Development and process optimization of freeze-dried reconstitutable noodle for astronauts

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Abstract : International Space Station (ISS) environment and microgravity alter the sensory perceptions greatly and unprecedented radiation damage to the food has led to the negligence of consumption. Thus undernutrition has accounted for about a 20% deficit in daily calorie intake for an astronaut. To provide sustainable energy for them a freeze-dried plant-based noodle is developed to bear the calorific values obeying RDI and joint FAO/WHO standards mandated for astronauts. To meet the countermeasures of the microgravity, the noodle is freeze-dried intending for long-term shelf stability. The noodle is providing up to 50.569 g of protein, 123.612 g of carbohydrate, and 15.748 g of fat from a single serving unit of 284.5 g packet of sample 3 (frozen at -40°C and dried for 6 hrs) formulated abiding USDA nutritive values which are within the range prescribed by RDI. There is no concomitant loss in protein due to the absence of heat in freeze-drying which also leaves complex polysaccharides and lipids of interest intact. ISS does not have a refrigerator to accommodate enough food. Thus freeze-drying at subatmospheric pressure and below eutectic temperature has led the noodle to weigh lighter up to 284.5 g from 369 gm of concoction for storage constraints up in ISS. Besides the antioxidant, polyphenol and flavonoid contents in sample 3 are found to be 76.44±0.05%, 97.80±0.04 mg GAE/g, and 79.44±0.04 mg QE/g which is pretty higher than the other two samples dried for 4 and 5 hrs separately. This proves that freeze-drying also protects the viability of thermo-labile bioactive compounds in concentrated form which could provide healthy physiology and psychosocial regulation detaining detrimental symptoms. The W.H.C and O.H.C for sample 3 are at least about 1.61±0.05 g/g and 1.05±0.01 g/g respectively with a moisture content of 0.02±0.01 g/g. The results are quite lesser than the other two less dried ones. The S.C of sample 3 is 5.17±0.04 g/g. This signifies that extended drying time can also sublime the unfrozen water remaining within fibre matrices hence checking the microbial spoilage. Freeze-drying recovers the food matrices, texture, and tissue morphology for mouthfeels inferred from the sensory analysis. The noodle is reconstitutable within 10 mins at 80°C in the LDPE bag. Freeze-drying also reduces shrinkage, cracks, and case hardening of the noodle to give better acceptability. It is providing approximately 838.456 kcal packet storage at 60-85°F(18-26.7°C) in the safe haven section of MPLM.

Index terms - **International Space Station, Freeze-drying, calorie, sublimation, noodle.**

I. INTRODUCTION

"Cosmos" the halo of space-time figment has been an imagination since time immemorial. It has been a wonder since the dawn of human civilization about 2.6 million years ago. The gradual metamorphosis of human intelligence and judgment has led to understanding this celestial paradigm. The indomitable zeal for flying high in the sky like birds led humans to invent flying machines. Modernization of those technologies and Astronomical studies has led humans to have a better understanding of the Cosmos and its Brobdingnagian realms. Till now humans have set course to different planets of our Solar system and the Moon through unmanned and manned spacecraft as well. This led to producing messengers of our Earth called "Astronauts" and "Cosmonauts" who have served and are still serving their lives for space explorations in unparallel magnitudes. To help astronauts with the best performances in microgravity, highly scientifically developed food is embarked upon. To meet the challenges in microgravity, more emphasis has been done on human habitability and adaptability in ISS, orbital vehicles, and manned satellites. In the past 5 decades provision of better food and nutrition has helped astronauts with better physiology like neurosensory, musculoskeletal, gastrointestinal, hematological, immunological, endocrine, and cardiovascular improvements. Besides, sustainable circadian rhythmicity and sleep have also been accounted for (Enrico, 2012). The food is processed exquisitely to mitigate the losses due to enzymatic degradation, photodegradation, chemical degradation, non-enzymatic degradation, physical changes, and phase separations (Taylor et al, 2020). To achieve stability the food undergoes microbial inactivation during ground processing (Cooper et al,

2011). With the onset of the Mercury mission(1960), pureed beef and vegetables, bite-sized cubes in gelatin coating, freeze-dried strawberries, pineapple cubes, and mushrooms in aluminium tubes were developed. In Gemini Food Program(1965), applesauce, turkey-bites, fruit cocktail, fruit juice, chicken stew, rice, chicken soup, shrimp cocktail, butterscotch puddings, and chocolate cubes were developed by dehydrcation techniques. In Apollo Food Program(1968), freeze-dried rehydratable chocolate puddings, tuna salads, beef roast, beef sandwiches, tortillas, tacos, frankfurters, scrambled eggs, spaghetti, cornflakes, bacon, and peanut butter were developed. Again on Skylab mission (1973), dining assorted foods like mashed potatoes, freeze-dried ice creams, steak, zucchini, asparagus, mushroom, chili, ham, etc were incorporated. In the Apollo-Soyuz test project(1975), compressed rehydratable pineapple cake, peach cake, beef with vegetables, chocolate pudding, lemon and tea powder, choco brownie, beef hash, fruit cereal slurry, jellied beef tongue, Riga bread, beet soup, cheddar cheese, etc were scoped. Now in ISS and space shuttles (1981 to present) for extended duration missions foods are stored and resupplied in Multi-Purpose Logictic Module (MPLM) every 90 days i.e. 3 months of incessant consumption. Long-duration missions require better nutrition enriched food to counteract the effects of microgravity and have a psychosocial impact on human physiology and crew morale (EG, 1999).

The International Space Station (ISS) foods are mainly prepared by dehydration(freeze-dried) e.g. chicken consomme, macaroni, cheese, ice cream, scrambled eggs, fruit cereals, non-fat dry milk, sugar powder punch, etc. Thermostabilized(high temperature pasteurized) foods include canned tunas, canned mushrooms, tomatoes, ham, chicken ala king, beef puddings, canned fish, etc. Irradiated foods(radiation pasteurized) included beef steak, chicken stew, chicken soup, and all. Intermediate moisture-containing foods(15-30% water content) include dried peaches, apricot, nuts, berries, droops, dried beef, pears, sapota, etc. Natural form foods(ready to eat) include granola bars, nuts, cookies, etc. Condiments(ready to eat) include mayonnaise, taco sauce, tomato sauce, liquid pepper, liquid salt, catsup, mustard, hot pepper sauce, etc. Frozen foods(iced) include casseroles, chicken pot pies, quiches, etc. Fresh foods(ready to eat) include apples, oranges, and bananas. Refrigerated foods(chilled) include cream cheese and sour cream (EG, 1999). Long-duration missions are also assisted by a frequent supply of supplementary diets to ISS through un-manned cargo spaceships (Carillo et al, 2020).

The Freeze-drying process occurs in three successive steps : (i)Freezing the food product(completely chilling at a very less temperature),(ii)Primary drying of the product(subliming the ice crystals at subatmospheric pressure), and (iii)Secondary drying (desorption of bound/unfrozen moisture within dried food matrices). The slower drying produces larger ice crystals which are easier to sublimate unlike quicker drying (Bhatta et al, 2020). Freezing is done below the eutectic temperature of the food material to ensure the complete formation of ice crystals. The larger crystals are easier to sublime which are formed by annealing the temperature between -50°C to -80°C slowly and this prevents cracks. In the initial drying phase, about 95% of water is warded off by creating a partial vacuum at subatmospheric pressure. In the terminal drying phase, the temperature of the material is elevated up to 0°C by increasing the pressure too to desorb any bound water interaction with food matrices and other biochemicals as well. Finally, the water content of about 1-4% is left in the product (Shukla et al, 2011).

Noodles are a staple and one of the most convenient foods for centuries due to their high calorific value, palatability, and easy reconstitution. For its excellent texture, it has created a mouthwatering sensation worldwide to date and is the most consumed fast food in the modern world. Freezing is done at -40°C, which increased the microstructure and texture of the noodles. More than 80% of water is frozen in the noodles during freezing which sublimes most of the water and helps preserve the texture and makes it consistent for longer storage (Pan et al, 2019).

II. MATERIALS AND METHODOLOGIES

2.1. Materials

2.1.1. Raw materials
Beans, Spinach, Potato, Carrot, Peas, Broccoli, Cashews, Almonds, Cornflakes, Egg, Meat, and Rice. All these are bought from the fresh groceries store of the Mall.

2.1.2. Reagents
Methanol, Ethanol, 1.25% sulphuric acid, 1.25% sodium hydroxide, HPLC(High-Pressure Liquid Chromatography) grade water, distilled water, refined oil, 0.1N sodium hydroxide, 0.3% Phenolphthalein solution, 1% Gallic Acid standard, Folin-Ciocalteau reagent, 20% sodium carbonate, 1% Quercetin standard, 5% sodium nitrite, 10% aluminium trichloride, 1M sodium hydroxide, 1,1-diphenyl-2-picryl-hydrazyl (DPPH) solution, potassium sulphate, copper sulphate, 40% sodium hydroxide, 0.2N hydrochloric acid, 4% boric acid, 0.1% methyl red, 0.2% bromocresol green, Petroleum ether, 0.2% Anthrone reagent, 2.5N hydrochloric acid, 95% sulphuric acid, 10% Glucose stock solution, sodium carbonate anhydrous, Silica gel. All these are bought from Sigma Aldrich, Loba Chemie, Emplura, Emsure, Merck, and Spectrochem.

2.1.3. Instruments and Glasswares
EYELA FDU-1200 Benchtop freeze dryer, Kjeldahl's apparatus, Soxhlet's apparatus, Centrifuge machine(REMI R-8C), Hot air oven, Muffle furnace, Desiccator, Crucible, Lab scale weight machine(WENSAR 0.001g-600g accuracy), ultrasonic bath(ASCENSION LIFE SCIENCE), heating mantle, magnetic stirrer(REMI), vortex machine(REMI), mortar & pestle, conical flasks, pipettes, beakers, funnels, round-bottomed flasks, petridish, burette, cuvette, test tubes, filter paper, aluminium foil, butter paper, parchment paper, clamp stand, falcons, measuring cylinders, cotton cloth, thermometer, spectrophotometer, texture analyzer (Stable Micro Systems TA.XT plus).

2.2. Methodologies

2.2.1. Development of the noodle

i. Formulating the primary & tertiary processed ingredients as per Food and Agricultural Organisation (FAO)/World Health Organisation (WHO)/United States Department of Agriculture (USDA)/Reference Daily Intake (RDI) standards of calorific intake given in table 2.2.1a. (Gebhardt and Thomas, 2020, Diet and Health 1989, RDA 1989 and JWFEC 2002).

Table 2.2.1a : FAO/WHO/USDA/RDI standardized calorific intake of ingredients considered

Vegetables	Weight(g)	Calorific Value(kcal)
Brocolli	100	47.92
Peas	83	49.47
Beans	100	22.50
Spinach	100	31.20
Potato	50	34.05
Carrot	50	31.30
Total	**483**	**216.44**
Fruits	**Weight(g)**	**Calorific Value(kcal)**
Cashew	25	143.70
Almonds	25	145.04
Total	**50**	**287.74**
Cereals	**Weight(g)**	**Calorific Value(kcal)**
Rice	100	121.62
Cornflakes	50	179.20
Total	**150**	**300.82**
Non-vegetables	**Weight**	**Calorific Value(kcal)**
Meat	50	117.00
Egg	50	77.40
Total	**100**	**194.40**
Grand Total	**783**	**1000.40**

ii.   Blanching and sulphiting them with 200 mg/kg of Potassium Metabisulphite in 100°C water as per FAO standards (FAO, 1997).

iii.   Cooling them up to an ambient temperature of 20-30°C

iv.   Pulverizing the ingredients in the form of slurry with additives as per Codex Alimentarius Commission (CAC) standards is given in table 2.2.1b. (CAC, 1995).

Table 2.2.1b : CAC standardized additives incorporated into the concoction

	Compounds	Functional Class	Level(g) for 683 g
Vegetables	Potassium metabisulfite	Antioxidant, Preservative	0.4
	Potassium dihydrogen phosphate	Acidity regulator, Humectant, emulsifier, Sequestrant, stabilizer	4.03
	Sodium benzoate	Preservative	0.68
	Calcium disodium ethylenediaminetetraacetate	Sequestrant	0.55
	Compounds	**Functional Class**	**Level(g) for 100 g**
Non-Vegetables	Sodium nitrite	Preservative	0.008
	Calcium disodium ethylenediaminetetraacetate	Sequestrant	0.0035
	Disodium hydrogen Phosphate	Emulsifying salt	0.2

	Potassium sodium Tartrate	Stabilizer, acidity regulator	0.05

v.   Mixing the slurry with all-purpose flour in a 1:2 weight ratio i.e. (123 g admixture + 246 g flour) keeping calorific constraints constant for a total of 369 g yielding 1000 kcal approximately.

vi.   Incorporating additives standardized for flour to develop noodle like consistency given in table 2.2.1c. (Gulia et al, 2014, Muhilal, 1998, Pongpichaidom and Songsermpong, 2018 and Wang et al, 2018).

Table 2.2.1c : Standardized additives incorporated for flour

	Compounds	Functional Class	Level(g) for 246 g
Flour	Sodium alginate	Stabilizer	0.5
	Guar gum	Thickener, emulsifier, Firming agent	0.5
	Baking Powder (Polyphosphate)	Conditioner	7.38

vii.   Kneading and compounding the admixture unless and until it gives a dough-like appearance (Gulia et al, 2014, Muhilal, 1998, Pongpichaidom and Songsermpom, 2018).

viii.   Resting the dough for proper gluten alignment for 30 mins at an ambient temperature of 20-30°C within a covered container (Gulia et al, 2014, Muhilal, 1998, Pongpichaidom and Songsermpom, 2018).

ix.   Again compounding and rolling the dough to form a sheet (Gulia, 2014, Muhilal, 1998).

x.   Slitting the sheet with dimensions of 100 mm length, 5 mm width, and 1.7 mm thickness (Hatsugai, 1986, Akira, 1999).

xi.   Air drying the strands up to 40°C for 15 mins and cooling to room temperature again (Hatsugai, 1986, Akira, 1999).

xii.   Freezing the noodles at -40°C for 24 hrs. in an ultrafreezer (Pan, 2019).

xiii.   Drying the noodle for 4 hrs, 5 hrs, and 6 hrs consecutively (Pan, 2019).

xiv.   Reconstituting the noodle at 80°C for 10 mins within the low density polyethylene (LDPE) bag (Taylor et al, 2020).

2.2.2. Physical Analysis

2.2.2.1. Moisture Content Analysis

Empty petridish with lid is dried in a hot air oven at 105°C for 3 hrs, then cooled inside a desiccator, weighed along with the lid. Then 3 gm of sample is transferred into the dish and subjected to drying at 105°C. Now cooling it again inside the desiccator and reweighing the entire petridish with the sample (AOAC, 2000). The final moisture content is calculated using the following formula in Eq. (2.2.2.1).

$$\text{Moisture Content} = \frac{\text{Initial weight of sample} - \text{Final weight of sample}}{\text{Initial weight of sample}} \qquad (2.2.2.1)$$

2.2.2.2. Water Holding Capacity

1 g sample is homogenized in a mortar by a pestle. An empty falcon is weighed first along with the cap. Now the homogenized sample is transferred into the falcon and filled with water completely. Now the setup is vortexed for 30 mins repeating for another 7-8 times with 10 mins intermittence. Then it is centrifuged for 25 mins at 2300 rpm and the supernatant is decanted. The falcon is dried in a hot air oven for 25°C for 50 mins. Finally cooled inside the desiccator and weighed (AACC, 2000). The water holding capacity is calculated using the following formula in Eq. (2.2.2.2).

$$\text{Water Holding Capacity} = \frac{\text{Final weight of the sample} - \text{Initial weight of the sample}}{\text{Initial weight of the sample}} \qquad (2.2.2.2)$$

2.2.2.3. Oil Holding Capacity Analysis

1 g sample is homogenized in mortar by a pestle. An empty falcon is weighed first along with the cap. Now the homogenized sample is transferred into the falcon and filled with oil completely. Now the setup is vortexed for 30 mins repeating for another 7-8 times with 10 mins intermittence. Then it is centrifuged for 25 mins at 2300 rpm and the supernatant is decanted. The falcon is dried in a hot air oven for 25°C for 50 mins. Finally cooled inside the desiccator and weighed (AACC, 2000). The oil holding capacity is calculated using the following formula in Eq. (2.2.2.3)
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$$\text{Oil Holding Capacity} = \frac{\text{Final weight of the sample} - \text{Initial weight of the sample}}{\text{Initial weight of the sample}} \qquad (2.2.2.3)$$

2.2.2.4. Swelling Capacity Analysis

1 g sample is homogenized finely. Then it is transferred into a conical adding about 15 ml water and heated on a magnetic heater stirrer at 55°C, 65°C, 75°C, 85°C, and 95°C with intermittent stirring for 30 mins. Then the entire solution is transferred into a falcon and centrifuged for 20 mins at 2000 rpm. The supernatant is decanted and the falcon with the swelled sample is weighed finally (AACC, 2000). The final swelling capacity of the sample is calculated using the following formula in Eq. (2.2.2.4).

$$\text{Swelling Capacity} = \frac{\text{Final weight of the sample} - \text{Initial weight of the sample}}{\text{Initial weight of the sample}} \qquad (2.2.2.4)$$

2.2.2.5. Solubility Index Analysis

1 g sample is homogenized nicely in mortar and pestle. Transferred into a conical with 15 ml distilled water and stirred for 30 mins on a magnetic stirrer. Then the entire solution is poured into a falcon and centrifuged at 3000 rpm for 5 mins. Now the supernatant is decanted into a small beaker which is weighed in empty dried condition. Now the beaker along with the supernatant is heated at 105°C in a hot air oven until a constant final weight is arrived (Eastman and Moore, 1984). The final solubility index is calculated using the following formula in Eq. (2.2.2.5).

$$\text{Solubility Index} = \frac{\text{Final weight of the supernatant}}{\text{Initial weight of the sample}} \qquad (2.2.2.5)$$

2.2.2.6. Texture Analysis

The texture analysis is conducted by a texture analyzer machine.

2.2.3. Chemical Analysis

2.2.3.1. Titrable Acidity Analysis

1 g sample is homogenized nicely and kept in a mortar. Then in a 100 ml conical flask, about 100 ml of distilled water is taken and boiled. Now the sample is introduced into this boiled distilled water and stirred continuously for 5 mins unless and until some of it gets dissolved and the solution becomes colored. Separately 0.1N NaOH solution is prepared in a 100 ml beaker. Now a burette is filled with this alkaline solution up to least graduation. The conical sample solution is placed below the burette and clamped in a burette stand. 0.3 ml of phenolphthalein solution is added to the sample solution. Titrated against 0.1N NaOH solution unless the sample turns pink for at least 30 secs (AOAC, 2000). The final titrable acidity is calculated using the following formula in Eq. (2.2.3.1).

$$\text{Titrable Acidity} = \frac{\text{Burette Reading} \times 0.1\text{N} \times \text{Equivalent weight of Malic Acid i.e.}0.0067\text{g}}{\text{Weight of sample}} \qquad (2.2.3.1)$$

2.2.3.2. Antioxidant Content Analysis

10 mg of DPPH is diluted into 100 ml of methanol and kept wrapped within aluminium foil completely in a beaker. Now 100 mg of the sample solution is prepared in 100 ml methanol in a conical. Then a range of (20, 40, 60, 80, 100)ug/ml of sample concentrations is made by pipetting (0.2, 0.4, 0.6, 0.8, 1.0)ml of sample solutions and bringing up to 10 ml with distilled water in round-bottomed flasks. Now 1 ml of each concentration is pipetted followed by 3 ml of DPPH solution in all test tubes. Separately a control is prepared with only 3ml DPPH solution and 1ml methanol. The entire setup is incubated in dark for 30 mins. Absorbance is noted at 517 nm (AOAC, 2000). The final antioxidant activity is calculated using the following formula in Eq. (2.2.3.2).

$$\% \text{ Scavenging} = \frac{\text{O.D of control} - \text{O.D of sample}}{\text{O.D of control}} \qquad (2.2.3.2)$$

2.2.3.3. Total Polyphenol Analysis

A stock standard solution is prepared first by dissolving 0.25g Gallic acid reagent in 250 ml HPLC grade water i.e 1mg/ml concentration in a volumetric flask and sonicated for 30 mins in an ultrasonic bath at 60°C. Then (1, 2, 3, 4, 5)ml of this solution is pipetted out into 25 ml volumetric flasks compensating the volume with water nextly to have a calibration concentration range of (40, 80, 120, 160, 200)mg/L respectively. Now 100 mg of the nicely homogenized test sample is dissolved into 100 ml methanol and sonicated for 2 hrs to completely extract the polyphenolic components. Now 5 ml of this solution is pipetted into 100 ml of methanol to dilute 20 times followed by sonication again. Then seven test tube series are made with 15 ml of water in each. 1 ml Folin-Ciocalteau's phenol reagent is added to each of the 7. Now in each of the 5 test tubes, 1 ml of each calibration standard solution is pipetted separately and consecutively. Then 1 ml of the sample solution is added into one test tube and the remaining one is served as a blank with 1 ml of water. They are given a quick vortex for 6 mins and 3 ml of 20% sodium carbonate is added into each lastly. Then they are heated at 100°C in a water bath for 30 mins. Then cooled to room temperature and subjected to a spectrophotometer at 765 nm (Kupina et al, 2017). The final polyphenolic content is calculated using the formula in Eq. (2.2.3.3).

$$\text{Total Polyphenol Content (mg GAE/g)} = \frac{A - b}{m} \times \frac{V \times D \times 100}{W \times 1000} \qquad (2.2.3.3)$$

2.2.3.4. Total Flavonoid Analysis

A stock standard solution is prepared first by dissolving 0.1g Quercetin reagent in 100 ml methanol i.e 1mg/ml concentration in a volumetric flask and sonicated for 30 mins in an ultrasonic bath at 60°C. Then (1, 2, 3, 4, 5)ml of this solution is pipetted out into 25 ml volumetric flasks compensating the volume with water nextly to have a calibration concentration range of (40, 80, 120, 160, 200)mg/L respectively. Now 100 mg of the nicely homogenized test sample is dissolved into 100 ml methanol and sonicated for 2 hrs to completely extract the flavonoid components. Then seven test

tube series are made. Into each of these 0.2 ml of each calibration standard solution are pipetted followed by 0.8 ml of methanol. The same is done for the test sample solution in one of the test tubes and the last one is served as blank with all but the sample solution. Now, 0.06 ml of 5% sodium nitrite is added to all of them and incubated in dark for 5 mins. Then 0.06 ml of 10% aluminium trichloride is added into all with again 6 mins of incubation in dark. Finally, 0.4 ml of 1M NaOH and 0.48 ml of distilled water are added to all the test tubes. Then all of them are given a quick vortex for 6 mins and subjected to a spectrophotometer at 510 nm (Matic et al, 2017). The final flavonoid content is given by the following formula in Eq. (2.2.3.4).

$$\text{Total Flavonoid Content (mg QE/g)} = \frac{A - b}{m} \times \frac{V \times D \times 100}{W \times 1000} \tag{2.2.3.4}$$

2.2.4. Proximate Analysis

2.2.4.1. Crude Fibre Analysis

Firstly 1.25% sulfuric acid standard solution is prepared by pipetting 2.5 ml of 98% concentrated sulfuric acid into a 200 ml round-bottomed flask containing 197.5 ml distilled water already since acid needs to be poured gently into the water but not reverse to avoid an unprecedented accident. Now 1.25% NaOH solution is prepared by dissolving 2.5 g NaOH in 200 ml distilled water in a round-bottomed flask. Now 5 g sample is homogenized finely and added into 200 ml 1.25% sulfuric acid solution in a conical flask. Now the entire setup is placed on a magnetic stirrer heater and brought to boiling for 30 mins with intermittent stirring of 5 mins. After digestion, the acid solution is filtered into another empty conical through a cotton cloth in a funnel mounted on top of the conical. Now the trace of acid is removed by hot water through the funnel with a cotton cloth. Now the remnants of the sample on the cotton are scrapped off by a spatula into 200 ml of 1.25% NaOH solution in another conical. And the setup is again heated up to boiling for 30 mins with intermittent stirring of 5 mins. After digestion again the alkali solution is filtered in the same manner followed by a hot water wash. Now scrap off the fibre residue into a dried clean weighed crucible and subject to heat at 550-600°C in a muffle furnace for 4 hrs. Then cool it inside a desiccator and reweigh the crucible with residue (AACC, 2000). The final crude fibre content is calculated using the following formula in Eq. (2.2.4.1).

$$\text{Crude Fibre (mg/g)} = \frac{\text{Initial weight of crucible with fibre} - \text{Final weight of crucible with residue}}{\text{Initial weight of sample taken}} \tag{2.2.4.1}$$

2.2.4.2. Protein Content Analysis

Kjeldahl's catalyst is firstly prepared with 9 parts by weight of potassium sulphate and 1 part by weight of copper sulphate. 0.2 N HCL standard solution is prepared and kept ready. Besides indicator mixture of 0.1% methyl red in 95% ethanol along with 0.2% bromocresol green in 95% ethanol is prepared. And 40% NaOH solution and 4% boric acid solution are kept ready for back titration. Now about 1 g of sample is introduced inside digestion chamber with 5 g catalyst mixture with 200 ml concentrated sulfuric acid. Similarly, a control solution is prepared without a sample. Now the setup is boiled briskly until the frothing of acid disappears. The digestion is accompanied by the addition of 40% NaOH solution to produce free ammonia. Then cooling is done. Now the digestion flask is promptly connected to a condenser with its tip being immersed in a receiver chamber containing 4% boric acid solution with an indicator mixture. The entire sample is slowly digested until all ammonia fumes are condensed into the receiver. Now the receiver is removed and condenser is washed and again the titration is repeated for the control solution. Now titration is done for the receiver end containing sample ammonia against excess standard 0.2N HCl solution to measure the exact amount of protons required to neutralize the equivalent no of nitrogen atoms of ammonia captured by the boric acid during the process (AACC, 2000). The final protein content is calculated using the following formula in Eq. (2.2.4.2).

$$\text{Protein Content (mg/g)} = \frac{(A - B) \times 14.007 \times N \times 6.25}{W} \tag{2.2.4.2}$$

2.2.4.3. Carbohydrate Content Analysis

Firstly 2.5 N HCl solution is prepared and kept aside. Then 0.2 g of Anthrone Reagent is dissolved in 100 ml of 95% sulfuric acid and kept in ice-cold condition wrapped in Aluminium foil entirely. Then glucose working standard solution is prepared by diluting 10ml of 100mg/100ml glucose stock solution into 100 ml distilled water separately. Now 100 mg of sample is boiled with 80% ethanol for 2 hrs in a test tube and then centrifuged readily followed by decantation of supernatant. Then again the residue of the test tube is boiled in a hot water bath for 3 hrs in 5 ml of 2.5 N HCl in a test tube. The setup is cooled to room temperature followed by the addition of sodium carbonate anhydrous until effervescence ceases. Now, this mixture is diluted with 50 ml distilled water and centrifuged to collect the supernatant. About 0.5 ml of supernatant is taken in a test tube followed by the addition of 0.5 ml distilled water to make up the volume to 1 ml. The calibration standard solution of glucose is made in (0.02, 0.04, 0.06, 0.08, 0.1)mg/ml concentrations by pipetting (0.2, 0.4, 0.6, 0.8, 1.0)ml of working standard solutions and making up the volume to 1ml with water. Now 4 ml of anthrone reagent solution is pipetted into each calibration standard as well as sample solution when a greenish-blue colored endpoint appears in all test tubes. Again the setup is heated for 8 mins in a boiling water bath and cooled rapidly in ice-cold water. Absorbance is noted at 630 nm (Hedge and Hofreiter, 1962). The final carbohydrate content is calculated from the formula given in Eq. (2.2.4.3).

$$\text{Carbohydrate Content (mg/g)} = \frac{A - b}{m} \times \frac{V}{W} \tag{2.2.4.3}$$

2.2.4.4. Fat Content Analysis

5 g of sample is homogenized nicely and wrapped in filter paper entirely. Previously the Soxhlet round bottle and the condenser is heated at 105°C for 4 hrs and cooled to ensure warding off impurities from them. The bottle is weighed. The sample is then transferred into the extraction thimble of the apparatus. Now 250 ml petroleum ether is incorporated into the round bottle and heated on a heating mantle along with a condenser at the top connected to the cold water supply.

Heating is done for about 4 hrs uninterruptedly and then the bottle is subjected to a vacuum evaporator to evaporate the solvent. Then again heated at about 90°C in a hot air oven. Finally cooled inside a desiccator. Then the bottle with dried sample residue is reweighed (AOAC, 2000). The final fat content is calculated using the following formula in Eq. (2.2.4.4).

$$\text{Fat Content (mg/g)} = \frac{\text{Final weight of bottle with residue} - \text{Weight of empty bottle}}{\text{Initial weight of sample taken}} \qquad (2.2.4.4)$$

2.2.4.5. Ash Content Analysis

The crucible along with the lid is heated inside a muffle furnace for 4 hrs at 550°C. Then cooled inside a desiccator for 30 mins. The empty crucible is weighed. Then 5 gm sample is transferred inside the crucible and subjected to heating inside the furnace. The setup is placed slowly inside the furnace to let off the initial fumes. Now heating is done again at 550°C for 4 hrs with an uncovered lid. Then cooled inside a desiccator and observed if grey-colored residue has appeared, if not then heating is repeated (AOAC, 2000). The final ash content is calculated using the following formula in Eq. (2.2.4.5).

$$\text{Ash (mg/g)} = \frac{\text{Weight of residue with crucible}}{\text{Weight of sample with crucible}} \qquad (2.2.4.5)$$

2.2.5. Sensory Analysis

The sensory analysis is given by a 9-point Hedonic scale Assessment: Mean of 3-panel members in each age range of Adolescence (10-18 yrs), Adult (19-59 yrs), and Senior Adult (>60 yrs) to have triplicate data mean demographically and hence cumulatively assess the population statistics of all the age range for each sample rationally having significant standard deviation among the age ranges.

2.2.6. Packaging Parameters

2.2.6.1. Arithmetic Mean Diameter Measurement

Vernier caliper is used to measure the length(L), width(W), and thickness(T) of noodle strands accurately up to 100mm, 1.7mm, and 5mm respectively. The arithmetic means the diameter of the noodle strand and packaging size is calculated using the following formula in Eq. (2.2.6.1) (AACC, 2000).

$$\text{Arithmetic Mean Diameter} = \frac{(L + W + T)}{L} \qquad (2.2.6.1)$$

2.2.6.2. Geometric Mean Diameter Measurement

The Geometric mean diameter of the noodle strand and packaging size are calculated using the following formula in Eq. (2.2.6.2) (AACC, 2000).

$$\text{Geometric Mean Diameter} = \sqrt[3]{(L \times W \times T)} \qquad (2.2.6.2)$$

2.2.6.3. Surface Area Measurement

The surface area of the noodle is calculated using the following formula in Eq. (2.2.6.3) (AACC, 2000).

$$\text{Surface Area} = 2 \times (L \times W + W \times T + T \times L) \qquad (2.2.6.3)$$

2.2.6.4. Shape Index Measurement

The shape index of the noodle is calculated using the following formula in Eq. (2.2.6.4) (AACC, 2000).

$$\text{Shape Index} = \frac{W}{\sqrt{(L \times T)}} \qquad (2.2.6.4)$$

2.2.6.5. Spericity Measurement

The sphericity of the noodle is calculated using the following formula in Eq. (2.2.6.5) (AACC, 2000).

$$\text{Sphericity} = \frac{\sqrt[3]{(L \times W \times T)}}{L} \times 100 \qquad (2.2.6.5)$$

2.2.6.6. Bulk Density Measurement

The entire packaging size of the noodle is introduced into a 1000 ml beaker. The internal radius (r) and height up to which the product is sitting are measured. Then the mass (M) of the product with the beaker is measured and the internal volume of the beaker with void spaces is also calculated. And the process is repeated for triplicate heights (h) up to which the product sets itself. The final bulk density is calculated using the following formula in Eq. (2.2.6.6) (AACC, 2000).

$$\text{Bulk Density} = \frac{M}{\pi r^2 h} \qquad (2.2.6.6)$$

2.2.6.7. True Density Measurement

A similar setup is filled with semolina to fill up the void spaces completely with proper tapping. This in turn helps to account for the unused/surplus space that is involved in packaging and also the exact volume of the product which is needed to be assessed for final packet development. In this case, the entire mass (M) of beaker plus product plus semolina is accounted for. The process is repeated for triplicate heights (H) of the semolina used to fill the pores each time recurringly to make the data robust. The final true density is calculated using the following formula in Eq. (2.2.6.7) (AACC, 2000).

$$\text{True Density} = \frac{M}{\pi r^2 H} \qquad (2.2.6.7)$$

2.2.6.8. Porosity

The porosity of the product helps to determine how much amount of void space is there which is carrying extra packaging cost and how much reconfiguration of the product is required and what type of packaging is suitable too. The final porosity of the product is calculated using the following formula in Eq. (2.2.6.8) (AACC, 2000).

$$\text{Porosity \%} = \left(1 - \frac{\text{Bulk Density}}{\text{True Density}}\right) \times 100 \qquad (2.2.6.8)$$

III. R ESULTS AND DISCUSSION

3.1. Physical Parameters

3.1.1. Moisture Content, water holding capacity, oil holding capacity, swelling capacity, and water solubility index of the noodle
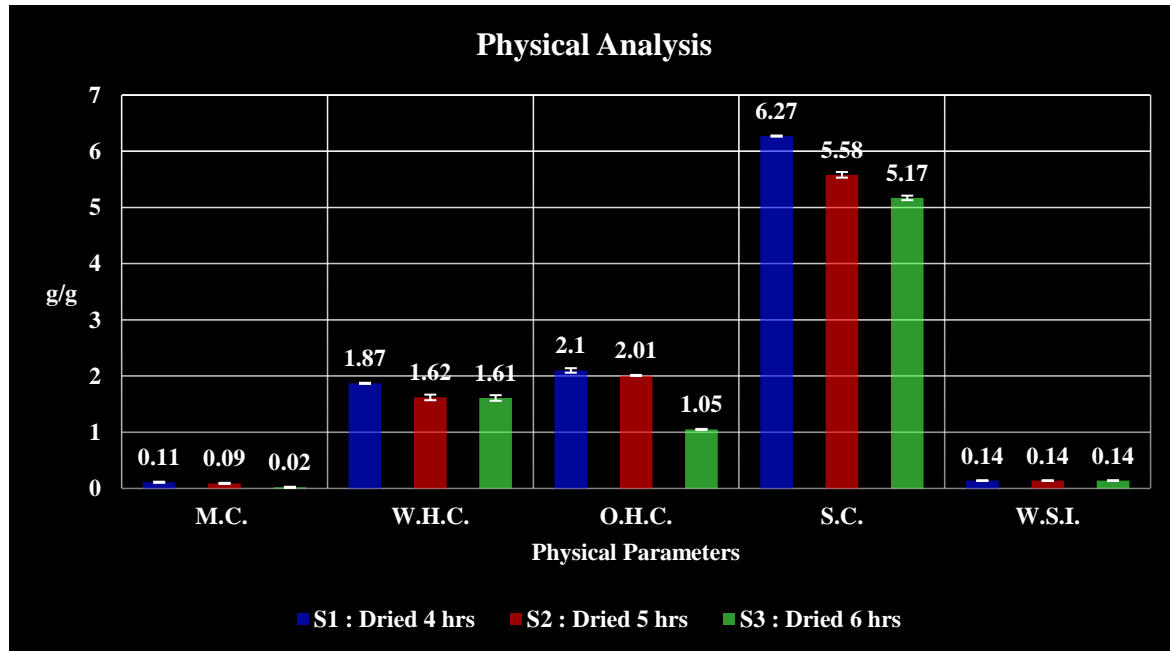
Figure 3.1.1: Effect of drying time on physical parameters of the noodle
*N.B.: All the values are calculated as Mean ± SD at P<0.05 level based on triplicate data.

The moisture content (M.C) of sample 3 is found to be lowest at 0.02±0.01 g/g obviously due to longer drying time rather than 0.11±0.01 g/g and 0.09±0.01 g/g of samples 1 and 2 respectively having shorter drying time. The water holding capacity (W.H.C) and oil holding capacity (O.H.C) for sample 3 are at least about 1.61±0.05g/g and 1.05±0.01 g/g respectively compared to the other two samples having higher values of 1.87±0.01 g/g, 1.62±0.05 g/g, 2.10±0.04 g/g, 2.01±0.01 g/g from the above **Fig. 3.1.1**. The swelling capacity (S.C) of sample 3 is 5.17±0.04 g/g which is much less than that of 6.27±0.01 g/g in sample 1. The drying time has a cumulative effect on samples. The inbound water content measured from S.C signifies that extended drying time can also sublime the unfrozen water remaining within fibre matrices hence the capacity to swell in contact with water decreases consequently even after intermittent heating. Now the W.H.C and O.H.C determine the surface water and oil adsorption phenomena respectively which is higher for samples 1 and 2. A substantial reason is shorter drying time aids infrequent desorption of bound water content which evenly distributes the surface molecules again with externally added water or oil. And longer drying time provoked sample 3 to be the lightest of all devoid of bound moisture. Contrarily water solubility index (W.S.I) is almost 0.14±0.005 g/g same for all of the three samples exquisitely. Probably the drying time is having no variation among the data for solubility of samples. Technically to dissolve in a solvent the solute molecules need to form certain bonds with the liquid. Here the ability of the sample molecules to form bonds with water is diminished due to the recovery of product structure on freeze-drying. Thus even if the product molecules are getting loosened due to their brittleness still very less number of physicochemical interactions are happening with the water molecules. The freeze-drying process aids in the recovery of the food matrix, heat-sensitive functional compounds, color, and essential nutrients of vegetables and fruits providing high-value products (Jiang et al, 2013).
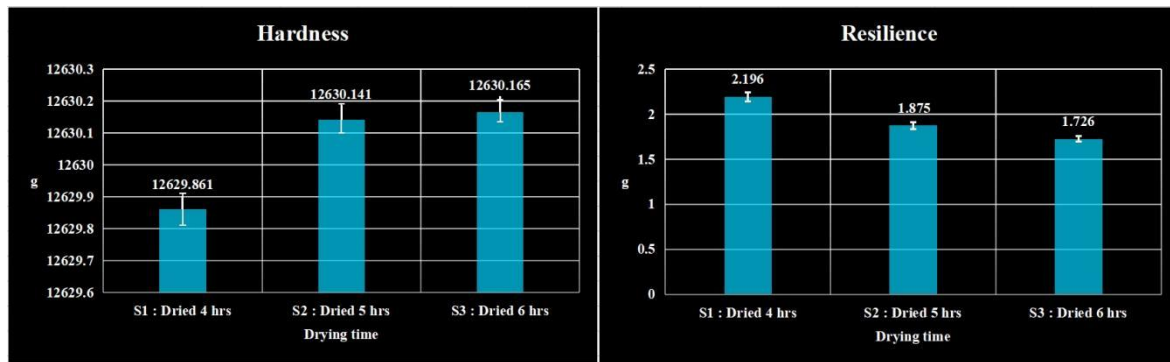
3.1.2. Texture of the noodle

Figure 3.1.2: Effect of drying time on the texture of the noodle

*N.B.: All the values are calculated as Mean ± SD at P<0.05 level based on triplicate data.

Figure 3.1.2 shows that the hardness of the most dried sample 3 is highest and needs about 12630.165±0.04 g force to disintegrate it rather than samples 2 and 1 using 12630.141±0.05 g and 12629.861±0.05 g respectively. Contrarily the resilience of sample 3 is least about 1.726±0.03 g compared to the other two having 1.875±0.04 g and 2.196±0.05 g. This proves that longer drying aids in making plant matrices more rigid with molecules being closest to each other whereas the resilience is decreased due to an increase in elasticity. The endurance of the molecules against abrasion and shear is lowered when elasticity increases hence the resilience is least for sample 3. Moreover, the drying is carried out at subatmospheric pressures for protecting heat-sensitive compounds and the ice crystals sublimes easily without an intermediate liquid phase. This prevents loss of texture, shrinkage, and cracking of the product. It is an indirect drying technique to improve product structure and quality using a vacuum chamber (Jangam et al, 2010).

3.2. Chemical Parameters
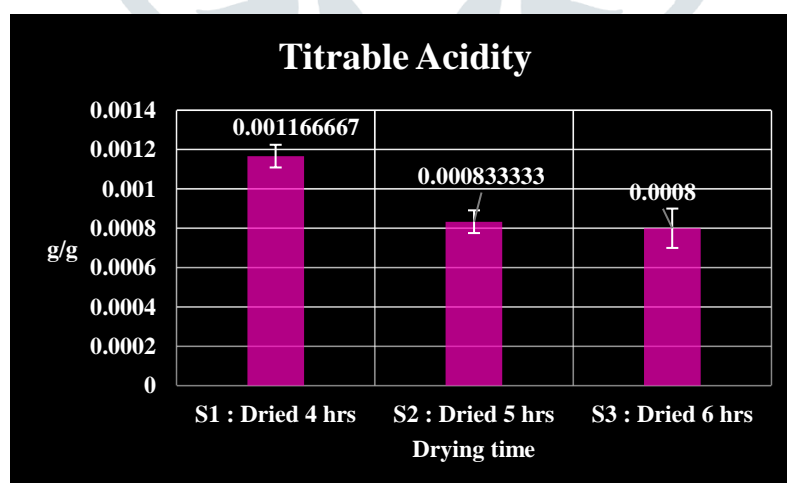
3.2.1. Titrable acidity of the noodle

Figure 3.2.1: Effect of drying time on the titrable acidity of the noodle

*N.B.: All the values are calculated as Mean ± SD at P<0.05 level based on triplicate data.

Figure 3.2.1 depicts that freezing drying also emits the excess acid off the product thus preserving its freshness for a longer duration. Sample 3 has an acidity of 0.0008±0.0001 g/g and has the least of the other two having 0.00083±0.00005 g/g and 0.00116±0.00005 g/g which is pretty higher. The plant byproducts which turn up toxic upon accumulation in the human body in microgravity might be dangerous. While annealing at the lowest temperatures these acidic compounds also freeze with water and sublime in subsequent stages of drying. Potential acids are secondary metabolites like phenolic acids which could often be detrimental to gradual accumulation in the body. Thus drying for a longer duration also gets rid of them and saves the product for a healthy aspect.

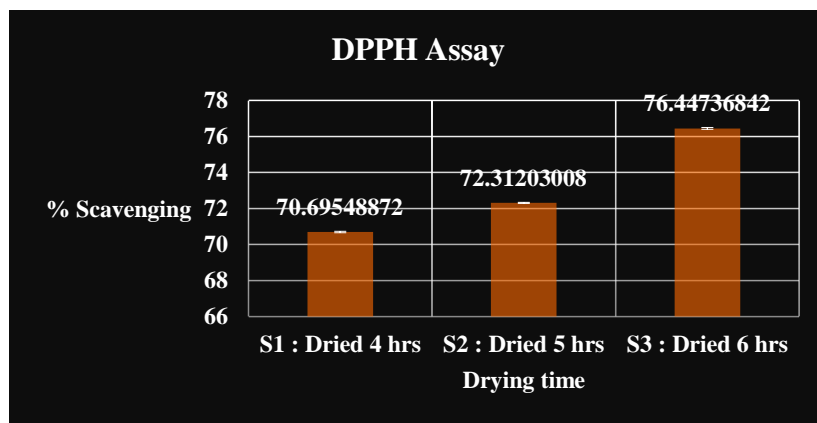### 3.2.2. Antioxidant activity of the noodle

Figure 3.2.2: Effect of drying time on the antioxidant property of the noodle
*N.B.: All the values are calculated as Mean ± SD at $P<0.05$ level based on triplicate data.

Freeze-drying is more antioxidant activity-friendly compared to other methods of convective, vacuum, and microwave drying (Santiago and Moreira, 2020). **Figure 3.2.2** shows that the scavenging activity of sample 3 is the highest about 76.44±0.05% measured at 517 nm. While other two are having 70.69±0.04% and 72.32±0.03%. This proves the efficacy of antioxidants present in the plants to bind with 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radicals thereby reducing it gradually hence the absorbance reading too. The more the drying the more the potency of antioxidants present in the sample. Drying instigates the concentration of antioxidant components present in the plant body. Thus the crude form of those is obtained by longer drying aid.

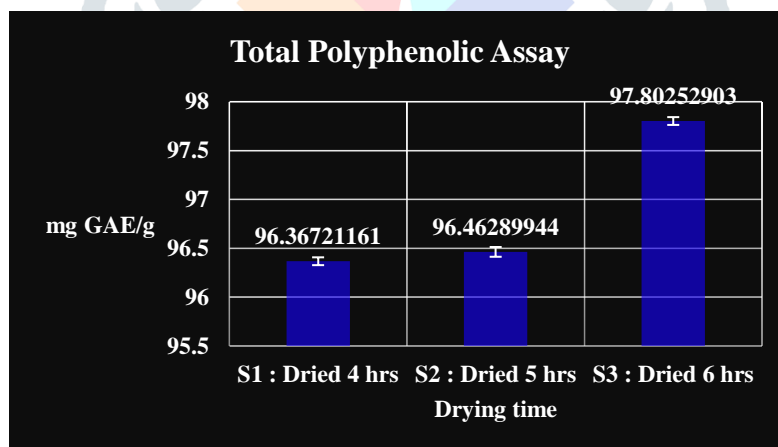### 3.2.3. Total polyphenolic content of the noodle

Figure 3.2.3: Effect of drying on the polyphenolic contents of the noodle
*N.B.: All the values are calculated as Mean ± SD at $P<0.05$ level based on triplicate data.
GAE: Gallic Acid Equivalent

The total polyphenol content is highest in sample 3 about 97.80±0.04 mg GAE/g rather than the other two containing 96.46±0.05 mg GAE/g and 96.36±0.04 mg GAE/g from **Fig. 3.2.3**. Maximal protection of bioactive functional materials is occurring for longer drying by vacuum freeze-drying which stands to be the best alternative for plant-based products. Hence the application of this process has culminated in space food production. Freeze-dried plant-based noodles, purees, soups, vegetable chunks, and slices are diversifying gradually. The availability of plant-based foods around the year is difficult due to the absence of proper cold storage, due to high water content and nutritional deterioration for long-term consumption in space hence drying is ultimately necessary for ease of all these challenges. Freeze-drying prevents oxidative cell damage, tissue damage, and nutrient loss unlike other methods of drying like osmotic dehydration, convective drying, sun drying, oven drying, etc. The phenolics, flavonoids, and carotenoids are well preserved in this method (Bhatta et al, 2020).

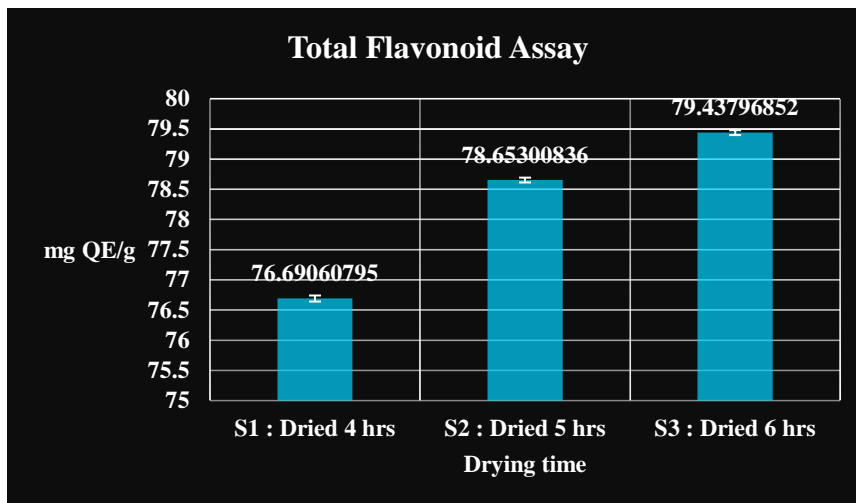**3.2.4. Total flavonoid content of the noodle**

Figure 3.2.4: Effect of drying on the flavonoid contents of the noodle

*N.B.: All the values are calculated as Mean ± SD at P<0.05 level based on triplicate data.

QE: Quercetin Equivalent

The process is enacted in the complete absence of oxygen and other atmospheric gases which could be deleterious for the crude bioactive components turning them into pale compounds. Besides, freeze-drying also improves tissue structure which exposes functionally important compounds (Garcia et al, 2010). **Figure 3.2.4** depicts that the extended drying time helped in retaining the flavonoids more in sample 3 accounting for about 79.44±0.04 mg QE/g which is pretty higher than 76.69±0.05 mg QE/g and 78.65±0.04 mg QE/g of samples 1 and 2 respectively. Perhaps the improved tissue structure helps in retaining these secondary metabolites and functional bioactive compounds more. Thus helping to preserve the plant-based product extendedly.

3.3. Proximate parameters

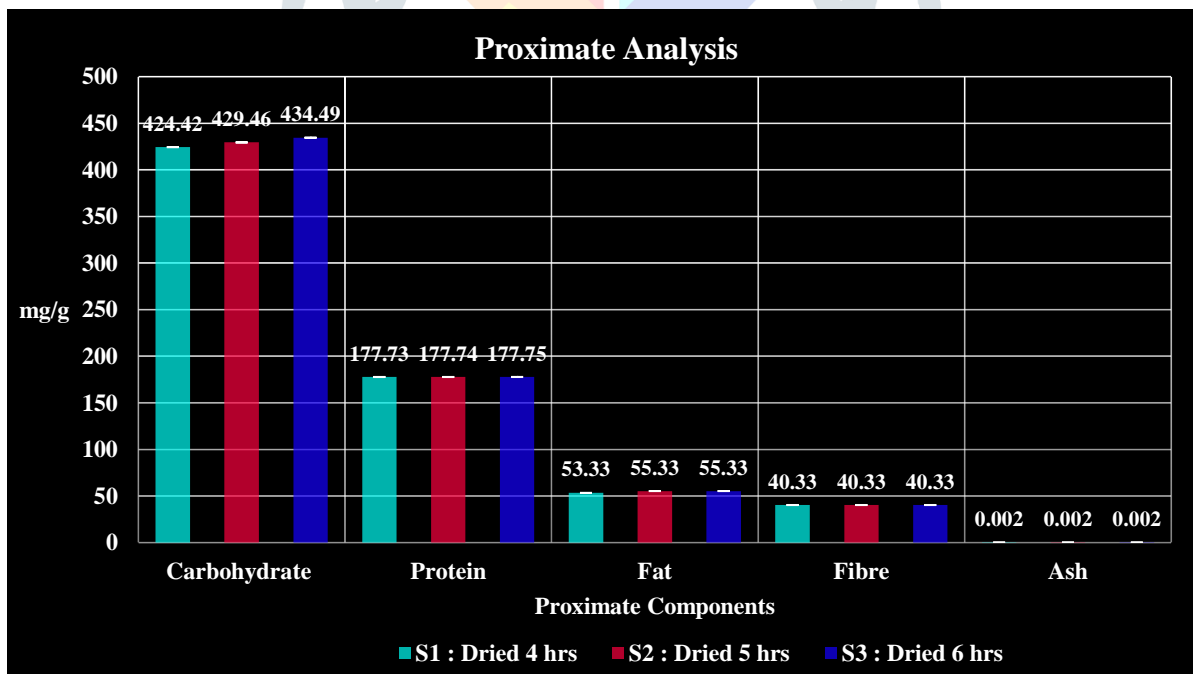**3.3.1. Carbohydrate, protein, fat, and fibre content of the noodle**

Figure 3.3.1: Effect of drying on the proximate components of the noodle

*N.B.: All the values are calculated as Mean ± SD at P<0.05 level based on triplicate data.

The above data **Fig. 3.3.1** corroborates that the longer drying time of the product exposes the viability of the proximate components. There is no significant variation of protein content concerning drying time due to the pertinent reason that without heat the protein cannot denature at all hence no loss of the initial content has been accounted for. 177.75±0.058 mg/g of protein is found in sample 3 which is evident for the other two also. The fat content is 55.33±0.05 mg/g for sample 3 which is more or less the same to sample 2 with 55.33±0.05 mg/g of fat. Thus drying for 5 and 6 hrs has no significant deviation in fat content. Moreover, the fibre content is 40.33±0.05 mg/g which is similar to that of sample 1 having 40.33±0.05 mg/g of fibre. Like these, sample 2 dried for 5 hrs resulted in 40.33±0.05 mg/g fibre which might have resulted due to uneven distribution of plant wall materials or some lower groups of oligosaccharides which breaks off during freezing with the ice crystals and evaporates on drying. This phenomenon is inevitable for all other proximate compounds

to some extent. There might be processing errors often which results in a concomitant loss in these components hence delivering unprecedented outcomes rather than an empirical approach. Besides the carbohydrate content is found at 434.49±0.05 mg/g in sample 3 compared to samples 1 and 2 having 424.42±0.03 mg/g and 429.46±0.04 mg/g carb respectively. This happens because during longer sublimation along with water other volatile organic compounds like lower alcohols, vinegar, and carboxylic acids ward off from the samples leaving only the complex polysaccharides and lipids behind. Thus up to 50.569 g of protein, 123.612 g of carbohydrate, and 15.748 g of fat are obtained from a single serving unit of the 284.5 g packet from 369 g of a concoction of sample 3. The total calorific value of this packet is 838.456 kcal experimentally whereas that of the ingredients initially formulated abiding USDA nutritive values (Gebhardt and Thomas, 2020) theoretically stands at 1000.40 (Table 3.2.1a). Thus there is no significant difference in the data from the range prescribed by RDI (RDA, 1989 and JWFEC, 2002). Ash content is somewhat similar for all three samples about 0.002±0.0005 mg/g. Drying has no significant effect on ash content i.e. the unburnt particles and inorganic metal atoms present. Thus all of them resulted in an equal volume of it. If enough calorie is consumed then the macro and micronutrient requirement can be compensated easily (Enrico, 2012). About 2800 kcal is consumed by actively working astronauts. The space shuttle astronauts consume about 2874 kcal/day (man) and 2160 kcal/day (woman) where protein intake is 12-15% within (Recommended Dietary Allowance (RDA) range (EG, 1999). Carbohydrates, protein, and fat provide major fuel to the astronauts up in microgravity to perform better than earth-based athletes and soldiers. Food and Agricultural Organisation (FAO) and World Health Organisation (WHO) have jointly standardized the physiological nutrient requirement for the ISS crew. Heavy working astronauts consume about 3490 kcal while typically working ones consume 3000 kcal (Shimada and Fujib, 2012). RDI and WHO charted values are actively followed by the ISS cabin crew. The pantry provides about 2100 kcal supplementation to the crew. Majorly three sections of food are there of which Safe Haven food provides exact 2000 kcal for a member to endure the critical period of 22 days during onboard failure. This special-purpose food is comprised of minimal weight and volume and stored at an ambient temperature of 18-26.7°C (Smith et al, 2020). Averagely an astronaut needs about 2500-3000 kcal per day to work efficiently (Cooper et al, 2011). About 50-55% of total kcal from carbohydrates, 12-15% of total kcal from protein, and 30-35% of that from fat is recommended by WHO whereas 45-65% of total kcal from carbohydrates (i.e. 130 g/day), 10-35% of total kcal from protein (i.e. 46-56 g/day) and 25-35% of total kcal from fat (i.e. 13-18 g /day) is recommended by RDI for astronaut (RDA, 1989 and JWFEC, 2002). Preservation of vegetables having high fibre content, high proximate compounds, minerals, vitamins, and antioxidants is of prior importance. They act as anticancer, antidiabetic, and antilipidemic agents (Jangam et al, 2010).
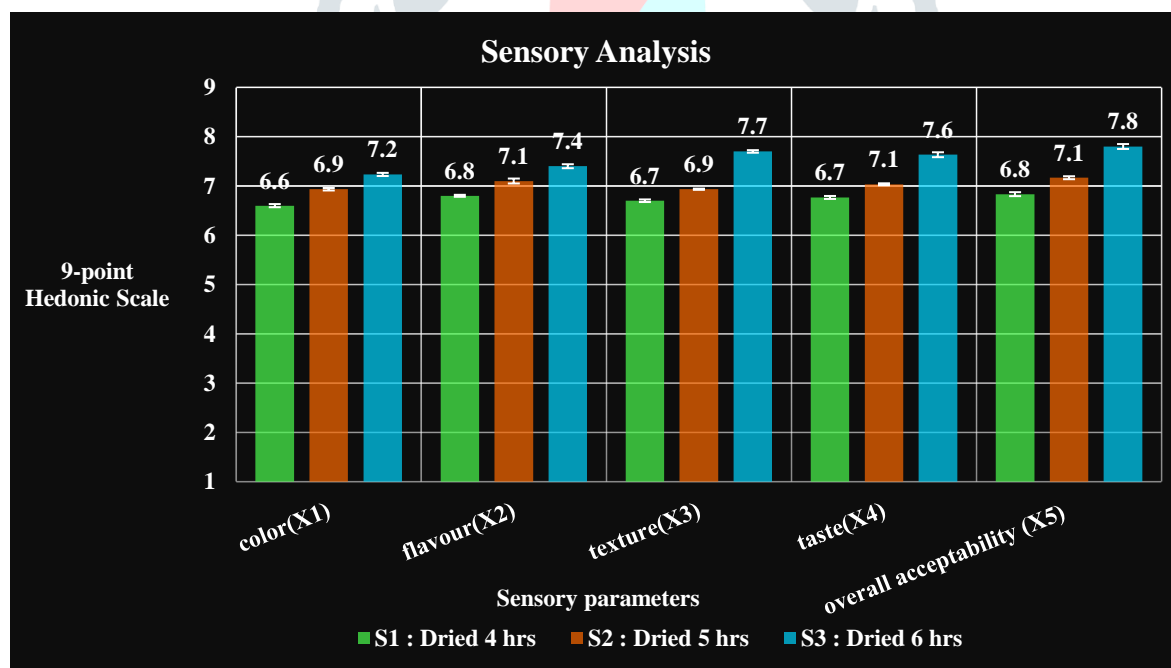
3.4 Sensory parameters

Figure 3.4: Effect of drying time on the sensory parameters of the noodle

*N.B.: All the values are calculated as Mean ± SD at P<0.05 level based on triplicate data.

Sensory evaluation has been done in the cross-sectional age range of Adolescence (10-18 yrs), Adult (19-59 yrs), and Senior Adult (>60 yrs) to have triplicate data mean demographically and hence cumulatively assess the population statistics of all the age range for each sample rationally having significant standard deviation among the age ranges which showed sample 3 to have the best texture and overall acceptability due to better mouthfeels compared to other ones as per **Fig. 3.4**. The mean result showed to have color, flavor, texture, taste, and overall acceptability of 7.2±0.03, 7.4±0.04, 7.7±0.026, 7.6±0.05, and 7.8±0.05 points of sample 3 calculated on a 9-point hedonic scale basis which is moderately likely due to better mouthfeels. Ready-to-eat products are nowadays manufactured by freeze-drying techniques. The process is advantageous for stability at room temperature, easy reconstitution, reduction of volume and weight, well-defined porous structure for rehydration, ease of sterile handling, etc. Retaining morphological, biochemical, immunological properties, volatiles, stoichiometric ratios, surface area, and reduced mass for easy storage, handling, and transportation. The food product is more acceptable in sensory values compared to other drying techniques (Ciurzynska

and Lenart, 2011). This process keeps irreversible changes in food products thus helping in forming high-value products (Kalantari). The-labile components are well guarded by this method. Major advantages are like preparing lightweight food, rapid reconstitution time, the product can be stored at ambient temperature without refrigeration, microbial spoilage is absent, and shrinkage or case hardening is also prevented. The most vital concept is during sublimation along with water other volatile organic compounds like lower alcohols, vinegar, secondary metabolites which are acidic, enzymes, cofactors, and inorganic wastes of plant cells vapourize leaving the components of interest behind. It also wards off pyrogens and particulates (Shukla, 2011). The ice state of water protects the plant tissue structure during the operation. The freeze-dried product has about 4-6 times higher rehydration ratio compared to air-dried ones making them widely acceptable for ready-to-eat, ready-to-cook, ready-to-serve. Shrinkage of food material due to freeze-drying is about (10-15)% compared to air drying which is about 80% All this makes the product dried for a longer duration acceptable overall in qualitative inclinations (Ratti, 2001).

3.5 Packaging parameters

Table 3.5: Packaging parameters of sample 3 finalized for shelf stability

Arithmatic Mean Diameter (cm)	**0.1067±0.003**
Geometric Mean Diameter (cm)	**0.9473±0.002**
Surface Area (cm^2)	**13.57±0.04**
Shape index	**0.384±0.01**
Sphericity	**9.473±0.02**
True Density (g/cm^3)	**0.616±0.015**
Bulk Density(g/cm^3)	**0.394±0.006**
Porosity (%)	**35.97±0.036**

*N.B.: All the values are calculated as Mean ± SD at $P<0.05$ level based on triplicate data.

3.6 Importance of freeze-dried food for astronauts

In microgravity, the peristalsis of the alimentary canal is interrupted therefore causing delayed metabolism. Inadequate calorie intake in long-term mission aboard ISS have been resulted from inadvertent radiation damage making food unpalatable and loss of water, muscle mass, and fat mass have resulted in weight loss in microgravity. The detrimental consequence of undernutrition is the deficiency of micronutrients and energy. Undernourishment has accompanied countermeasures like space anorexia. Underconsumption also led to a 20% deficit in Dietary Reference Intake (DRI) values of daily calorie intake. Moreover, microgravity and the ISS cabin environment alter the physiologies e.g. reduced flavor perception, redistribution of body fluid, gut microbiota, psychological processes, gustatory, olfactory, and auditory perceptions as well. This results in reduced calorie intake in sedentary or heavy exercise thus imbalances the metabolism (Taylor et al, 2020). These adversely affects the alimentary, gastrointestinal, nervous, and cardiovascular system. Thus potential risks of calcium loss from bones, kidney stones, vitamin C,D,K loss leading to brittleness, osteoporosis, paralysis, muscle loss leading to muscular atrophy, impairment of endocrine system leading to elevated levels of stress hormones like epinephrine, norepinephrine, cortisol, adrenocorticotrophin, increased blood plasma glucose and lipids in liver, elevated levels of catecholamines, renin-angiotensin leading to sodium extravasation and fluid accumulation, gastrointestinal problems like inflation, gas, indigestion, diarrhea, impaired cardiovascular functioning causing arrhythmia, cardiac muscle weakness, augmented oxidative stress due to increased lipid peroxidation, DNA damage due to lack of Vitamin C,E and trace elements, ophthalmic failure due to intracranial pressure, choroidal folds, retinal damage, optic disc edema, cornea flattening due to lack of Vitamin B12, B7, immune system failure due to too much free radicals in deficiency of antioxidants, impaired T-cell, B-cell, NK cell, cytokines, lymphocytes, antibody production due to lack of macronutrients, cofactors like vitamin B-12, vitamin C and omega-3-fatty acid have been inevitable (Enrico, 2012).

To mitigate these phenomena, food is supplied with nutrient-dense, shelf-stable for at least 5 years, fortified, preserved, vitamin supplemented, semi-processed, tertiary processed manner to provide sustainable health benefits for astronauts. But no freezer or refrigerator has been installed in ISS yet (Cooper, 2011). Having not enough room for a moderate-sized refrigerator on board the major concern lies with fresh food storage and spoilage in microgravity. Hence astronauts nowadays are sticking to freeze-dried and thermostabilized products for longer shelf stability (Carillo, 2020). The ISS is also lacking in sufficient energy supply to sustain a refrigerator hence fresh food is unappealing. Thus mass and volume of food need to be compromised for limited storage (Shimadaa, 2012). Thus freeze-drying stands to be the correct alternative for reduced weight and volume storable at an ambient temperature of 60-85°F(18-26.7°C). Hence vegetables, pulses, and cereals with high nutritive values of proteins, vitamins, minerals, and high phenolics, and flavonoids including potatoes, spinach, carrot, peanuts, cashews, broccoli, peas, beans, and rice are made rehydratable for astronauts (EG, 1999 and Carillo, 2020).

IV. CONSLUSION

Amelioration of lifestyle and habitation have paved newer dimensions of industrialization. The major economy of any country relies upon food. The advent of newer technologies and incessant research have helped to manufacture high value-added tertiary processed convenient products. A fast lifestyle requires healthy food, single-serving size, less consumption time, tasty and eco-friendly too. Hence to incorporate the aesthetics of cooked food and nutritive food consumption, the food ingredients are semi-processed, tertiary processed, and packed aseptically intending for long-term storage and handling. But semi-cooked like secondary processed and high value-added tertiary processed products possess

degradative threats in aseptic packaging conditions too when subjected to long-term storage. Thus drying the product stands to be the handsome technology to keep it fresh entirely. Freeze-drying and other hurdle drying technologies stand as the best opportunity alternative to the existing sun, oven, microwave, osmotic, tray, batch, and vacuum drying technologies in industries. This technique can store food products considerably without concomitant loss in native nutritive and sensory features. Higher calorie and vitamin content can mitigate the countermeasures faced due to microgravity in ISS and space shuttles thus providing balanced physiological and psychosocial aspects. Thus the right selection of ingredients is of non-negotiable importance. The noodle so developed with USDA dietary values conforms to the RDI and joint FAO/WHO standards mandated for astronauts. Freeze-drying the noodle could assist the qualitative inclinations for adequate food and its acceptability throughout extended storage for the safe-haven section providing 838.456 kcal for 12 hours at least from a single serving size of 284.5 g packet. Being a plant-based product, it is dehydrated easily with high final quality which is lighter for minimal storage and volume. Thus has better rehydration characteristics due to different dimensional approaches hence reliable packaging. The said could be stored for at least 270 days at normal atmospheric pressure of 760 mm Hg within ISS. The entire single-serving size gets easily reconstituted within 5 minutes only at 80℃ inside the LDPE bag. The said preservatives could be stored for an extended time without refrigeration inside ISS and space shuttle and also without biological or microbial spoilage due to the absence of external oil-dipping and flash drying. Moreover, the maximum quantity of antioxidants and functional components are preserved in the noodle by this method. Hence the medicinal aspects of the food imply well physiological regulation up in ISS microgravity. The mineral and nutrient deficiency could be compensated henceforth. The noodle retains the high quality of morphology, texture, and tissue matrices for better palatability with a spoon from the packet only hence mitigating the loss of time and effort of consuming multiple products onboard ISS for acquiring the requisite energy of a day. It could alleviate the myriad of consequences in an astronaut's body in microgravity conditions due to the presence of the best sources of nutrients and vitamins and is easier to make in lab-scale machines for more lots. This technology elucidates further its commercialization cost-effectively in the realms of food security and food inflation in the lacuna of psychosocial, physical, and habitual well-being not only for astronauts but also for ordinary civilians as well.

V. CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

VI. ACKNOWLEDGEMENT

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