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Microencapsulation of Ascorbic Acid Powder for the Designing of Functional Pork Nuggets

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ABSTRACT

Livestock products are deficient in vitamin C, however the direct addition of it in meat products is challenging due to its thermal stability and effect on sensory attributes. Therefore, the present study was conducted to develop microencapsulated ascorbic acid (MAA) powder and optimization of its level for the designing of vitamin C fortified functional pork nuggets. Ascorbic acid was encapsulated with maltodextrin (maltodextrin: ascorbic acid: 1:4) as wall material using spray drying technique. MAA was incorporated at three different levels viz. 1% (FPN-C1), 1.5% (FPN-C2) and 2% (FPN-C3) in pork nuggets replacing lean meat in the formulation. The products were compared with control for the various physico-chemical, instrumental texture and colour profile and sensory quality attributes. The water activity, moisture, cooking yield, ascorbic acid, ash and acid insoluble ash content exhibited a significant increase ($p < 0.05$) whereas pH, protein, fat and crude fiber content decreased ($p < 0.05$) with the increase in the level of incorporation of MAA. Redness (a^*) and yellowness (b^*) value of the functional pork nuggets increased whereas Lightness (L^*) decreased. Incorporation of MAA significantly ($p < 0.05$) reduced the hardness, springiness, cohesiveness and gumminess of the developed functional pork nuggets. On sensory evaluation, FPN-C1 was rated as 'Very Good to Excellent' and the highest amongst the treatments. Therefore, MAA can be effectively incorporated at 1% level without affecting the quality attributes of pork nuggets.

HIGHLIGHTS

- Vitamin C is required for the normal regulatory functions of the body and must be supplied through the diet.
- It is an unstable compound and undergoes degradation during processing; microencapsulation is a method to stabilize sensitive compounds.
- Livestock products are deficient in Vitamin C, so incorporation of Microencapsulated ascorbic acid for the development of Functional Pork Nuggets has commercial importance.

Keywords: Microencapsulation, ascorbic acid, Functional Pork nuggets, Spray drying

The increase in incidences of lifestyle related chronic diseases led to the establishment of close relationship between diet and health, that has resulted in the rise of demand for health oriented functional foods (Miguel and Aleixandre, 2006). Functional foods or designer foods are formulated to provide health benefits over and above their normal nutritional values within daily dietary patterns (Kwak and Jukes, 2001). The nutritive value of meat and meat products can be altered either by adding ingredients that are considered beneficial for health or by eliminating or reducing components that are considered harmful, thus the modified foods can be considered "healthy" or "functional" (Fernández-Ginés *et al.,* 2005). Moreover, the nutritional security to combat deficiency diseases to the masses can be achieved through formulating strategies

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of fortification of food with micronutrients (vitamins and minerals) (Thangaraj and Seethalakshmi, 2015).

L-ascorbic acid (AA) is physiologically and biochemically an essential water-soluble active compound, required for the normal regulatory functions and must be supplied regularly in the diet as the human body is incapable of synthesis and storage of ascorbic acid. Ascorbic acid also possesses strong antioxidant property owing to its ability to donate hydrogen atoms to neutralize free radicals (Ball, 2004). So, it is identified as 'stress buster' and Recommended Dietary Allowance (RDA) of Vitamin C is 75 mg/day for adult female and 90 mg/day for adult men (Institute of Medicine, 2000). Further, it is known to extend the storage life of food products. However, ascorbic acid is highly unstable compound and traditional preservation methods, such as thermal processing, drying and freezing, are often linked to a substantial Vitamin C loss (Giannakourou and Taoukis, 2021). Therefore, maximizing vitamin C retention during processing is a challenge for food scientists.

Microencapsulation is an innovative method to stabilize sensitive compounds. A small solid particles, liquid droplets, or gas molecules are enclosed within a layer of coating/ wall material, or embedded in a homogenous or heterogeneous matrix. Spray drying is one of the most widely used microencapsulation techniques as it provides rapid evaporation of water, maintains the particles at low temperature, easier control on microsphere properties with the change in the operating parameters etc. (Rigon and Noreña, 2015).

Pork and other meats are considered as an excellent source of high quality protein, fats, B complex vitamins and minerals, but low in calcium, vitamin C and E (Mehta *et al*., 2015). Enhancement of meat and meat products with various bioactive compounds improve the technological and nutritional quality of the products (Serdaroğlu *et al*., 2017). Published literature on the fortification of pork nuggets with microencapsulated ascorbic acid is very limited. Therefore, the present study was conducted with an objective to microencapsulate ascorbic acid (MAA) with maltodextrin as wall material using spray drying technique and to optimize the level of incorporation of developed MAA for the designing of functional/fortified pork nuggets.

MATERIALS AND METHODS

Microencapsulated ascorbic acid

Microencapsulated Vitamin C (ascorbic acid) (MAA) was prepared following the method described by Chang *et al*. (2010), with slight modification. Spray-drying was performed using a BÜCHI mini spray Dryer B-290 (BÜCHI, Switzerland) with a standard 0.7 mm nozzle. The maltodextrin @12% in the ratio of 1:4 with ascorbic acid was selected based on the study conducted in our laboratory. The ascorbic acid and maltodextrin were pre-blended in distilled water using an ultra turrex homogenizer (T-25D S22 digital ultra-TURRAX Germany) for 25-30 min to obtain uniform mixture and kept for 24h to stabilize the emulsion. The aqueous solution of maltodextrin containing ascorbic acid was fed to the spray dryer. The inlet and outlet temperature of spray drier were 140^{o}C and 80-85^{o}C, respectively (Table 2). The encapsulated ascorbic acid was collected in a dry and sterile vacuum container and stored at -18˚C for further use.

Encapsulation efficiency (EE%)

The efficiency of microencapsulation of ascorbic acid was determined as per Al-Ismail *et al*. (2016) with slight modification and expressed as percentage.

Encapsulation efficiency (%) =

$$\frac{\text{Vitamin C in spray dried powder}}{\text{Total vitamin C added before drying}} \times 100$$

Percent Encapsulation yield (EY %)

The percent encapsulation yield was estimated as per Marcela *et al*. (2016). EY (%) was calculated as the ratio of weight of the spray dried powder (any microcapsules adhering to the walls of the drying chamber or cyclone were not considered) and the weight of all solids (including wall and core materials) in the emulsion, expressed as percentage.

Bulk density

It was calculated by using the method of Jinapong *et al*. (2008). The powders were gently loaded into a 100 ml tarred graduated cylinder. The volume read directly from the loaded cylinder was then used to calculate the bulk density (d) according to the mass/volume relationship.

Tapped density

It was evaluated using the method described by de Barros Fernandes *et al*. (2014). Approximately 5 g of powder was poured into a 25 ml graduated cylinder and then the cylinder was repeatedly tapped by lifting and dropping it under its own weight until a negligible difference in volume between successive measurements was observed. Given the mass (m) and the apparent (tapped) volume (V) of the powder, the powder bulk density was calculated as m/V (g/cm^3).

Pork

Crossbred (Landrace x Local) live pigs of age 7 months weighing approximately 100 Kg, procured from University Livestock Farm, College of Veterinary Science, Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana was slaughtered in experimental slaughter house following the standard procedure while keeping animal welfare aspects under consideration. The dressed carcass was hot deboned manually and the fascia, external fat and other connective tissue were removed. The recovered deboned meat was chilled over-night at refrigeration temperature. The lean meat and fat were cut and packed, and stored in frozen condition (18±1˚C) in LDPE pouch for further use.

Other ingredients

Spice mix, refined wheat flour, soy protein, condiments and salt were procured from local market of Ludhiana. Analytical and food grade chemicals, and reagents used in the experiment were procured from reputed firms (Sigma-Aldrich, Hi media, MP Biomedicals).

Preparation of pork nuggets

The pork nuggets were prepared following the protocol described by Thomas *et al*. (2016), and formulation as listed in Table 1. The microencapsulated ascorbic acid (MAA) was incorporated at three different levels viz. 1% (FPN-C1), 1.5% (FPN-C2) and 2% (FPN-C3) replacing the lean meat in the formulation. MAA was added along with other non-meat ingredients at the time of batter formation and mixed properly for uniform distribution. The meat emulsion was packed compactly in food grade stainless steel (SS-316) molds of size (21×10×5.5 cm) and closed tightly. The meat blocks were pressure cooked at 15 psi at 121^{o}C for 30 mins, however the pressure was released slowly, thereafter, the product was cooled at ambient temperature. The cooked meat block was cut into the shape of nuggets and evaluated for sensory and other quality parameters.

Table 1: Formulation (g/100g) for optimization of vitamin C level in pork nuggets

Ingredients	CPN	FPN-C1	FPN-C2	FPN-C3
Lean meat	68.0	67.0	66.5	66.0
Fat/ oil	10.0	10.0	10.0	10.0
Water	10.0	10.0	10.0	10.0
Soy protein	3.0	3.0	3.0	3.0
Refined wheat flour	3. 0	3.0	3.0	3.0
Condiments	3.0	3.0	3.0	3.0
Spices	1.5	1.5	1.5	1.5
Salt	1.5	1.5	1.5	1.5
Nitrate (ppm)	0.015	0.015	0.015	0.015
MAA	—	1.0	1.5	2.0

CPN: Pork nuggets without MAA; FPN-C1: Pork nuggets with 1% MAA; FPN-C2: Pork nuggets with 1.5% MAA; FPN-C3: Pork nuggets with 2% MAA.

Physico-chemical analyses

Cooking yield was determined by the method performed by Murphy *et al*. (1975) and expressed as percentage. The pH was measured using digital pH meter (S22 digital ultra TURRAX, Germany) as per Trout *et al*. (1992). Water activity (a_w) was determined using a potable digital water activity meter (Rotronix HYGRO Palm AW1 Set, Rotronix Instrument (UK) Ltd., West Sussex and UK).

Proximate analysis

The proximate composition such as moisture, protein, fat, crude fiber and ash content of sample were determined by standard methods as per AOAC (2005). Moisture and ash content was determined using hot air oven and muffle furnace, respectively. Fat content was extracted from moisture free sample in a Soxhlet extraction apparatus (Socs Plus, SCS-6-AS, Pelican Industries, Chennai). The protein content of pork nuggets was estimated using automatic digestion and distillation unit (Kel Plus- KES 12L, Pelican Industries, Chennai).

Vitamin C

The Vitamin C content was estimated by the 2, 6-Dichloroindophenol method (AOAC, 2005). The samples were weighed and dissolved in 100 ml of metaphosphoric acid, followed by filtration. The extract and metaphosphoric acid were mixed together in 1:1 ratio and thereafter 0.4ml of freshly prepared colour reagent (composed of 2,4-dintro phenyl hydrazine, cupric sulfate solution and thiourea) was added followed by cooling in ice bath for 5 min. Then 2ml of ice cold 85% H_2SO_4 was added in each tube and allowed to stand for 30 mins. The absorbance was measured at 500nm. The metaphosphoric acid was taken as blank and standard solution was prepared using different concentration of ascorbic acid and standard curve was drawn to estimate the Vitamin C content.

Instrumental colour profile analysis

Instrumental colour values (*L**, *a** and *b**) of the pork meat nuggets were measured using CR-400, Konica Minolta, Chromameter (Japan). The *L** value denotes brightness (100) or lightness (0), *a** (+ redness/- greenness), and *b** denotes (+ yellowness/-blueness) values. The cut surface of the cooked meat nuggets were directly measured by placing pre-calibrated instrument at different points and readings were recorded.

Instrumental texture analysis

Texture profile analysis (TPA) was conducted using texture analyzer (TMS-PRO, Food Technology Corporation, USA) as per the procedure outlined by Bourne (1978). Cooked pork nuggets of size 1.0 cm x 1.0 cm x 1.0 cm were subjected to pretest (30mm/sec) and post-test speed (100mm/sec) to a double compression cycle with a load cell of 100N. A compression platform was used as a probe. Parameters like hardness, gumminess, stringiness, springiness, resilience, chewiness and cohesiveness were calculated automatically by the preloaded software in the equipment from the force time plot.

Sensory evaluation

Seven experienced panelists from the scientific staff and postgraduate students of GADVASU, Ludhiana, India conducted sensory evaluation of the pork nuggets using 8- point descriptive scale, where, 8= extremely desirable and 1= extremely undesirable (Keaton, 1983). Sensory evaluation for all the batches were carried out, coded samples were presented and evaluated according to the international standards (ASTM, 1986).

STATISTICAL ANALYSIS

The data generated from various trials under each experiment were pooled and analyzed by statistical method of one-way ANOVA and Mean ±SE using IBM SPSS Statistics software (Version 20.0 for Windows; IBM SPSS Inc, Chicago, 111, USA) and means were compared by using Duncan's multiple range test (Steel and Torrie, 1981). The statistical significance was expressed at 5% level of significance.

RESULTS AND DISCUSSION

Quality analysis of microencapsulated ascorbic acid

Microencapsulated ascorbic acid (MAA) was prepared using spray drying technique with an inlet and outlet temperature of 140˚C and 80-85˚C, respectively while maintaining an aspiration rate of 100% and feed flow rate of 16-18%. The developed MAA was evaluated for its various properties and presented in Table 2.

Table 2: Properties of spray dried microencapsulated ascorbic acid

Parameters	Values
Moisture (%)	4.98
Water activity (a_w)	0.26
pH	2.84
Total ascorbic acid content(mg/100mg)	18.29
Encapsulation yield (%)	78.48
Encapsulation efficiency (%)	91.45
Inlet temperature (˚C)	140±2^{o}C
Outlet temperature (˚C)	80±2^{o}C
Aspiration rate (%)	100
Feed flow rate (%)	16-18
Bulk density (g/cm^3)	0.344
Tapped Density	0.283

The quality attributes of microcapsules are directed by spray drying conditions such as feed flow rate, inlet and outlet temperature, suction power etc. (Marcela *et al*., 2016). Residual moisture content of powder is a significant factor in determining its storage and chemical stability, solubility, hygroscopicity, bulk density, flowability and total acceptability (Chew *et al*., 2018; Premi and Sharma, 2017; Sánchez-Reinoso *et al*., 2017). Moisture is an indicator of the drying efficiency and affects shelf life and adhesiveness of the product. The moisture content in the product was 4.98%. Nizori *et al*. (2012) also reported a moisture content of 4-9% in ascorbic acid microcapsules prepared by spray drying. Higher moisture content in powder results in rapid oxidation or breakdown of encapsulated active principle and microbial contamination (Edris *et al*., 2016; Santana *et al.,* 2016 and Toledo Hijjo *et al*., 2015).

The water activity of the spray dried powder is within the limit of 0.30, which is positive for powder stability (Quek *et al*., 2007). The stability of microcapsule is directed by the type of wall material. Maltodextrin is food grade polysaccharide and relatively stable at acidic pH (Chronakis, 2014). The pH of spray dried powder is 2.84, which is slightly higher than the pH of ascorbic acid (1-2.5) and this may be due to dilution effect of maltodextrin (O'Neil, 2006).

Encapsulation efficiency (EE%)

EE is considered as an indicator of success of encapsulation process and the level of loss of core material during the drying process. The encapsulation efficiency of the prepared spray dried powder was 91.45% (Table 2). On the contrary, Desai and Park (2005) also encapsulated vitamin C in chitosan microspheres with TPP by spray drying method and achieved an encapsulation efficiency of 58.3%. Maltodextrin would lead to the formation of a dry crust around the drying droplets that ultimately hindered the core particles to escape from the matrix resulting in subsequently higher EE (Hee *et al*., 2015). Similar findings have been reported by Premi & Sharma (2017) and Kanth *et al*. (2018).

Encapsulation yield (EY%)

Microencapsulation of bioactive food ingredients allows the formation of protective film around the droplets or particles with the microencapsulated (core) material (Nizori *et al*., 2012). The yield of microspheres depends upon the experimental conditions (inlet temperature, flow rate and compressed air flow during spray drying process (Desai and Park, 2005). In the present study, the encapsulation yield (EY %) was estimated as 78.48%. Marcela *et al*. (2016) recorded an encapsulation yield of 59.74% using sodium alginate as wall material (L-ascorbic acid to Sodium alginate in the ratio 1:3.5) at an inlet temperature of 125˚C. Finotelli and Rocha-Leão (2015) also reported a yield of 52% with a mixture of capsule/maltodextrin (1:1) to encapsulate ascorbic acid. Encapsulation yield tends to be lower at higher concentration of wall material, this may be related to formation of large droplets due to increase in viscosity of the emulsion that are more difficult to dry and stick to the wall of the drying chamber (Santana *et al*., 2014).

Bulk and tapped density

Bulk density is defined as the ratio of the mass of an untapped powder sample and its volume that contributes to the interparticulate void volume. Higher value indicates more stability during storage which might be due to the absence of air in the powder. It is important property in packaging, reconstitution and retail disbursement of any encapsulated powder. It is a factor determined by size, shape and moisture content (Shamaei *et al*., 2017). The bulk density of MAA in the present study was 0.344g/cm^3, could be due to lower moisture content (4.98%) at higher inlet temperatures (140±2^{o}C). Further at higher drying temperature hollow microcapsules with higher sphericity and large size particles will be formed that leads to occupation of more space (Sánchez-Reinoso *et al*., 2017, Shamaei *et al*., 2012).

Tapped density directs the packaging, transport, and commercialization of powders w.r.t. filling of the container (Botrel *et al*., 2012 and Finney *et al*., 2002). Developed MAA powder recorded 0.283 gm/cm^3 tapped density whereas Kanth *et al.* (2018) measured 0.37 gm/cm^3 for rosemary oil powder using maltodextrin as wall material. This might be attributed to maltodextrin and moisture (Raigar and Mishra, 2015). Higher moisture content results in clumping of particles thereby increasing tapped density (Quispe-condori *et al*., 2011).

Total vitamin C content in spray dried powder

The content of Vitamin C was estimated as 18.29 mg/100 mg of the spray dried powder which is much lower than that reported by Marcela *et al*. (2016). The lower ascorbic acid content in the spray dried powder of this experiment may be attributed to the destruction of ascorbic acid at higher inlet temperature as increase in temperature markedly increases the conversion of ascorbic acid to 2,3-diketogluconic acid (Muzaffar *et al*., 2016).

Physico-chemical analysis

The functional pork nuggets fortified with three levels of vitamin C: 1%, 1.5% and 2% as FPN-C1, FPN-C2 and FPN-C3, respectively were compared with control (CPN) for various physico-chemical and sensory parameters to draw inference for the optimization of the levels.

The cooking yield, water activity (a_w) and moisture content increases with the incorporation of microencapsulated ascorbic acid (MAA) and follows an increasing trend with increase of level of incorporation. Although there was a decrease in pH of the treated products, the cooking loss was lower in the treatments which may be attributed to the hygroscopic nature and binding affinity of maltodextrin with water that compensate the water loss due to low pH and therefore result in higher yield (Carvalho *et al*., 2017) and also higher water activity. Crehan *et al*. (2000) also observed that frankfurters formulated with maltodextrin had significantly lower cook loss than control with no added ingredients.

The incorporation of microencapsulated ascorbic acid/ Vitamin C (MAA) resulted in lowering of pH, protein, fat and crude fiber content of the treatments. The pH of the cooked nuggets decreased significantly ($p<0.05$) with the incorporation of MAA. The lowering effect of pH might be due to low pH of the ascorbic acid as 5% solution of ascorbic acid in water has a pH of 2.2-2.5 (Chang *et al*., 2010; O'Neil, 2006). Ozer *et al*. (2010) also confirmed decrease in pH of raw mechanically deboned chicken patty with the addition of ascorbic acid. Similarly, a significant lowering of pH with the incorporation of ascorbic acid in low fat chicken meat patties was reported by Mehta *et al*. (2015).

The decrease in the protein, fat and crude fiber content of the treated products as compared to the control might be due to the dilution effect brought about by the replacement of lean meat with MAA. Similar findings were reported by Irshad *et al*. (2016) in restructured buffalo meat loaves incorporated with calcium lactate and Mehta *et al*. 2015 in low-fat chicken meat patties incorporated with ascorbic acid.

On the other hand, the increasing trend observed in ash and acid insoluble ash content in the treated products attributed to the corresponding increase in the level of

Table 3: Physico-chemical quality of pork nuggets incorporated with microencapsulated Vitamin C

Parameters	CPN	FPN-C1	FPN-C2	FPN-C3
Water activity (a_w)	0.981±0.04	0.983±0.08	0.986±0.03	0.988±0.03
pH	6.33±0.02^d	6.25±0.02^c	6.19±0.06^b	6.14±0.02^a
Vitamin C (mg/100g)	N.D.	108.79±0.09^a	165.63±0.07^b	221.86±0.30^c
Cooking yield (%)	91.89±0.40^a	92.53±0.10^{ab}	93.33±0.30^{bc}	93.57±0.30^c
Moisture (%)	56.68±0.10^a	57.88±0.30^b	57.92±0.20^b	58.72±0.50^b
Protein (%)	19.08±0.30^b	18.79±0.40^{ab}	17.97±0.07^a	17.86±0.30^a
Fat (%)	15.65±0.20^b	15.17±0.30^{ab}	14.85±0.70^{ab}	14.42±0.30^a
Crude Fiber (%)	1.49±0.02^c	1.44±0.02^{bc}	1.34±0.04^{ab}	1.29±0.03^a
Ash (%)	1.95±0.02^a	2.03±0.07^b	2.07±0.07^b	2.13±0.02^c
Acid insoluble Ash (%)	0.28±0.02^a	0.29±0.03^a	0.31±0.03^a	0.40±0.02^b
Loss of Vitamin C during processing (%)	—	40.52±0.30^b	39.63±0.50^{ab}	39.35±0.30^a

Mean ± SE values bearing same superscripts row-wise (small alphabets) do not differ significantly ($p<0.05$). n=6

CPN: Pork nuggets without MAA; FPN-C1: Pork nuggets with 1% MAA; FPN-C2: Pork nuggets with 1.5% MAA; FPN-C3: Pork nuggets with 2% MAA

Table 4: Instrumental colour analysis of pork nuggets incorporated with encapsulated Vitamin C

Parameters	Control	FPN-C1	FPN-C2	FPN-C3
Lightness *(L*)*	48.87±0.30[b]	48.24±0.30[ab]	47.92±0.40[ab]	47.41±0.40[a]
Redness *(a*)*	8.32±0.02[a]	8.48±0.02[b]	8.71±0.01[c]	8.84±0.01[d]
Yellowness *(b*)*	18.48±0.04[a]	18.59±0.05[a]	18.82±0.04[b]	19.20±0.03[c]

Mean ± SE values bearing same superscripts row-wise (small alphabets) do not differ significantly ($p<0.05$). n=6

CPN: Pork nuggets without MAA; FPN-C1: Pork nuggets with 1% MAA; FPN-C2: Pork nuggets with 1.5% MAA; FPN-C3: Pork nuggets with 2% MAA

MAA. The increase in ash content with increasing level of ascorbic acid is in accordance with the findings reported by Mehta *et al*. (2015) in low fat chicken meat patties incorporated with ascorbic acid.

The cooking loss of vitamin C in FPN-C1 is higher as compared to FPN-C2 and FPN-C3 which might be due to the draining of water soluble vitamin C in the moisture loss during cooking. However, the loss in Vitamin C during cooking ranges from 39.35 to 40.52%, which indicated that microencapsulation of ascorbic acid was efficient in retention of vitamin C during processing.

Instrumental colour analysis

Incorporation of MAA is shown to exhibit a lowering effect on the Lightness (L^*) of the pork nuggets, the lowest was recorded for FPN-C3 (47.41±0.03). Tahmouzi (2016) also observed decrease in L^* value with increase in percentage of additives in Asian hot dogs and suggested that the increased water retention of hygroscopic materials may have absorbed free water within the product and thereby reduces the lightness value.

Redness (a^*) and yellowness (b^*) values increased significantly ($p<0.05$) in treated products and increased in dose dependent manner i.e. with the level of incorporation. Ascorbic acid as an antioxidant and a reducing agent maintains the myoglobin in ferrous state and prevent the occurrence of oxidation during cooking, resulting in an increase in the redness of cooked product. Similar observations were also observed by Perlo *et al*. 2018 in pork *L. dorsi* steaks sprayed with ascorbic acid solution (500ppm). Tahmouzi (2016) also reported higher redness (a^*) in Asian hot dogs with higher concentrations of ascorbic acid.

Instrumental texture analysis

Parameters of instrumental texture analysis such as hardness, springiness, cohesiveness and gumminess were reduced due to incorporation of MAA in pork nuggets. This might be due to maltodextrin reducing the bind strength between meat particles (Crehan *et al*., 2000). The decrease in the hardness and other parameters may be due to the dilution effect of the non-meat ingredients in the meat protein systems (Das *et al*., 2008). However, an increase in the stringiness, chewiness and resilience were also observed in the treated products. An increase in the chewiness and resilience of beef burger incorporated with maltodextrin was also reported by Hassan *et al*. (2004).

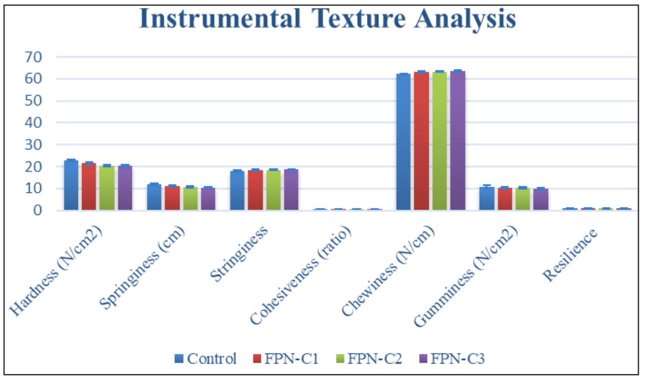

Fig. 1: Instrumental texture analysis of pork nuggets incorporated with encapsulated Vitamin C.

CPN: Pork nuggets without MAA; FPN-C1: Pork nuggets with 1% MAA; FPN-C2: Pork nuggets with 1.5% MAA; FPN-C3: Pork nuggets with 2% MAA

Sensory evaluation

The colour and appearance of the pork nuggets at 1% level of MAA incorporation (FPN-C1) was comparable to control, however, a significant decrease ($p<0.05$) was observed in FPN-C2 and FPN-C3. This may suggest that 1% level is sufficient to maintain the appealing red colour of pork nuggets and the reddening of colour beyond this level was not appreciated by the panelists.

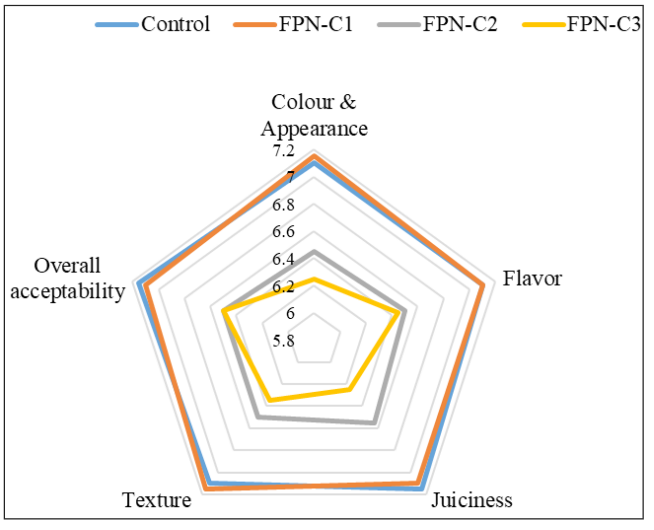

Fig. 2: Sensory evaluation of pork nuggets incorporated with encapsulated Vitamin C

The flavor and juiciness of treated products were significantly reduced at the incorporation level above 1.5%, although the FPN-C1 was comparable to control. The lowering of flavor and juiciness scores were significant only at higher level of incorporation. The sour flavor of ascorbic acid may be more pronounced at incorporation level above 1.5% and might have contributed to the lowering of flavor. Moreover, the maltodextrin at higher level might have a masking effect on the flavor of meat. Juiciness is often associated with the lubrication brought about by the melting of fat in the meat products. In this study the treated products with lower fat content were scored lower for juiciness, which may indicate that the decrease in fat content is responsible for the lowering of juiciness score. Yogesh *et al*. (2013) also reported an increase in juiciness in chicken nuggets with higher fat contents.

The panelists recorded highest texture scores for FPN-C1 among all the products. The reduction in meat binding due to maltodextrin which was more pronounced in FPN-C2 and FPN-C3 might have a negative influence on the texture of pork nuggets. Mean sensory scores of FPN-C1 was comparable to control although the incorporation of MAA above 1.5% resulted in a significant ($p<0.05$) lowering of the overall acceptability of the pork nuggets.

CONCLUSION

Microencapsulation of ascorbic acid can be effectively performed by spray drying method using maltodextrin as the wall material so as to overcome the unstable nature of ascorbic acid during processing. MAA powder can be successfully incorporated at 1% level to deliver 108.79 mg of Vitamin C per 100 g of pork nuggets which fulfill RDA of 90mg/ adult man. The developed functional pork nuggets have appreciable sensory quality parameters and improved processing characteristics. The microencapsulation of ascorbic acid is recommended to reduce the processing losses of ascorbic acid usually encountered with heat treatment.

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