CHAPTER 5

To develop functional food product by incorporating encapsulated Norabogori extract

5.1 Introduction

The efficacy of natural antioxidants depends on preserving their stability. However, antioxidants in their free form have a rapid rate of metabolism and are very susceptible to heat, oxygen, and light [1-3]. Encapsulation is an efficient way to increase their stability throughout food processing and storage as well as their bioavailability throughout gastrointestinal digestion until they reach the desired location in the body [4]. The quality of the finished product may also be improved, the shelf life extended, incompatible components may be separated, and the shelf life may be prolonged by controlled administration via encapsulation [5-7]. In this regard, in recent years, hydrogels have frequently been used to encapsulate bioactive substances.

Hydrogels are cross-linked, three-dimensional, hydrophilic polymer matrices that have a tendency to absorb a lot of water, and they can be either neutral or ionic depending on the side groups of the polymer [8]. Although both natural and synthetic polymers can be utilized to create hydrogels, the latter have garnered more interest in the scientific community [9]. Applications for hydrogels are numerous in the fields of medicine, pharmaceuticals, food science, and biotechnology [10]. In the swelled stage, they provide substantial open spaces between cross-linked networks that can trap various chemicals [11].

Alginate is one of the materials that is utilized most commonly for the production of hydrogels because of its straightforward gelation, low cost, and non-toxicity [12]. It is a 1-4 linked linear anionic water-soluble hydrophilic colloidal carbohydrate derived from marine brown algae with varied ratios and distributions of ß -D-mannuronate (M) and ß -L-guluronate (G) [13]. Alginate solutions can gel by lowering the pH below the pKa value of the guluronic residue or by the presence of divalent ions, such as calcium ions [14]. Alginate can be gelled externally (external gelation) or internally (internal gelation) by dispersing calcium from a less soluble form into the alginate solution and releasing it gradually [15].

Norabogori is only harvested once a year in the autumn, thus it's important to use processing technologies that preserve the fruit while preserving its organoleptic qualities and nutritional value. Norabogori would be available all year long as a result. In this regard, making fruit rolls or leathers from dried fruits presents a practical way to commercialize fruits with a limited shelf life. A thin layer of dried fruit purée is used to create fruit leather, a reformed product.

Fruit that has been processed into fruit leathers determines the majority of the composition of these products, which are mostly rich in carbohydrates (primarily cellulose and peptic

compounds to a significant extent) [16] [17]. Fruit leathers, however, frequently have hydrocolloids added. Among other things, hydrocolloids have stabilizing, emulsifying, and gelling capabilities. This sort of polysaccharides comes in a wide range and can be introduced on purpose. They can be botanical, algal, microbial, or animal in origin. The most popular of this class of ingredients, utilized in various fruit leather recipes, are pectin, gelatin, carrageenan, and starch. [17-20]. Fruits or mixes of fruits high in carbs and fiber make up the majority of the basic materials needed to manufacture fruit leather. The impact of process variables such drying air temperature and sample thickness has been studied using mango and apple [21,22].

The extracted phytochemicals from a fruit can be directly incorporated as such into food for product development. However, several limitations may arise while incorporating extracted bioactive compounds directly into food products, such as their susceptibility to oxygen, enzymes, pH, light, temperature, and low stability [9]. Additionally, phytochemicals, particularly polyphenols naturally have an astringent flavor that could hinder or mask a food product's overall sensory appeal. To incorporate plant extracts into a food product and get their profits, it is necessary to resolve the technological challenges related to sensory or stability [10]. Microencapsulation serves as a modern embedding technique where microcapsules encapsulate the bioactive materials as a delivery medium. Polysaccharides such as maltodextrin, gum arabic, cellulose, chitosan, modified starch, etc., and proteins like soybean protein, corn zein, whey protein, sodium caseinate, etc., are frequently utilized in microencapsulation encapsulating agent because of their excellent stability, availability, and encapsulating ability [11,12]. The solution generated by dissolving sodium alginate in water possesses softness, homogeneity, and other great properties that are challenging to get from other counterparts like arabic and xanthan gum. Sodium alginate contains strong hydrophilicity and can be dissolved in water to form a very viscous and homogeneous solution. It boosts the gel's viscosity, shields the drugs and bioactive compounds from gastrointestinal enzymes and acid, and improves its bioavailability [13]. The microencapsulated beads resulted from the gelation of Ca^{2+} ions with sodium alginate, are used in a variety of applications where they are meant to swell and release the compounds in the near-neutral intestinal environment while remaining intact in the acidic gastric environment [14,15].

Fruit puree has been dried to a very thin layer creating fruit leather, which has a chewy feel. Since all the nutrients are concentrated in one product, fruit leathers are a cost-effective and convenient alternative to fresh fruits with superior nutritional properties (particularly in terms of

minerals, antioxidants, fibers, and energy) [23]. Various fruit leather products are developed and are made available commercially, like mango leather, guava leather, banana leather, grape leather, apricot leather, jack fruit leather and roselle fruit leather [24].

The aim of the study presented in this chapter is to utilize the norabogori fruit in terms of a product developed from it and also to protect the norabogori fruit phytochemicals and deliver it in target site. To accomplish this goal, a fruit leather was developed with selected hydrocolloid. The extracted phytochemical extract from norabogori fruit using optimized conditions as explained in chapter 2 was encapsulated with NaAlg and $CaCl_2$ by ion-gelation method and analyzed its physical and release properties. At last, the encapsulates were incorporated in the fruit leather to preserve the maximum nutrients for the consumers and their organoleptic properties were studied.

5.2 Materials and methods

Norabogori fruit samples were harvested at the matured stage from the kitchen garden around Tezpur University in Sonitpur district of Assam Region (India) (Latitude: 26° 51' 44.226". Longitude: 92° 51' 27.7596"). The chemicals and reagents utilized in the experiments were obtained from Sigma, Merck, and Himedia and all are of analytical grade and high purity.

5.2.1 Sample preparation

The pits were removed from the fruits and were sliced in thin slices and kept for freeze drying at -80 °C for 16 h. The dried samples were stored in refrigerated condition at 4°C. The sample was then ground into fine powder and sieved to ensure homogeneity. The powder was further used for extraction and leather preparation. As detailed in chapter 2, the optimized conditions were employed to extract phytochemical extract from norabogori fruit powder. The optimized extract was used for encapsulation later.

5.2.2 Development of norabogori leather

The norabogori fruit leather was developed according to the procedure described by Barman et al. (2021) with slight modifications [25]. For the fruit leather, the ingredients used are freeze-dried dried norabogori powder, sucrose (20%) and the hydrocolloids (guar gum, xanthan gum, starch and pectin) at 1% concentration. An adequate amount of water (~15%) was added to the mixtures for smooth mixing and preparation of leather. Control leather was developed without

using any additional hydrocolloids. After combining the ingredients the dough-like material was uniformly distributed across clear glass petri dishes and dried for 2 h at 40°C in a tray dryer. The norabogori fruit leathers were then packed in plastic pouches and stored in ambient temperature in a dry place, away from sunlight, for further investigation.

5.2.2.1 Color analysis of norabogori fruit leather

The color of the leather of norabogori fruit was evaluated using a Hunter Color Spectrophotometer (Hunter Lab, USA) with a CR-400 measuring head color and an illuminance value of D65/10. The results were defined in terms of L* (darkness/whiteness), a* (greenness/redness), and b* (blueness/yellowness). Equation (1) was used to determine the color difference (ΔE) between the fruit leathers [26].

$$\Delta E = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2} \qquad (1)$$

Where,the measures for control leather's colors are L_2, a_2, and b_2, whereas those for fruit leather made with hydrocolloids are L_1, a_1, and b_1.

5.2.2.2 Textural properties of norabogori fruit leather

The tensile characteristics of the norabogori fruit leather were measured using texture analyzer (Stable Micro System, UK). A rectangular strip of norabogori fruit leather was taken as a sample and they were pulled apart using a cell load of 100 N at a 50 mm/min speed until they ruptured. Equations (2) and (3) were used to compute the tensile strength (MPa), rupture strength (N), extensibility (mm), and percentage elongation at break (%Elongation) from the extension force-displacement curve (3).

Tensile strength = Force / leather thickness × length of the leather (2)

% Elongation = (Elongation at rupture/ initial length of the leather) × 100 (3)

The chewiness and cohesiveness of the norabogori fruit leather were determined with a 25 kg load cell using a texture analyzer. The data were calculated for a two-cycle compression by fitting in a force versus time curve, and the disc probe, which has a 35 mm diameter, was utilized at pretest and posttest speeds of 5 mm/s, 1 mm/s, respectively. Texture analyzer in-built software

was used for the generated data analysis. The results were obtained in terms of chewiness and cohesiveness parameters from the test curves [23].

5.2.3 Microencapsulation of crude extract

In the microsphere preparation, the crude extract obtained after optimized microwave-assisted extraction was encapsulated with sodium alginate (NaAlg) by ionic gelation method. NaAlg (2% w/w) was used as the gelling agent and calcium chloride ($CaCl_2$ 5%) was used as the crosslinking agent [27] (Fig.5.1). The crude extract and NaAlg were taken in 1:2, 1:4, and 1:8 ratios (extract:NaAlg) and NaAlg with no norabogori extract was taken as control beads for the encapsulation.

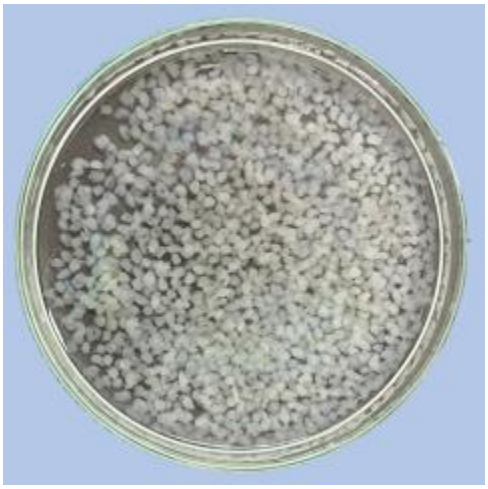

Fig.5.1 Microspheres prepared using ionic gelation method

5.2.4 Physicochemical characterizations of microbeads

5.2.4.1 Encapsulation efficiency

The amount of TPC encapsulated in the microbeads was used to express the encapsulation efficiency of all encapsulated samples. The technique was based on Uji et al. [14] with a few minor changes. To start, the microbeads were combined with phosphate buffer saline (PBS) 1M at a ratio of 1:10 (w/v), sonicated for 30 minutes at room temperature to destroy the encapsulating structure, centrifuged for 10 minutes at 8000 rpm, collected the supernatant, and then the TPC was calculated. Equation (4) was used to calculate the encapsulation effectiveness:

$$EE\% = \frac{\text{TPC from microbeads}}{\text{TPC present in initial solution}} \times 100\% \qquad (4)$$

In a nutshell, the Folin-Ciocalteu assay was used to examine the TPC as described in chapter 2. After leaving the reaction in the dark for 60 minutes, the sample was combined with calcium carbonate (8% w/v) and distilled water in a 1:1:10 (v/v) ratio. Then, the color development was measured at 765 nm using a spectrophotometer. [28] [29].

5.2.4.2 *In vitro* simulated gastro-intestinal digestion release study of the micro-encapsulates

Two release mediums representing different digestion and absorption environment of different pH was created for the evaluation of *in vitro* release of encapsulated extract. The first release medium, simulated gastric fluid (SGF) was prepared using sodium chloride and pepsin (porcine stomach mucosa) and maintained at a pH of 1.2 was maintained. Similarly, simulated intestinal fluid (SIF) was formulated using monobasic potassium phosphate, sodium hydroxide (0.2N) and pancreatin and maintained at a pH of 6.8 [30]. After digestion, the solutions were neutralized (pH 7.0) by adding 0.2 N sodium hydroxide and later on the samples were analyzed for total phenolic content by the Folin-Ciocalteau method [31] and antioxidant activity by DPPH free radical scavenging mechanism [32].

5.2.4.3 Microparticle size analysis by Scanning Electron Microscope (SEM)

The microparticles were visualized and their sizes were evaluated by Scanning Electron Microscope (SEM). The encapsulates were coated with a thin layer of gold and mounted on stubs with the help of a double sided adhesive tape. The SEM images were then obtained using a JSM-6390LV scanning electron microscope (SEM; JEOL, Japan) at 20 kV.

5.2.4.4 DPPH assay

The radical scavenging activity of the encapsulated norabogori extract after its release at *in vitro* simulated gastric fluid and intestinal digestion fluid separately was determined using DPPH (2,2-diphenyl1-picrylhydrazyl) method [32] with slight modification. Sample volumes of 0.1 mL and 3.9 mL of DPPH solution were combined and thoroughly shaken, for 30 min while being kept in dark. The UV-Vis spectroscopy was used at a wavelength of 517 nm to measure the absorbance of the solution. The sample's antioxidant activity (AA) in the mixture was determined using the following formula (5):

$$AA\ (\%)\ = \left(\frac{A-B}{A}\right) \times 100 \qquad (5)$$

Where,

A=Absorbance of DPPH solution at 517nm. B=Absorbance of sample in DPPH solution at 517nm.

5.2.5 Fortification of microencapsulate to norabogori leather

5.2.5.1 Fruit leather development

Two different amounts of encapsulate powder (2.5% and 5%) were added to prepare the norabogori leather and evaluated its quality characteristics [33]. Based on the initial screening study, the most effective hydrocolloid xanthan gum in terms of textural properties was added to the leather. The control norabogori leather was also prepared under the same conditions and ingredients without the incorporation of any microencapsulated powders. The resulting products were evaluated for their color and texture obeying the above-mentioned conditions (Section 2.9.1).

5.2.5.2 Physio-chemical characteristics of norabogori fruit leather

The standard method of AOAC (1990) was adopted for the determination of moisture, pH and ascorbic acid (vitamin C) contents [34]. pH was measured by inserting electrodes into 10 ml beaker containing the sample. The ascorbic acid content was determined by 2, 6-dichlorophenol indophenol dye method [35]. The Folin-Ciocalteu method was used for determining the total phenolic content (TPC) in terms of milligrams equivalent of gallic acid per 100 g of fruit leather (mg GAE/100 g) [31].

5.2.5.3 Sensory acceptability analysis of norabogori leather with encapsulate

A sensory acceptability test was conducted according to Moura et al. [36] and 25 semi-trained panellists, including students and employees from Tezpur University (Assam) and the age ranged from 20 to 50. The samples were assessed on a 9-point hedonic scale, with the descriptive phrases ranging from 9 ("like extremely") to 1 ("dislike extremely"), for qualities like the look, taste, texture, and general acceptability.

5.2.6 Statistical analysis

The statistical analysis of the obtained data were carried using SPSS 16.0. Every experiment was run at least three times, and the means were assessed using an analysis of variance (ANOVA) and multiple range tests by Duncan were used to identify significant variances. ($p<0.05$).

5.3 Results and Discussion

5.3.1 Development of norabogori leather

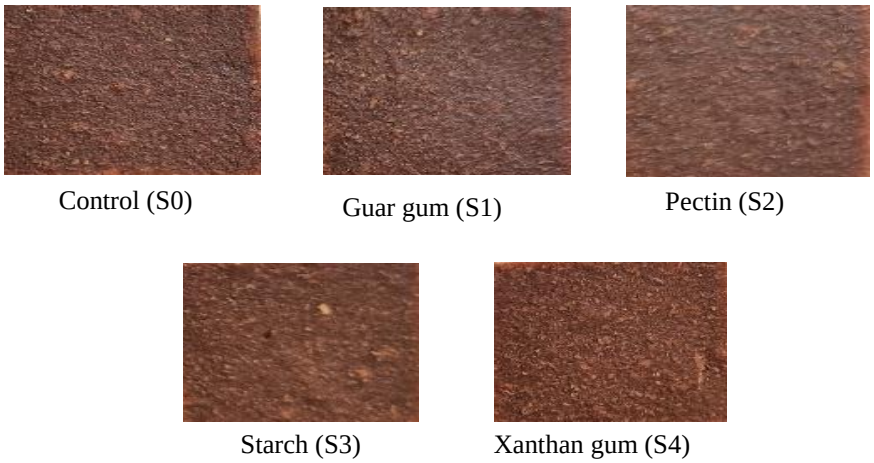

Fig.5.2 Developed product with different hydrocolloids

5.3.1.1 Color analysis

The hue of norabogori leather, which may be defined as reddish-brown, was a crucial factor in determining consumer choice. The L*, a*, and b* values of the leather ranged from 44.23-46.23, 3.94- 5.86 and 2.63- 5.35, respectively presented in and tabulated in Table 5.1 (**Fig.5.2)**. Hydrocolloids changed the color profile of the product. The leather with guar gum (46.23) followed by pectin (44.87) and starch (44.68) showed the highest lightness of leathers (L* values). The maximum a* values were produced by xanthan gum (5.85) and starch (4.83), which also showed the least amount of redness in the sample. The pectin molecule had the lowest value (2.63) and the b* value indicated how yellowish the norabogori fruit leather was. The leather with guar gum had a color difference ΔE score of 0.93, while the leather with 1% starch received a score of

2.77. With the addition of hydrocolloids, the browning index (BI) value changed from 6.80 to 10.51 [37,38].

Table5.1 Colour profile analysis of norabogori leather with different hydrocolloids

Sample	Color				
	L*	**a***	**b***	**ΔE**	**BI**
Control (S_0)	47.43± 0.43[a]	5.86±0.17[a]	5.08±0.31[a]		9.77
Guar gum(S1)	46.23± 1.94[a]	4.65±0.08[b]	3.84±0.43[b]	2.10	7.93
Pectin (S2)	44.87± 1.11[a]	3.94±0.35[c]	2.63±0.43[c]	1.95	6.80
Starch (S3)	44.68± 0.84[a]	4.83±0.08[bd]	2.81±0.62[cd]	0.92	8.25
Xanthan gum(S4)	44.23± 0.88[a]	5.85±0.35[a]	5.35±0.54[a]	2.77	10.51

(Values represent mean± SD; n=3. Mean with significant difference at $p<0.05$)

Textural properties

The texture profile analysis on norabogori leather was expressed in terms of gumminess (N mm), chewiness (N mm), springiness and cohesiveness with a considerable variation among the formulation of norabogori leather (Table 5.2). The obtained values are found to be in the range with the results shown in kiwi fruit leather [14]. Cohesiveness is a crucial factor for dried fruit goods because it might indicate how sticky the items are [39]. It can seen the hardness decreased while cohesiveness and dryness increased, which was required in order to make a bolus that could be properly ingested. The cohesiveness values of leather ranged from 0.99 – 1.87. Pectin-containing leather was observed having the highest cohesiveness values, whilst leathers made without hydrocolloids had the lowest values. In comparison to control leather, hydrocolloid-developed leathers were found to be chewier. The values varied from 33.90 – 92.14 N mm, with the control leather having the lowest chewiness value (33.90 N mm) and the leather produced with 1% xanthan gum having the highest chewiness value (92.14 N mm). The inclusion of hydrocolloids increases the higher values in the texture profile analysis of the leather because the molecules of the hydrocolloids are hydrogen-bonded to one another and create cross-links that strengthen resistance of the leather to deformation caused by the probe of the texture analyzer [40].

Table5.2 Texture profile analysis of norabogori leather with various hydrocolloids

Sample	Texture			
	Gumminess (N mm)	**Chewiness (N mm)**	**Springiness**	**Cohesiveness**
Control (S_0)	57.71 ± 0.5^{b}	33.90 ± 0.3^{b}	5.87 ± 0.4^{b}	0.99 ± 0.01^{a}
Guar gum(S1)	68.67 ± 0.7^{c}	42.60 ± 0.4^{b}	6.20 ± 0.5^{b}	1.61 ± 0.01^{a}
Pectin (S2)	110.58 ± 0.2^{b}	65.56 ± 0.2^{b}	5.93 ± 0.4^{b}	1.87 ± 0.02^{a}
Starch (S3)	118.48 ± 0.9^{c}	71.61 ± 0.5^{b}	6.04 ± 0.3^{b}	1.35 ± 0.02^{a}
Xanthan gum(S4)	138.45 ± 0.3^{b}	92.14 ± 0.2^{b}	6.66 ± 0.5^{b}	1.59 ± 0.01^{a}

(Values represent mean± SD; n=3. Mean with significant difference at $p<0.05$)

5.3.2 Encapsulation of the norabogori extract analysis

5.3.2.1 Encapulation efficiency

The encapsulation efficiency of the hydrogel (Table 5.3) mainly depended on phenolic compounds and encapsulated material [4]. In this research, encapsulation efficiency was calculated based on the TPC retained in the encapsulated sample after cross-linking with the Ca^{2+} ion. The results showed that the increasing concentration of extract with respect to NaAlg, the encapsulation efficiency increases significantly (Table 5.3). The % encapsulated efficiently increased from 56.56% to 70.80% and 79.34% for 1.8, 1:4 and 1:2 ratios respectively. Though the core phenolic content (CPC) of 1:8 and 1:4 ratio was of not much difference, but significant difference in their surface phenolic content (SPC) results in a wide difference in their percentage encapsulation. Higher concentration of NaAlg gives more crosslinking and thus higher encapsulation efficiency [41]. Though the drastic two fold increase in the NaAlg concentration, the lower amount of the extract gives small differences in encapsulation efficiency. It maybe possible that the increase in NaAlg concentration the crosslinking thus the encapsulation efficiency increases, but less amount of extract makes it hard to contain.

Table 5.3: Encapsulating efficiency of norabogori extract by NaAlg and $CaCl_2$

Extract:NaAlg	Surface phenolic content (SPC) of encapsulate (mgGAE/g)	Core phenolic content (CPC) of encapsulate (mgGAE/g)	% Encapsulation
1:02	13.16 ± 0.192^{a}	63.71 ± 0.314^{c}	79.34 ± 0.294^{c}
1:04	13.43 ± 0.366^{a}	45.99 ± 0.214^{b}	70.80 ± 0.731^{b}
1:08	18.39 ± 0.372^{b}	42.34 ± 0.715^{a}	56.56 ± 0.902^{a}

5.3.2.2 In vitro gastrointestinal release of the microencapsulate under simulated conditions

The in vitro simulated gastric and intestinal (GI) fluid-assisted digestion and release of the microencapsulated formed are reported in Table 5.4. It established how phenolic chemicals are released from encapsulates and how they prevented free radicals in the GI tract from oxidizing lipids and DNA [11,30].

The intestinal simulated medium with pH 6.8 released more phenolic material from the encapsulates than the simulated gastric fluid with pH 1.2. The behavior of the encapsulates in a simulated GI media and release of phenolic contents are well-connected to various factors viz., the nature of the surrounding matrix, the encapsulates resistance to susceptibility to digestive enzymes, their susceptibility to those enzymes, and GI parameters like pH range [42,43]. The encapsulated extract's role in preventing oxidative damage to lipids and DNA by free radicals in the GI tract was demonstrated by the results of the % DPPH radical scavenging assay, which are shown in Table 5.4. Microspheres with 1:2 formulation demonstrated 48.55% radical scavenging activity (RSA), those with 1:4 formulation showed 43.75% and those with 1:8 formulations shown 38.87%. These results are attributable to the extract’s residue in the encapsulated state within the microspheres from inefficient release. The bioactive compounds encapsulated in the microspheres could be shielded from environmental factors viz., heat, oxygen, light, and others so that they can retain their antioxidant properties [39,42].

Table5.4 *In vitro* release study of microencapsulates

Extract:NaAlg	TPC (mg GAE/g)		Antioxidant activity (%)	
	Simulated gastric fluid (SGF)	Simulated intestinal fluid (SIF)	Simulated gastric fluid (SGF)	Simulated intestinal fluid (SIF)
1:02	8.144 ± 0.211^{a}	39.028 ± 1.458^{b}	16.846 ± 0.861^{c}	48.549 ± 1.721^{c}
1:04	7.417 ± 0.212^{a}	31.136 ± 1.540^{a}	12.341 ± 0.090^{b}	43.755 ± 1.225^{b}
1:08	7.081 ± 0.163^{a}	29.012 ± 0.285^{a}	9.952 ± 0.369^{a}	38.874 ± 1.092^{a}

5.3.2.3 Microparticle size analysis by Scanning Electron Microscope (SEM)

The images (Fig. 5.3) showed slightly oval shaped norabogori fruit extract encapsulated microparticle beads without any significant cracks. The microencapsulate beads of Uniform and controlled spherical size in minimum value are crucial for efficient release of encapsulated material in target region of GI tract. A gradual reduction in size of the microparticles from 0.92 mm to 0.68mm are recorded as the concentration of sodium alginate increases from 1:2 ratio of Extract to sodium alginate to 1:8 ratio. The results are in agreement with those of Saikia et.al [44]. This could be due to the improved encapsulation and viscosity of sodium alginate resulted from the higher degree of cross-linkage. The smaller sized beads are optimal to use as a food additive and shows better sensory evaluation.

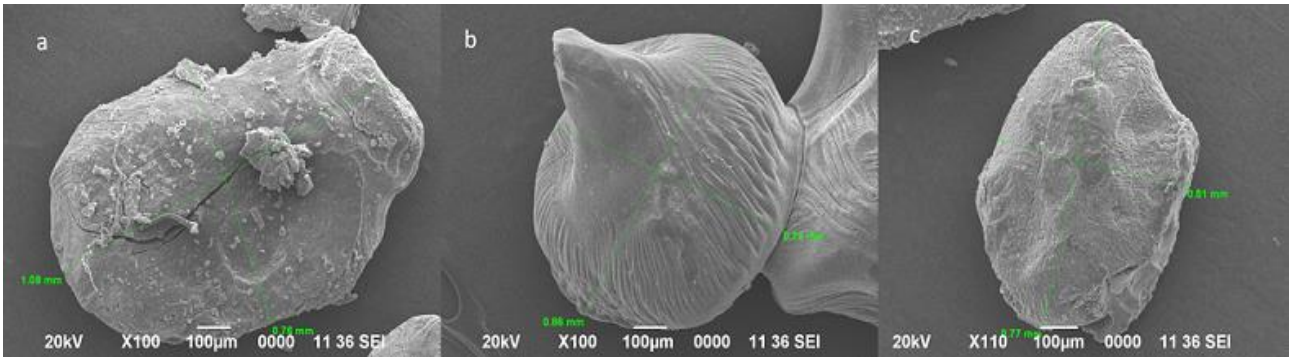

Fig.5.3 SEM images of microparticles formed in different extract-NaAl ratios showing their sizes. a) 1:2, b) 1:4 and c) 1:8

5.3.3 Encapsulate incorporated leather development

5.3.3.1 Texture analysis of encapsulate incorporated leather

The texture analysis of norabogori fruit leather incorporated with encapsulated norabogori extract showed significant differences in the evaluated parameters (Table 5.5). In all parameters, the leather showed a higher value in case of a products with 2.5% of encapsulate than with 5% incorporated encapsulates. The fruit leather prepared with pectin and 2.5% encapsulate showed the lowest values in every parameter however, the values were still higher than the control. In an increased encapsulated beads concentration, the hydrogen-bond created by the hydrocolloids might be disturbed because of their homogeneous presence and decreased their effects resulting in lower gumminess, chewiness and springiness values [45].

Table5.5 Texture profile analysis of microencapsulate incorporated norabogori leather

	Gumminess (N mm)	**Chewiness (N mm)**	**Springiness**	**Cohesiveness**
Control (A)	57.71 ± 0.91^{a}	33.90 ± 1.01^{a}	5.87 ± 0.35^{a}	0.99 ± 0.13^{a}
Xanthan gum (1%)+ encapsulate (5%) (B)	97.42 ± 0.88^{b}	66.07 ± 1.01^{b}	6.85 ± 0.41^{b}	1.27 ± 0.28^{a}
Xanthan gum (1%)+ encapsulate (2.5%) (C)	107.35 ± 0.77^{c}	79.41 ± 1.16^{c}	7.93 ± 0.54^{c}	1.37 ± 0.44^{a}
Pectin (1%)+ encapsulate (2.5%) (D)	83.53 ± 0.81^{bc}	48.58 ± 1.01^{a}	6.04 ± 0.73^{bd}	1.23 ± 0.36^{a}

(Values represent mean± SD; n=3. Mean with significant difference at $p<0.05$)

5.3.3.2 Physio-chemical composition of norabogori fruit leather

The moisture content of the Norabogori fruit pulp showed to be significantly many fold higher than the fruit leather with or without encapsulate. The decreasing moisture content increases the stability of the product and thus, the shelf life increases. The final product showed the least amount. The value of pH does not vary abruptly between the fresh and the leather. The stability might be maintained due to absence of any abrasive and harsh processing step. A slight increase in pH for the encapsulate incorporated leather was observed. The similar conditions were resulted

in case of ascorbic acid and TPC content. Though the differences are very low, the encapsulate incorporated leather showed highest ascorbic acid and TPC content owing to its fortification.

Table 5.6: Physio-chemical characteristics of norabogori fruit leather

Parameters	Fresh norabogori fruit	Norabogori fruit leather	Final product[a]
Moisture (%)	84.45±0.45	22.26 ± 0.29	18.74 ± 0.36
Ascorbic acid (Vit. C)(mg/100g)	8.19 ± 0.19	8.93 ± 0.03	9.94 ± 0.19
pH	4.30 ± 0.13	4.07 ± 0.02	4.68 ± 0.04
TPC (mg GAE/g)	55.80 ± 0.49	60.57 ± 0.85	65.84 ± 0.31

5.3.3.3 Sensory evaluation of the final product

It was observed from Fig.5.4 that the appearance and taste did not show much difference in 2.5% and 5% encapsulate incorporated leather. Due to the dark color of the control product, encapsulates did not affect in color and appearance of the product. The addition of a higher amount of encapsulates affected the texture of the leather and showed less score in 5% addition (Xanthan gum incorporated: 5.75, pectin incorporated: 5.76) than the 2.5% addition (Xanthan gum incorporated: 7.92, pectin incorporated: 7.23). Similar trends for hydrocolloids were found in dragon fruit leather [45]. The xanthan gum added fruit leathers were better accepted than the pectin-added leather. So, norabogori leather having 2.5% encapsulate and xanthan gum as a part of its ingredients evinced an excellent overall sensory acceptability.

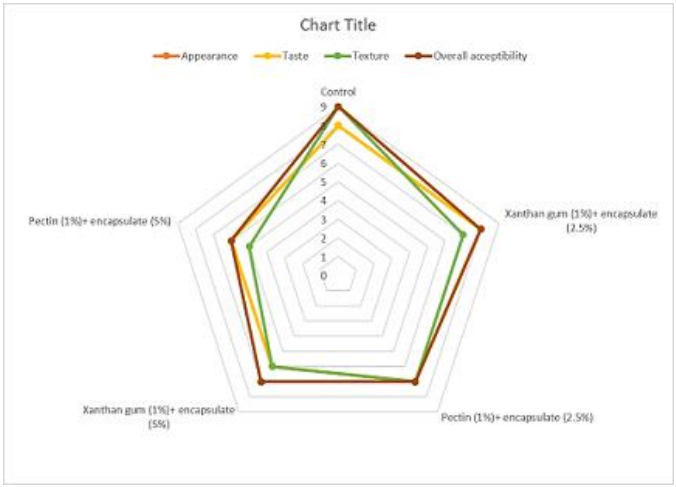

Fig.5.4 Sensory evaluation of microencapsulate incorporated norabogori leather

5.4 Conclusion:

This study concluded that different kinds of hydrocolloids being from the similar compound type (Hydrocarbons), they act differently in case of product development. They give different results in case of textural properties precisely and the leather that contained 1% xanthan gum (among guar gum, pectin, starch, and xanthan gum) demonstrated the highest overall acceptance in this aspect.

Next, the encapsulation is a proven efficient procedure to endure the sensitive phytochemical extract from environmental effects like heat, light, temperature etc. and metabolic factors like, pH, enzyme, digestion mechanism etc. It can directly transfer the compounds to its targeted absorption site. The extract:NaAlg ratio of 1:2 found out to be the best for this procedure and after that a crosslinking step with $CaCl_2$ completed the process. The phenolic extract was successfully encapsulated using NaAlg polymer in the present study. The leather that contained 2.5% microencapsulate and 1% xanthan gum (among guar gum, pectin, starch, and xanthan gum) demonstrated the highest overall acceptance in both objective and sensory evaluations. In order to increase the nutraceutical value of functional foods, confectionary, sauces, chocolates, jellies, ice cream, candy goods, and a range of instant drink powders, microencapsulated norabogori extract could be utilized as a natural additive.

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