CHAPTER 7

Encapsulation efficiency of polyphenol extracts within polysaccharides-based beads and to evaluate the feasibility of the incorporation in the food product

7.1. Introduction

The use of plants for medicinal purposes for the treatment of various diseases has occurred for thousands of years and the wide structural variability of molecules with biological activity has been appreciated more recently (Tanaka and Kashiwada, 2021). The World Health Organization (WHO) suggests that developing countries, comprising around 80% of the world population, depend on traditional medicine for primary health care (Cameron et al., 2011). However, most of the natural compounds which are highly lipophilic are not ideal for drug delivery because they do not dissolve well in the body. They have lower bioavailability and require repeated administration or higher doses to achieve the desired therapeutic effects, which can lead to acute toxicity, adverse effects, and low patient compliance (Gunasekaran et al., 2014).

There are several techniques in which bioactive compounds can be encapsulated, of which Ionic gelation is one of the techniques. Among the several methods for encapsulating active compounds, Ionic gelation is one of the most straightforward and inexpensive techniques for encapsulating bioactive compounds since it does not require high temperatures or solvents; thus, it is especially useful for heat-sensitive compounds. The process, so-called ionic gelation or ionotropic gelation begins with an aqueous polymeric solution, with ions of low molecular mass that interact with polyelectrolytes of opposite charges, reacting and forming an insoluble gel (Henning et al., 2012). The principle of encapsulation consists in simply entrap an active substance and to further release it via gel phase changes, in response to external stimuli. Different triggering mechanisms are used to release the encapsulated active as pH changes, mechanical attrition, enzymes, osmotic forces, and actives are released via diffusion.

Ionic gelation can be conducted by atomization processes, extrusion and coextrusion or electrostatic deposition (Messaoud et al., 2016). Usually, a polymeric or hydrocolloid

solution is dripped or atomized into an ionic solution, under constant agitation. The active compound to be encapsulated is dissolved in the polymeric solution. The drops that reach the ionic solution immediately form spherical gel structures, which contain the active dispersed in the whole polysaccharide matrix (Belščak-Cvitanović et al., 2016). It is a simple and easy procedure, does not require specialized equipment, high temperature or organic solvent and can be considered low cost. Alginate, low metoxilation pectin, chitin, chitosan are normally used as coating agents and the ion Ca^{+2} is the most used reticulation agent. They can be considered a very good encapsulation system for food compounds and controlled release, as they are atoxic, highly biocompatible and mechanically strong (Poncelet et al., 1999).

Among the most popular items, cereal-based foods are thought to be a favourable vehicle for the fortification of micronutrients, such as minerals, omega-3 fatty acids, phenolic compounds, plant extracts, essential oils, flavouring agents, probiotics, enzymes, anthocyanins, and carotenoids. Yet, because they are lost during processing and storage due to degradation, including the free form of bioactive chemicals into such food products provides a difficulty (Rousta et al., 2021). In a study by Ćetković et al., 2022, durum-wheat pasta was enhanced with concentrated carrot waste extracts in oil, which were produced using freeze-drying (FDE) or spray-drying methods (SDE). Furosine, carotenoids, tocopherols, colour, in vitro bioactivities, cooking performance, texture, and sensory quality were assessed in five different types of pasta (control, supplemented with 10% FDE, 10% SDE, 20% FDE, or 20% SDE). The inclusion of encapsulates greatly enhanced the durum-wheat pasta's nutritional and technological properties. In a different study by Elsebaie et al., (2022), encapsulation decreased the antioxidant activity loss rate by 67.73% as compared to free Azolla powder. Except for water absorption and weight growth, none of the fresh macaroni's cooking or textural characteristics were significantly impacted by the insertion of microcapsules; nonetheless, the overall acceptance index (85.13%) was unaffected.

Clerodendrum glandulosum Lindl. (Synonym: C. colebrookianum *Walp*.), is an important member of this family which abundantly grow as a wild species across Northeast region (NER) of India as well as tropical and subtropical zones of the South-Asian sub-continent (Deori et al., 2013). In India, the genus comprises several species distributed from foothills of Himalayas to coastal areas of Kanyakumari in various agro-ecological zones. The genus

Clerodendrum represents 18 species and 2 varieties in Northeastern part of India. It is commonly known as Nefafu in Assamese and Phuinum in Mizo ethnomedicinal practices (Nath and Bordoloi 1991; Kalita et al., 2012). Having several potent medicinal properties, this species holds a special place in folk medicines and culinary habits of NER and is consumed regularly as a food. *Clerodendrum glandulosum* (CG) has been reported for its therapeutic uses to cure various metabolic syndromes (MetS) including hypertension, high cholesterol, diabetes, obesity etc. (Deb et al., 2015). Extracts obtained from leaves of CG have been reported as antioxidant, hepatoprotective, anti-inflammatory, cardioprotective, hypolipidemic, ant obesity, anti-hyperglycemic and antidiabetic (Jadeja et al., 2012).

The present study was an attempt to develop innovative fuctional pasta with high antioxidant properties by fortification with encapsulated beads of *Clerodendrum glandulosum* Lindl. extracts and assess the effect of fortification on physiochemical and texture of fortified pasta. The beads have been prepared using vibration dripping extrusion.

7.2. Materials and methods

7.2.1. Materials and plant extract preparation

Clerodendrum glandulosum Lindl. were collected from street vendors and local markets in Churachandpur district, Manipur. The collected plant samples were washed thoroughly with water tap to remove sand, seeds, and clay, then dried at 40°C on air oven for 48 h. to obtain dry sample which was later coarsely powdered in a blender (HL1643/04 600-Watt, Phillip) and used for solvent extraction. Semolina for dough preparation was collected from the local market in Tezpur, Assam. The chemicals used for the experiments were all analytical grades. Double distilled water was used to prepare the solution for the experiments.

To extract active compounds from the leaf powder, especially polyphenolic compounds, ultrasonic aided extraction was used. It was carried out by utilising the Ultrasonic Homogenizer (U500, Takashi, Japan). The process parameters were 20% liquid-to-solids ratio, 70% ethanol, and 30 minutes of extraction time. The extract was lyophilized, and the dried extracts were stored for further analysis.

7.2.2. Preparation of core shell polymer-based formulations

Polymer-based nanoparticles with diameters ranging from 10 to 1000 nm are ideal for delivering plant-derived natural products. These nanoparticles are synthesized using biodegradable and biocompatible polymers and can be used to control the release and delivery of bioactive compounds. Natural polymers (e.g. alginate and chitosan) as well as synthetic polymers (e.g. polyvinyl alcohol, poly [L-lactic acid], polyethylene glycol [PEG], and poly [lactic-co-glycolic acid]), are widely used for the synthesis of polymer-based nanoparticles (Patra et al., 2018). The extracts were mixed with sodium alginate (1.5 g/100 mL) in pH 5 buffer using a portable blender (Phillips HL 1643/04 600-Watt) for 1 min at a fixed speed. A core-shell hydrogel biopolymer system was formulated with 1.5% sodium alginate combined with guar gum. The hydrogel-based core-shell biopolymer solution was blended at 2% (w/v) combined with optimized *Clerodendrum glandulosum* Lindl. extract prepared with ethanol based ultrasonic-assisted extraction, subsequently their combination at a specified mass proportion of 20:80 (w/w) (de Moura et al., 2018). The distance from the top nozzle to the bottom surface of the $CaCl_2$ solution (2% (w/v), 5°C) was selected 15 cm after the major trials. The microgel beads were stirred at 100 rpm using a magnetic stirrer (Abdos, India) for 15 min for hardening. Then, each set of microgel beads was filtered through a filter paper (Whatman 1). The varied microgel beads were subjected to the lyophilisation process using a freeze dryer (Lyolab, India). The moisture content of the plant extracts microgel beads was determined gravimetrically. 30 mg of beads were dried using hot air oven drying at 70 °C until constant mass retained (Sharma et al., 2022).

7.2.3. Pasta formulation and dough preparation

In the formulation, dried plant extract beads were added by substituting 0%, 2.5%, 5%, 7.5%, and 10%w/w semolina (Table 7.1). Samples were swirled in a bowl for 10 minutes to ensure equal mixing. Semolina or pasta that hasn't had plant extracts beads added to it is referred to as "control." To achieve a wet basis moisture content of 40%, a predetermined amount of water was added to each sample. Each sample was manually kneaded before being ran five times from each pass through the pasta machine to produce a consistent sheet (Model no.: Imperia Italy dal 1932). Using a calliper, the ultimate 2.5 mm thickness of each dough sheet was determined. Fresh pasta was produced using a machine equipped with a pasta die (2.25 mm diameter of die hole). The samples were packed in plastic bags

and left to rest for 10 minutes before each test. Other samples were dried at 45–50 °C for 4-5 hours to get a moisture content of 6.0–6.5% in preparation for a subsequent inquiry that required dried samples. Several mixtures of dried goods were packaged in polyethylene bags (Kaur et al., 2013).

Table 7.1.: Dough formulations of fresh pasta with the inclusion of different levels of plant extract beads

Sample code	Semolina (g/100g)	Extract encapsulated beads (g/100g)
CNT	100	0.00
E-2.5	97.50	2.50
E-5.0	95.00	5.00
E-7.5	92.50	7.50
E-10.0	90.00	10.00

CNT- control; E-encapsulated beads pasta

7.2.4. Cooking quality of fortified pasta

7.2.4.1. Optimum cooking time (OCT)

Pasta strands (20 g) were cut into an equally and cooked in 300 ml of boiling water. During cooking, the optimal cooking time was evaluated every 30 s by observing the time of disappearance of the white core of pasta, by squeezing it between two transparent glass slides according to the AACC Method 66-50 (2000). The time at which the white core completely disappeared was taken as the optimum cooking time (OCT).

7.2.4.2. Cooking loss (CL).

The amount of solid substance lost in the cooking water was determined according to the AACC, Method 66-50 (2000). Ten grams of pasta were cooked in 300 ml of boiling water at optimal cooking time. Rinsed with 100 mL of cold water, trained for 30 s to determine the cooking loss of the pasta. The cooking water was collected in an aluminum vessel, placed in an air oven at 105 °C to evaporate the water until a constant weight was reached. The residue was weighted and reported as a percentage of starting materials. The analysis was carried out in triplicate.

Swelling index and water absorption index

The swelling index (SI) of cooked pasta (g water per gram dry pasta) was determined according to the procedure described by Cleary and Brennan (2006). Pasta (100 g) was weighed after cooking and dried at 105 °C until constant weight was reached. The swelling index was determined using the Eq. 7.1

$$\mathrm{SI} = \frac{W_c - W_d}{W_d} \tag{7.1}$$

where W_c is weight of cooked pasta (g) and W_d is weight of pasta after drying (g).

The water absorption index (WAI) (g per 100 g) was determined using the Eq. 7.2

$$\mathrm{WAI} = \frac{W_c - W_r}{W_r} \times 100 \tag{7.2}$$

where *Wc* is weight of cooked pasta (g) and W_r is weight of uncooked pasta (g).

7.2.4.3. Moisture content of the pasta

The moisture content of the control and formulated pasta of cooked was determined according to AACC 44-40 (2000).

7.2.5. Total phenolic content

The total phenolic content was determined by the spectrophotometric method (Singleton and Rossi, 1965). In brief, 1 mg mL^{-1} sample of leaf extract was mixed with 1 mL of Folin-Ciocalteu's phenol reagent. After 5 min, 10 mL of a 7% Na_2CO_3 solution was added to the mixture followed by the addition of 13 mL of deionized distilled water and mixed thoroughly.

The mixture was kept in the dark for 90 min at 25°C, after which the absorbance was read at 750 nm with a spectrophotometer. The total phenolic content was determined from extrapolation of calibration curve which was made by preparing Gallic acid solution as standard. The estimation of the phenolic compounds was carried out in triplicate. The total phenolic content in prickly pears fruit peel extract was expressed as μg of gallic acid equivalents (DW) per g of sample extract.

7.2.6. DPPH radical scavenging activity assay

The free radical scavenging activity of the encapsulated pasta were measured by 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay according to the method described earlier by Brand-Williams et al., (1995). The stock solution was prepared by dissolving 24 mg DPPH with 100 mL ethanol and stored at 20°C until required. The working solution was obtained by diluting DPPH solution with ethanol to attain an absorbance of about 0.98±0.12 at 517 nm using the spectrophotometer. A 3 mL aliquot of this solution was mixed with 0.1 mL of the sample at various concentrations (5-35 mg mL^{-1}). The reaction mixture was shaken well and incubated in the dark for 15 min at room temperature. Then the absorbance was taken at 517 nm.

The control was prepared as above without any sample. The scavenging activity was estimated based on the percentage of DPPH radical scavenged using the Eq. 7.3

$$\text{Scavenging effect (\%)} = \frac{\text{Control absorbance-Sample absorbance}}{\text{Control absorbance}} \times 100 \quad (7.3)$$

7.2.7. FT-IR Spectroscopic analysis

Powder samples of pasta were grounded with KBr at a (1:100) ratio. The samples were pressed at a high pressure into KBr pellet. The spectral analysis was carried out using a FT-IR spectrometer (Perkin Elmer Spectrum-model 100, USA). The FT-IR spectra of the sample were recorded in the range of 4000-400 cm^{-1} region at room temperature.

7.2.8. Color analysis

The parameters of raw and cooked pasta were determined with the reflective method using a spherical spectrophotometer (Hunter ColorLab Ultrascan Vis). They were assessed using a standard light source (D65) and a standard colorimetric observer with a 10° visual field. A 12.3 mm diameter hole was used for the measurement. Colour coordinates (L*, a*, b*) were determined. Changes in the colour of the pasta as a result of addition of the encapsulated beads (ΔE) were determined relative to the CNT sample (raw and cooked) using the Eq. (7.4).

$$\Delta E = \sqrt{\{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2\}} \quad (7.4)$$

where L_2*, a_2*, b_2* are colour parameters of control sample taken as reference, and L_1*, a_1*, b_1* referred to colour parameters of pasta samples.

7.2.9. SEM analysis

The microstructure of the spaghetti was analyzed by SEM (JEOL JSM-6390 LV, SEM, USA). Samples were placed carefully in a metal stud with double-sided tape, using a sputter gold coater. The morphological structure of the sample's graphs were observed at a magnification of 100X and 1000X with accelerating voltage of 10 kV.

7.2.10. Statistical analysis

Experiments were carried out in triplicates and presented as mean ± standard deviation of mean using SPSS version 16. The data were statistically analyzed by Duncan's multiple range tests at 5% significance level. The Origin 8.5 (Origin Lab Corporation, Northampton, USA) software was used for statistical analysis.

7.3. Results and discussion

7.3.1. Cooking characteristics of cooked pasta

The findings for the OCT, cooking loss, swelling index, WAI, and moisture of pasta manufactured with various concentrations of encapsulated beads of *Clerodendrum glandulosum* Lindl. leaf extracts are shown in Table 7.2. When soluble starch and other soluble ingredients, such as non-starch polysaccharides, leak out into water during cooking, the cooked water thickens as a result. Formulated pasta has a different cooking profile than the Control, which is made entirely of semolina flour. For both the formulated and control pasta samples, six minutes was the ideal cooking time, which was achieved when the pasta's centre was fully moistened. Several investigations that concur with the current study demonstrated a reduced cooking loss value for the control pasta made with 100% durum wheat semolina. As the prepared cooked pasta evenly increases from E-2.5 (2.21±0.32%) to E-10.0 (1.22±0.04%), the control cooked pasta had a cooking loss of 2.19±0.32%. 6.40–6.50 g/100 g of raw spaghetti pasta were reported as cooking loss values by Manthey and Schorno, (2002). The cooking loss value reported by Brennan and Tudorica, (2007) was lower (0.93 g/100 g of raw spaghetti pasta).

The moisture content of the formulated pasta rose from 39.74±0.32% to 53.68±0.94% in the control pasta. The water that is absorbed by the starch and proteins during cooking and

used for starch gelatinization and protein hydration is indicated by the pasta's swelling index. The swelling index and water absorption (%) of formulated functional pasta increased in comparison to control, according to the results reported in Table 7.2. According to reports, the cooked pasta's formulated E-2.5 (1.22±0.02) to E-10.0 (1.40±0.01) gradually increases while the CNT's swelling index is stated to be smaller. This could be because the gum's carboxyl and hydroxyl groups enable them to bind with easily accessible water, increasing swelling index and water absorption. When the range of the formulation rises, the moisture increases but the capacity to absorb water diminishes. The maximum recorded value was 57.97±1.68% for the control, and the lowest value was 46.92±0.99% for the pasta with the greatest formulation (E-10.0). WAI fell as moisture content rose, which may be explained by the plasticization of melt at higher moisture levels reducing the elasticity of dough (Ding et al., 2006). WAI of the product decreases when formulations increase from 2.5% to 10%.

Table 7.2.: Values of Optimal cooking time, Cooking loss, Swelling index, Water absorption and moisture of encapsulated beads pasta

Sample code	OCT (min)	Cooking loss (%)	Swelling index (SI)	Water absorption (%)	Moisture (%)
CNT (CP)	06.00	2.19±0.32^{a}	1.22± 0.04^{a}	57.97±1.68^{d}	39.74±0.50^{a}
E-2.5(CP)	06.00	2.19±0.18^{a}	1.32±0.04^{b}	55.89±0.89^{c}	42.90±1.66^{b}
E-5.0(CP)	06.00	2.29± 0.06^{a}	1.38±0.06^{b}	54.04±1.75^{c}	44.68±2.09^{c}
E-7.5(CP)	06.00	2.51± 0.18^{c}	1.4±0.08^{c}	49.94± 1.37^{b}	51.51±1.00^{d}
E-10.0(CP)	06.00	2.33± 0.31^{b}	1.4±0.08^{c}	46.92± 0.99^{a}	53.68±0.94^{e}

- CNT- control; EBP-encapsulated beads pasta

Means with different letters in the same row indicate that there is significant difference between the samples ($p \leq 0.05$)

7.3.2. Total phenolic content

The use of powders and extracts from plant foods and food by-products in pasta-making is among the strategies recently explored to obtain functional pasta, both gluten-containing and gluten-free. Functional pasta was prepared by incorporating encapsulated beads of *Clerodendrum glandulosum* Lindl. leaves ultrasonicated extracts in a blend of wheat semolina with 2.5%, 5%, 7.5% and 10% respectively. A significant difference in TPC content was observed between the control and the formulated pasta. The addition of pasta encapsulated beads provided the high total phenolic content (TPC) values from uncooked pasta (11.81±0.31 to 26.34±2.00 mg GAE/g) and cooked pasta (14.39±0.72 to 32.12±1.63 mg/g), while control of uncooked pasta (9.12±0.77 to 8.16±0.62 mg GAE/g) contributed at a lower extent (Table 7.3). TPC showed an increased pattern in the finished product, as the encapsulated beads range increases. This may be attributed to the high phytochemical content of the plant extracts and due to cooking the bioactive compounds may have been released from the cell thus increasing the TPC content. Pasta contains a variety of phytochemicals that are released during cooking and consumption, including flavonoids, phenolic acids, and carotenoids. Pasta's proteins and starches swell and gelatinize as a result of the heat and water. By dissolving the food matrix, this process increases the accessibility of phytochemicals. For instance, when pasta is cooked, phenolic compounds may be liberated from the pasta matrix. After the pasta is eaten, the food matrix is further broken down by digestive enzymes in the gastrointestinal tract, which releases phytochemicals. These bioactive substances may interact with macronutrients, affecting their intestinal reactivity and bioavailability. Phytochemicals' interactions with other food ingredients can affect their bioavailability. For example, the release and absorption of these substances may be impacted by the presence of dietary fiber and other non-starch polysaccharides (Camelo-Méndez et al., 2016; Arribas et al., 2020)

The contribution of mushroom powder addition to the phenolic content of spaghetti was also explored (Lu et al., 2018). Three different powders from white button, from shiitake and from porcini mushrooms were used, at three different substitution levels. It emerged that all mushroom-powder-supplemented pasta samples had TPC values significantly higher than semolina pasta, except for 5% and 10% shiitake mushroom pasta. The greatest values were found in porcini mushroom pasta samples. The fortification of traditional GF flours with sorghum (*Sorghum bicolor* (L.) Moench) flour in pasta-making has been also

studied. Gluten free pasta was produced with white and brown sorghum (Palavecino et al., 2019). Total phenolic compound content was higher in the two sorghum-based pasta samples than in the controls. Sorghum pasta, after cooking, also showed higher radical scavenging activity and ferric reducing ability than the control samples, without significant differences between sorghum varieties. There have been several studies conducted on the fortification of plants and other food substances with semolina. However, addition of encapsulated beads with herbal extracts on the effect of phenolic and antioxidant activity have been conducted except for few studies in which the effect on the final product has been studies. One such study was to investigate the effect of encapsulated fish oil and herbal extracts on the quality and shelf-life of fish burger (*Hypophtalmichtys molitrix*) (Bahramizadeh, 2022). The conclusion of this study was fish burgers enriched with omega-3 emulsion containing rosemary and cinnamon extract prevent fat oxidation, microbial spoilage and preserve the nutritional value of the product during storage at -18°C in the freezer for up to 4 months.

7.3.3. DPPH Analysis

The DPPH scavenging activity was affected by the formulations and the applications of heat and it was observed that there was significant difference in the results ($p \leq 0.05$) as the formulation increases. The DPPH radical scavenging of the control sample of uncooked pasta (23.21±2.01%) and cooked pasta (22.042±1.44%), shown in Table 7.3. The DPPH radical scavenging was found to be higher as we increased the formulations from 32.73±2.53% to 61±2.77% for both uncooked and cooked pasta. The highest scavenging activity being found in the highest (10%) formulated pasta. The DPPH scavenging activity is directly dependent upon the TPC content of the sample. Therefore, the change in TPC content in the pasta sample proportionately changed the DPPH scavenging activity. In this study the cooking has no effect on the DPPH activity in which the pasta was cooked in one optimum temperature, as the formulations has been increased so does the scavenging activity increases uniformly. This result is in alignment to the study conducted by Lisiecka et al., (2019), the addition of *C. incanus* to fortify wheat pasta increased total phenolics content and antioxidant activity with some significant differences according to the extraction procedure used. A similar type of observation was reported by Sharma al., (2016), the increase in scavenging activity may be due to the increase in TPC in the product for the lysis of cell structure or Maillard reaction.

Table 7.3: Total phenolic content and Antioxidant activity in uncooked and cooked Pasta with the addition of *Clerodendrum glandulosum* Lindl. extract beads

SAMPLE	TPC mg GAE/g	DPPH Activity (%)
CNT(UP)	9.12±0.77^{a}	23.21±2.20^{a}
E-2.5(UP)	11.81±0.31^{b}	32.73±2.53^{b}
E-5.0(UP)	14.72±0.60^{c}	37.73±0.54^{c}
E-7.5(UP)	18.22±0.71^{c}	42.05±1.04^{d}
E-10.0(UP)	26.34±0.66^{f}	46.78±0.38^{e}
CNT(CP)	8.16±0.62^{a}	22.04±1.44^{a}
E-2.5(CP)	14.39±0.72^{c}	43.22±2.44^{d}
E-5.0(CP)	16.76±0.28^{d}	46.16±1.38^{e}
E-7.5(CP)	18.71±1.56^{e}	55.66±2.33^{f}
E-10.0(CP)	32.12±1.63^{g}	61.87±2.77^{g}

Means with different letters in the same row indicate that there is significant difference between the samples ($p \leq 0.05$)

7.3.4. Fourier transform infrared spectroscopy (FT-IR) analysis

FT-IR spectra for control pasta and pasta blends with encapsulated beads of formulated pasta is represented in Fig. 7.1. The figure showed various peaks in different wavenumber ranges from 572.95-3502.05 cm^{-1} and predicts major functional groups. The band peaks found approximately in the region of 853.74 indiacted α-glycosidic linkages of the glycosyl residues which confirmed the samples were carbohydrate in nature (Tsumuraya and Misaki, 1979). Peaks obtained in region 1600-1700 cm^{-1} is associated with amide-I region and associated with the presence of intermolecular β-sheets (Sahni et al., 2020). The frequency of the vibration at 1544.66 cm^{-1} corresponds to COOH group. Peaks at 2927.95 cm^{-1} which is a characteristic of the presence -NH and NH+ group respectively. There were also broad peaks between 3200-3600 cm^{-1} in all the cooked and uncooked pasta samples except in Control uncooked sample which is absent. Various researchers have suggested that these broad bands observed are attributed to –OH stretching vibrations and hence, indicates the presence of phenolic –OH (Park et al., 2008).

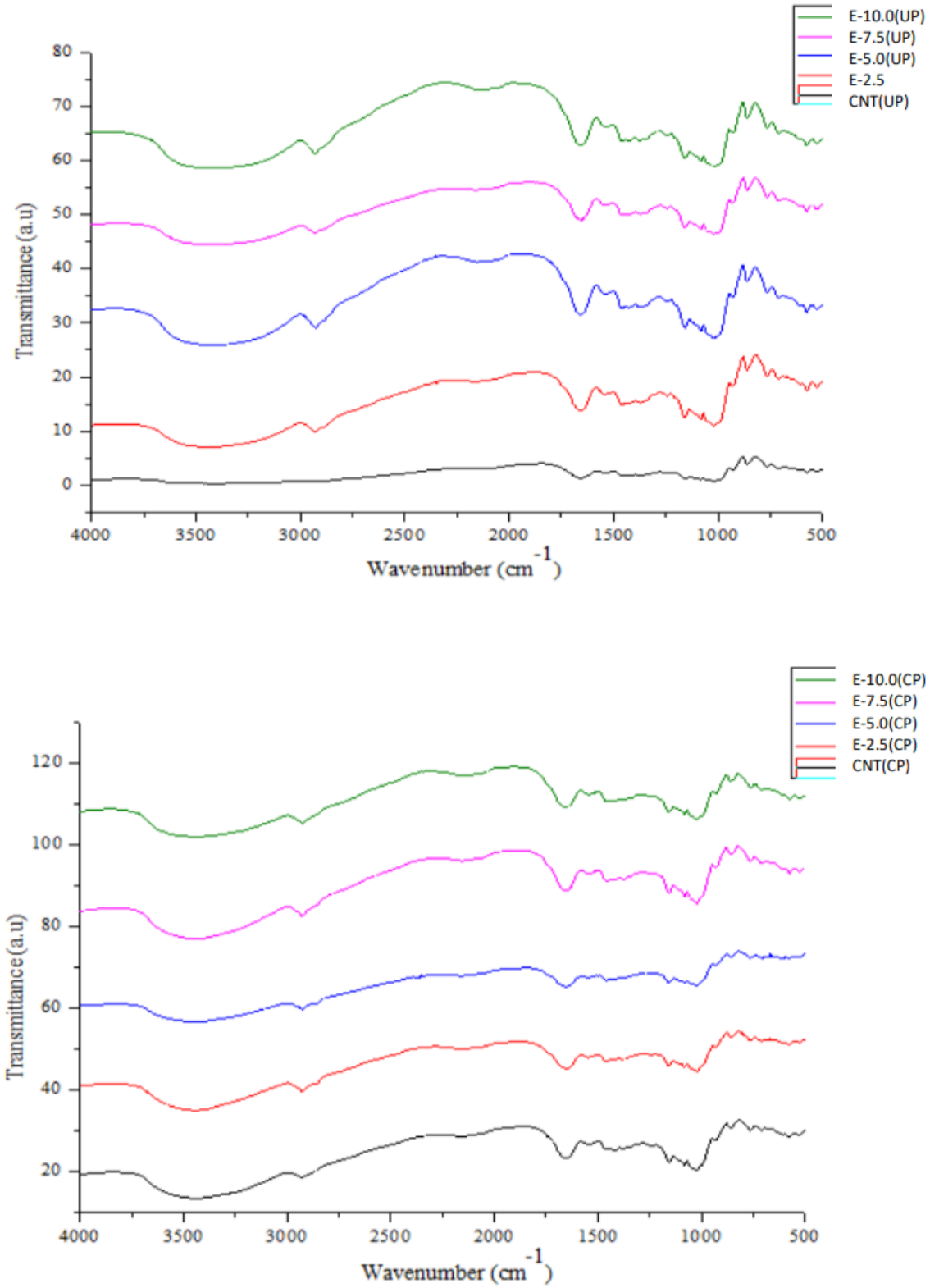


Fig. 7.1: FT-IR spectra of the uncooked and cooked encapsulated beads pasta samples

7.3.5. Color analysis

Color is an important factor for assessing the visual quality and market value of food products. Color values were measured for both cooked and uncooked pasta samples. The L*, a*, b* and ΔE values of the samples are given in the Table 7.4.

Table 7.4 L*, a*, b* and ΔE values of the pasta samples

Sample	**L***	**a***	**b***	**ΔE**
CNT(UP)	86.06±1.47^{i}	0.08±0.06^{d}	11.83±0.93^{b}	70.12±1.40^{i}
E-2.5(UP)	83.46±0.51^{h}	-0.58±0.22^{b}	13.93±0.80^{c}	68.24±0.32^{h}
E-5.0(UP)	76.91±1.34^{g}	0.87±0.11^{a}	18.81±1.37^{e}	64.6±1.50^{g}
E-7.5(UP)	71.94±2.28^{f}	-0.33±0.34^{b}	18.6±1.81^{e}	60.92±2.59^{f}
E-10.0(UP)	65.52±2.47^{d}	-0.44±0.41^{b}	19.65±1.45^{f}	56.45±2.93^{d}
CNT(CP)	71.13±2.14^{f}	-0.01±0.29^{c}	9.77±1.27^{ab}	58.12±2.12^{e}
E-2.5(CP)	67.91±0.94^{e}	0.16±0.16^{f}	10.79±1.27^{ab}	55.57±1.16^{d}
E-5.0(CP)	62.06±0.94^{c}	-0.2±0.22^{c}	8.57±2.51^{a}	42.56±1.20^{a}
E-7.5(CP)	63.32±0.98^{c}	1.08±0.35^{g}	17.11±1.47^{d}	61.42±1.31^{f}
E-10.0(CP)	59.47±1.56^{b}	-0.14±0.11^{c}	11.89±0.92^{b}	49.26±1.31^{c}

Means with different letters in the same row indicate that there is significant difference between the samples ($p \leq 0.05$)

Overall, a statistically significant difference was found between all the observed samples ($p \leq 0.05$). Uncooked control (durum semolina) pasta showed highest lightness L^* value (86.05±1.47) followed by formulated uncooked pasta – E-2.5 (UP) which is 83.46±0.51. Pasta samples after cooking showed a decrease in L^* value and this decrease in lightness may be due to color loss during cooking. The highest a* (yellowness) value was obtained in the control pasta sample with 0.09±0.29 while 0.61±0.16 was recorded in formulated pasta with 2.5%. The redness values in the samples did not uniformly increase or decrease. This may be due to encapsulated beads not being uniformly distributed. The highest b* yellowness value was obtained in the pasta sample formulated with 10% encapsulated beads (24.11±1.81). The ΔE calculated value was found to be highest in the uncooked (85.21±0.32) and cooked (61.24±1.31) samples formulated with 2.5%. The uncooked and cooked pasta samples are shown in Table 7.5.

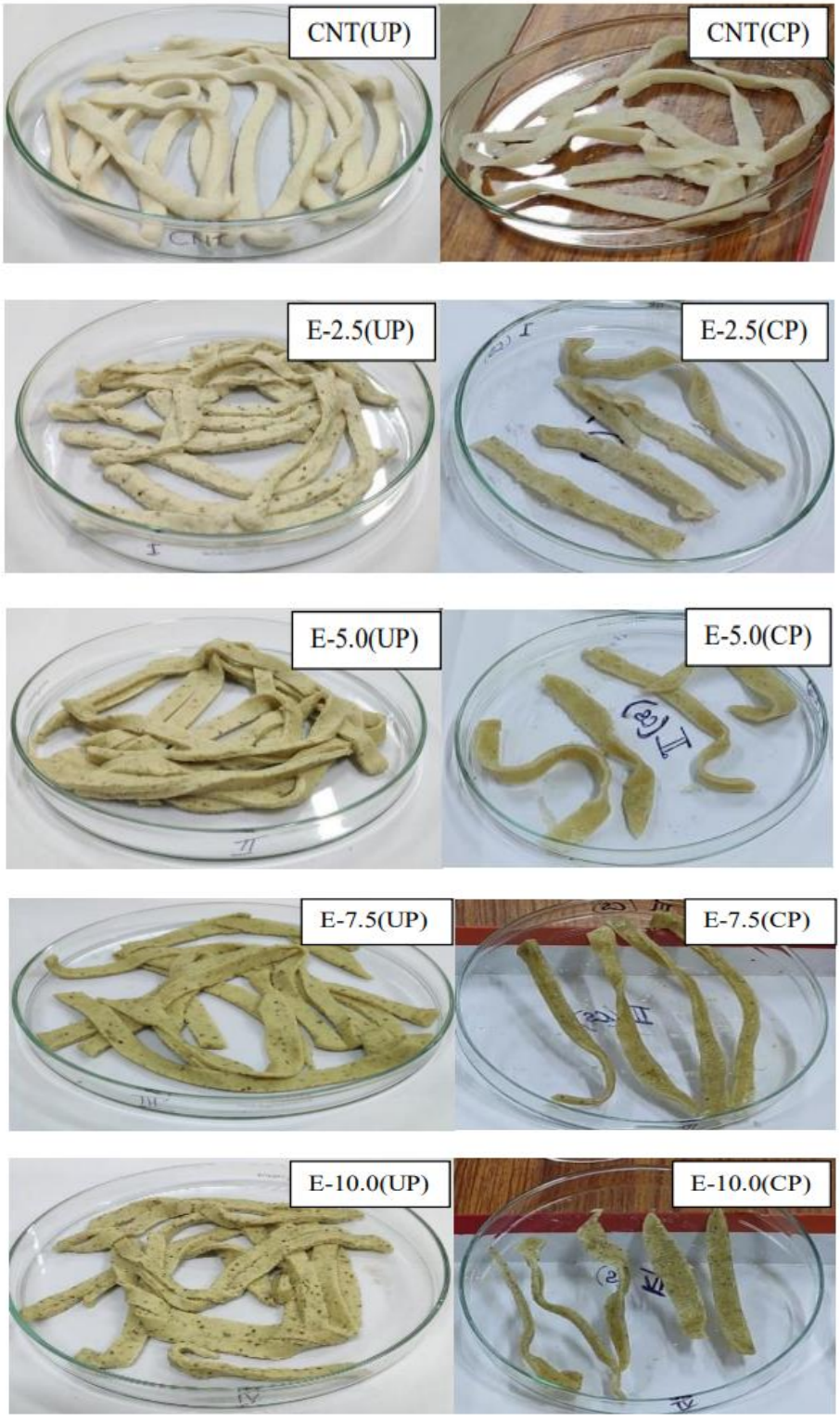
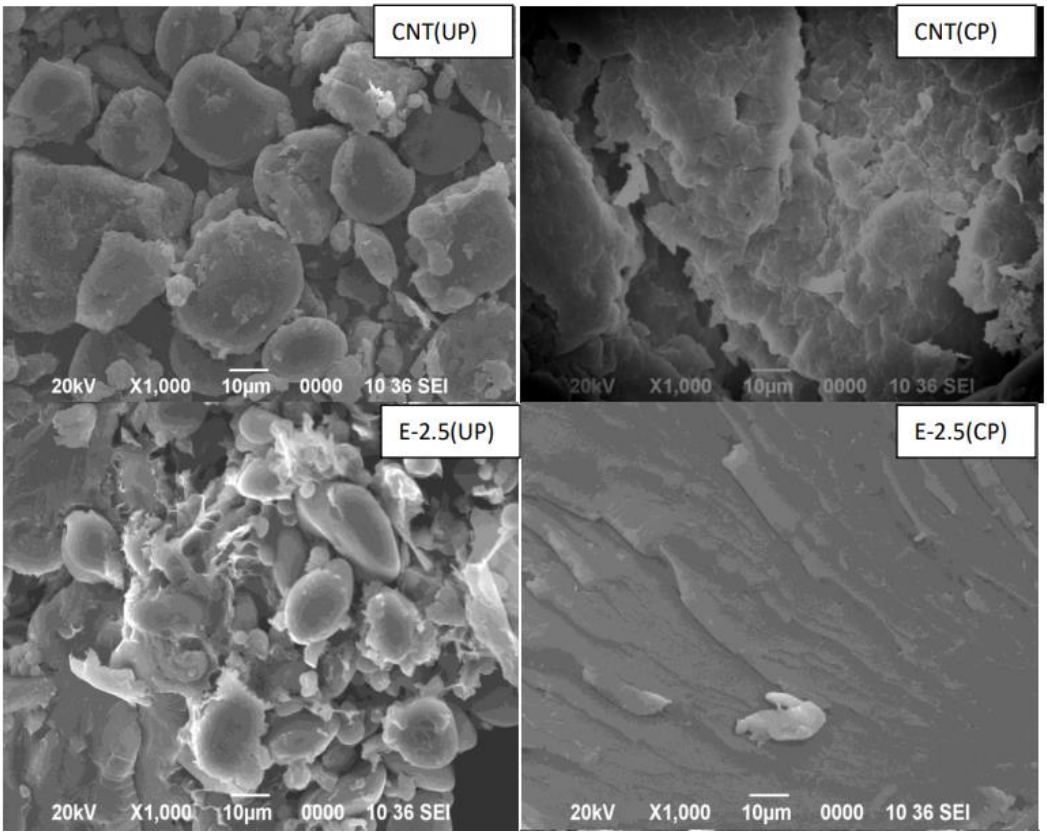


Table 7.2: Images of Uncooked and cooked pasta samples Left column: uncooked pasta samples; Right column: cooked pasta samples

7.3.6. Scanning electron microscopic (SEM) studies of pasta samples

Scanning electron microscopy (SEM) shows arrangement of starch granules and gluten network in pasta. Scanning electron microscopic (SEM) studies were carried out using uncooked and cooked fresh pasta samples. As shown in Fig.7.2 numerous starch granules were visible on the surface of uncooked pasta samples. However, both cooked pasta samples presented a smooth outer surface in which starch granules are completely embedded in protein matrix. This may be because pasta strands expand in volume during cooking and as a result great deal of stress was imparted on the enveloping protein film; thus, surface of pasta samples becomes smooth. It is also evident from cooked pasta micrograph images which show better protein starch network. Marked changes were observed by incorporating encapsulated beads where the surface became scratched, cracked, and rougher. Hence overall encapsulated beads of *Clerodendrum glandulosum* Lindl. extracts inclusion into semolina-based pasta encapsulates the starch granules and thus reduces the leaching of starch upon cooking. Smooth and intact microstructure with addition of xanthan gum in gluten free pasta was also observed by Susanna and Prabhasankar (2013). Similarly Rajeswari et al., (2013) also reported that starch granules are tightly bound in gluten network with addition of gum Arabica in onion based pasta.



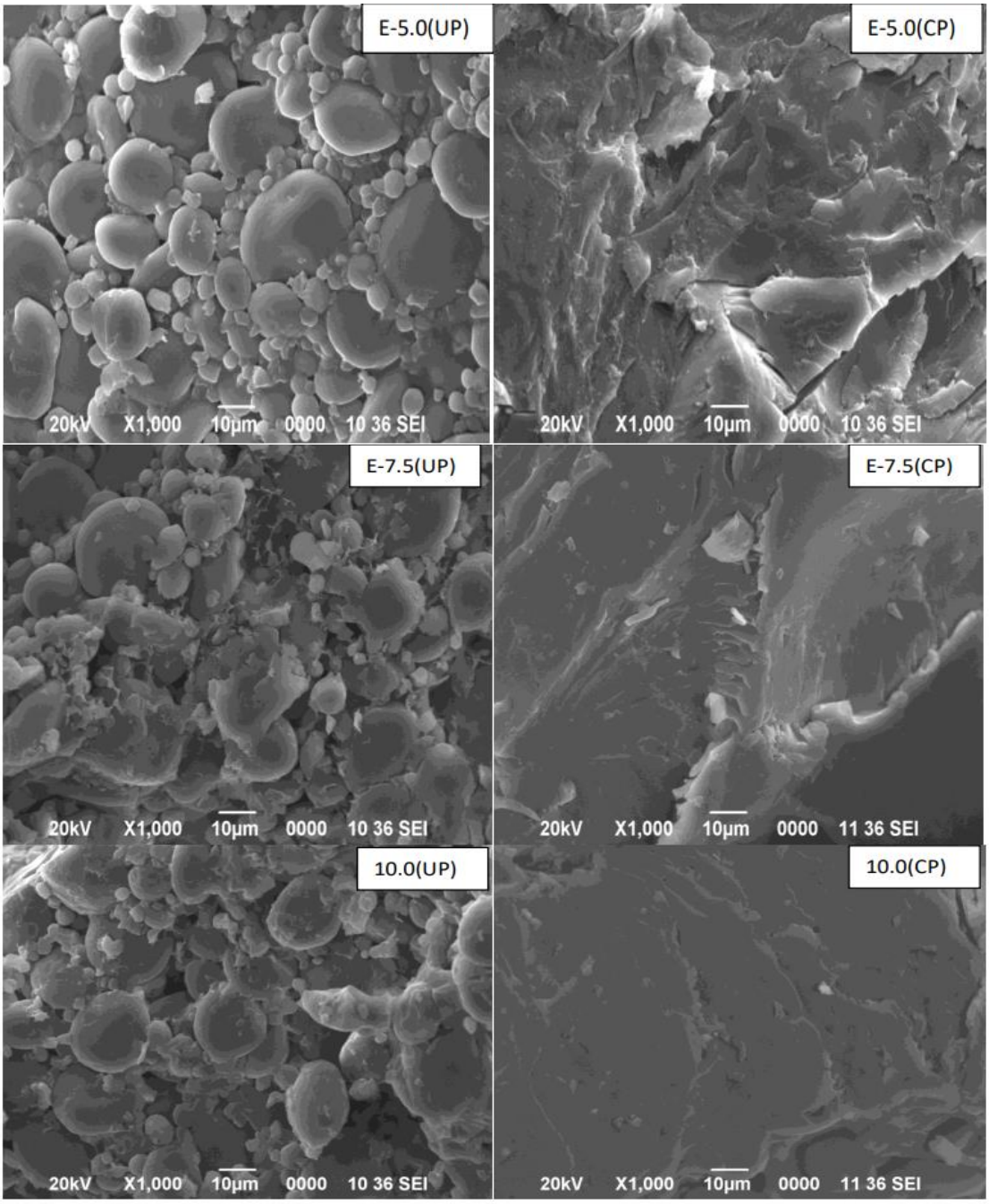


Fig.7.3: SEM micrographs of uncooked and cooked encapsulated beads with different levels of *Clerodendrum glandulosum* Lindl. leaves extarcts. Left row of micrographs shows surface of uncooked pasta and right row shows surface of cooked pasta. Both the rows represent pasta with (1%, 2.5%, 5% and 10% respectively)

7.3.7. Conclusions

This study was conducted for the purpose of evaluating the effects of adding *Clerodendrum glandulosum* Lindl. leaves extracts hydrogel beads on the quality properties

(colour, texture, and cooking properties), phytochemical properties of fresh pasta. According to the results, the hydrogel beads were perfect for inclusion into fresh pasta. According to reports, the cooked pasta's swelling index gradually increases while the CNT's swelling index is stated to be smaller. The moisture content of the formulated pasta increases compared to the control pasta TPC showed an increased pattern in the finished product, as the encapsulated beads range increases. Pasta samples after cooking showed a decrease in L^* value and this decrease in lightness may be due to color loss during cooking. The DPPH scavenging activity is directly dependent upon the TPC content of the sample. Therefore, the change in TPC content in the pasta sample proportionately changed the DPPH scavenging activity. In this study the cooking has no effect on the DPPH activity in which the pasta was cooked in one optimum temperature, as the formulations has been increased so does the scavenging activity increases uniformly. As a general conclusion, the findings presented in this study show potential prospects for *Clerodendrum glandulosum* Lindl. use as a component in fresh pasta as a healthy dietary option.