381.12±0.00^{bc}	21.85±0.03^{bc}	44.13±0.00^{bc}	8.04±0.03^{bc}
25	217.25±0.02^{bc}	90.51±0.00^{c}	851.12±0.02^{c}	366.04±0.02^{c}	21.24±0.01^{c}	43.87±0.02^{c}	7.86±0.01^{c}
28	206.61±0.01^{cd}	84.33±0.03^{cd}	837.99±0.00^{cd}	347.83±0.01^{cd}	21.01±0.00^{cd}	43.19±0.00^{cd}	7.55±0.01^{cd}
31	201.34±0.00^{d}	80.17±0.02^{d}	830.05±0.01^{d}	329.14±0.00^{d}	20.63±0.02^{d}	42.78±0.03^{d}	7.32±0.01^{d}

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%).

Table 6: Effect of extrusion temperature (ºC) on the physicochemical, phytochemical and sensory attributes of the extrudated orange-fleshed sweet potato-shrimp snack

Extrusion temperature (ºC)	Expansion ratio	Bulk density (g/L)	Hardness (g)	WAI	WSI	DPPH (%)	Overall acceptance
100	234.13±0.00^{d}	109.11±0.02^{cd}	904.12±0.02^{d}	406.74±0.03^{cd}	22.97±0.02^{c}	44.64±0.01^{a}	8.52±0.02^{bc}
105	242.34±0.01^{cd}	111.36±0.01^{c}	906.30±0.00^{cd}	408.52±0.03^{c}	23.16±0.02^{bc}	44.20±0.00^{ab}	8.63±0.01^{b}
110	247.05±0.03^{bc}	113.57±0.00^{bc}	909.14±0.01^{c}	411.01±0.00^{bc}	23.37±0.01^{b}	44.03±0.02^{b}	8.77±0.00^{a}
115	250.31±0.00^{ab}	117.34±0.02^{b}	913.26±0.00^{bc}	415.33±0.02^{b}	23.51±0.00^{ab}	43.86±0.03^{bc}	8.70±0.01^{ab}
120	256.34±0.02^{a}	121.47±0.01^{a}	924.14±0.03^{a}	421.34±0.01^{a}	23.76±0.03^{a}	43.64±0.01^{c}	8.47±0.02^{c}
125	248.02±0.00^{b}	119.06±0.02^{ab}	920.66±0.01^{ab}	418.72±0.03^{ab}	22.75±0.02^{cd}	43.25±0.03^{cd}	8.35±0.00^{cd}
130	244.36±0.02^{c}	105.34±0.01^{d}	917.83±0.02^{b}	401.39±0.01^{d}	22.24±0.02^{d}	43.06±0.01^{d}	8.06±0.00^{d}

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%).

It's clearly shown that extrusion temperature at 120ºC gave the best quality of snack so this value was selected for implementation. According to Qing et al. (2005), higher barrel temperature increased the extrudate expansion but reduced density, increased the WSI and crispness of extrudate. Increase in water absorptivity index was directly proportional to temperature (Yagci and Gogus, 2008). The increase in the barrel temperature decreased the expansion ratio of the extrudate (Mahesh et al., 2012). Ranendra and Ratankumar (2014) proved that the fish-based expanded snacks obtained at 100–110ºC had the best expansion ratio, bulk density, porosity and water solubility index characteristics. According to Sangnark et al., (2015), increasing temperature caused an increase in expansion ratio and a decrease in density and hardness of extrudate. The bulk density increased with the increase in moisture content at higher temperatures, which may be due to change in the molecular structure of extrudates. The maximum value of expansion ratio and minimum bulk density was at 110ºC barrel temperature (Vijaya et al., 2016). Orange-fleshed sweet potato and bambara groundnut were extruded at 100 and 130ºC in first and second zones respectively. Ricardo et al. (2018) reported that the highest expansion index was obtained by 170°C at the exit die. Ready-to-eat healthy mushroom-rice snacks were developed and processed. The optimum extrusion was recorded at barrel temperature 130ºC (Hataichanok et al., 2018).

CONCLUSION

Extrusion is a high-temperature, short-time process in which starch and other ingredients are plasticized and cooked in a tube by a combination of moisture, pressure, temperature and mechanical shear. The orange-fleshed sweet potato contained high moisture and starch content while protein and fats are present in very less concentrations. Shrimp meat combination with orange-fleshed sweet potato can provide the highly nutritious extruded snack. In this research, we have successfully investigated different technical parameters in extrusion possibly affecting to the physicochemical, phytochemical and sensory characteristics of the orange-fleshed sweet potato-shrimp snack.

.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

ACKNOWLEGEMENT

We acknowledge the financial support for the publication provided by Ho Chi Minh City Open University, Vietnam.

AUTHOR CONTRIBUTIONS

Minh Phuoc Nguyen arranged the experiments and also wrote the manuscript.

REFERENCES

Ainsworth P, Ibanoglu S, Plunkett A, Ibanoglu E, Stojceska V. Effect of brewers spent grain addition and screw speed on the selected physical and nutritional properties of an extruded snack. *Journal of Food Engineering* 2007; 81: 702-709.

Amagloh FK, Coad J. Orange-fleshed sweet potato-based infant food is a better source of dietary vitamin A than a maize— Legume blend as complementary food. *Food and Nutrition Bulletin* 2014; 35: 51–59.

Badrie N and Mellowes WA. Texture and microstructure of cassava flour extrudate. *Journal of Food Science* 1991; 56: 1319–1322.

Brennan MA, Derbyshire E, Tiwari BK, Brennan CS. Ready-to-eat snack products: The role of extrusion technology in developing consumer acceptable and nutritious snacks. *International Journal of Food Science and Technology* 2013; 48: 893–902

Buzo H, Ivan MM, Richard JM. Proximate composition, provitaminA retention, and shelf life of extruded orange-fleshed sweet potato and bambara groundnut-based snacks. *Journal of Food Processing and Preservation* 2017; e13415.

Cátia SC, Paula V, Claire P, Tzvetelin D, Kristin M, Anne R, Hanne Z, Stefan S, Svein HK.The impact of extrusion parameters on physicochemical, nutritional and sensorial properties of expanded snacks from pea and oat fractions.*LWT*2019; 112: 108252.

David IG, Iro N, Mamudu HB. Effect of feed moisture, variety and single screw extrusion on physicochemical properties and acceptability of grain sorghum.*International Journal of Food Science and Nutrition* 2017; 2: 130-135.

Eman HA, Hanan AH, Eman MS. Development of nutritious extruded snacks.*Life Sci J* 2019; 16: 23-31.

Faiz UHS, Mian KS, Masood SB, Muhammad S. Development of protein, dietary fibre, and micronutrient enriched extruded corn snacks. *Journal of Texture Studies* 2016; 1-10.

Gbenyi DI, Nkama I, Badau MH. Optimization of physical and functional properties of sorghum-bambara groundnut extrudates.*Journal of Food Research* 2016; 5: 81-97.

Guha M, Ali SZ, Bhattacharya S. Twinscrew extrusion of rice flour without a die: Effect of barrel temperature and screw speed on extrusion and extrudate characteristics. *Journal of Food Engineering* 1997; 32: 251-267.

Hataichanok K, Chulaluck C, Nipat L, Worapol P. Influence of process parameters on physical properties and specific mechanical energy of healthy mushroom-rice snacks and optimization of extrusion process parameters using response surface methodology. *J Food Sci Technol.*2018; 55: 3462–3472.

Huang D, Ou B, Propr RL. The chemistry behind antioxidant capacity assays. *Journal of Agricultural and Food Chemistry* 2005; 53: 1841-1856.

Liu Y, Hsieh F, Heymann H, Huff HE. Effect of process conditions on the physical and sensory properties of extruded oat-corn puff.*Journal of Food Science* 2000; 65: 1253–1259.

Mahesh BZ, Jadhav MV and Annapure US. Process optimization and characterization of sorghum based extruded product. *Journal of Food Science and Engineering* 2012; 2: 367-375.

Mishra A, Mishra HN, Srinivava, Rao P. Preparation of rice analogs using extrusion technology.*International Journal of Food Science and Technology* 2012; 47: 1789–1797.

Noorakmar AW, Cheow CS, Norizzah AR, Mohd ZA, Ruzaina I. Effect of orange sweet potato (*Ipomoea batatas*) flour on the physical properties of fried extruded fish crackers.*International Food Research Journal* 2012; 19: 657-664.

Osman KT, Nalan G, Kirsi J, Satu K. Development of extruded shrimp-corn snack using response surface methodology.*Turkish Journal of Fisheries and Aquatic Sciences* 2017; 17: 333-343.

Pansawat N, Jangchud K, Jangchud A, Wuttijumnong P, Saalia FK, Eitenmiller RR. Effects of extrusion conditions on secondary extrusion variables and physical properties of fish, rice-based snacks.*Lebensmittel-Wissenschaft and-Technologie* 2008; 41: 632- 641.

Qing BD, Paul A, Gregory T, Hayley M. The effect of extrusion conditions on the physicochemical properties and sensory characteristics of rice-based snacks. *Journal of Food Engineering* 2005; 66: 283-289.

Ranendra KM,Ratankumar SRK. The effect of extrusion conditions on the physicochemical properties and sensory characteristics of fish-based expanded snacks. *Journal of Food Processing and Preservation* 2014; 38: 864-879.

Ricardo ONC, Ernesto AP, Javier CR, Reyna NFC, Arturo CR, Efrén DL, Carlos AGA. Physicochemical and sensory characterization of an extruded product from blue maize meal and orange bagasse using the response surface methodology. *CyTA - Journal of Food* 2018; 16: 498-505.

Rose IM, Vasanthakaalam H. Comparison of the nutrient composition of four sweet potato varieties cultivated in Rwanda. *American Journal of Food and Nutrition* 2011; 1: 34–38.

Sangnark A, Limroongreungrat K, Yuenyongputtakal W, Ruengdech A, Siripatrawan U. Effect of Hom Nil rice flour moisture content, barrel temperature and screw speed of a single screw extruder on snack properties. *International Food Research Journal* 2015; 22: 2155-2161.

Satheesh N, Solomon WF. Review on nutritional composition of orange-fleshed sweet potato and its role in management of vitamin A deficiency. *Food Science and Nutrition* 2019; 7: 1920-1945.

Sebben JA, Trierweiler LF, Trierweiler JO. Orange –fleshed sweet potato flour obtained by drying in microwave and hot air. *Journal of Food Processing and Preservation* 2017; 41: 1-8

Silva E, Sagis LMC, Van DLE, Scholten E. Effect of matrix and particle type of rheological, textural, and structural properties of broccoli pasta and noodles.*Journal of Food Engineering* 2013; 119: 94–103.

Singh S, Gamlath S, Wakeling L. Nutritional aspects of food extrusion: a review. *International Journal of Food Science and Technology* 2007; 42: 916-929.

Teow CC, Truong VD, Feeters RF, Thompson RL, Pecota KV, Yencho GC. Antioxidant activities, phenolic and betacarotene contents of sweet potato genotypes with varying flesh colours.*Food Chem.* 2007; 103: 829-38.

Ukom A, Ojimelukwe P, Okpara D. Nutrient composition of selected sweet potato [*Ipomeabatatas* (L) Lam] varieties as influenced by different levels of nitrogen fertilizer application. *Pakistan Journal of Nutrition* 2009; 8: 1791–1795.

Vijaya PD, Edukondalu L, Sivala K, Lakshmi J. Physico- chemical analysis of sorghum based extruded products. *International Journal of Engineering Research and Technology* 2016; 5: 201-205.

Yagci S and Gogus G. Response surface methodology for evaluation of physical and functional properties of extruded snack foods developed from food-by- products. *Journal of Food Engineering* 2008; 86:122-132.

Yang JH, Thi TTT, Van VML. Corn snack with high fiber content: Effects of different fiber types on the product quality. *LWT - Food Science and Technology* 2018; 96: 1–6.

Yao OL and Andrew RK. Dietary fibre basics: Health, nutrition, analysis, and applications. *Food Quality and Safety* 2017; 1: 47–59.