"Optimization and shelf-life study of vegetables through different solar drying methods"

Summary

Submitted to

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Lucknow

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BHIMRAO
AMBEDKAR
UNIVERSITY
LUCKNOW
प्रज्ञा शील करुणा
ESTABLISHED 1996

For the award of the degree of

Doctor of Philosophy in Home Science

(Human Development and Family Studies)

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Enrolment no-1077/17

2023

Summary

Fruits and vegetables are both major food products in their own right and key ingredients in many processed foods (Jongen, 2007). They are of greater nutritional importance since they make a significant contribution in supplying wealth of essential vitamins, minerals, antioxidants, fibre and carbohydrate that improve the quality of the diet (Barrett, 2007). Fruits and vegetables are also important components of a healthy diet and their sufficient daily consumption has been strongly associated with reduced risk of some major diseases such as cardiovascular, diabetes, hypertension, and certain types of cancer (Bazzano et al., 2002). studies about the drying process are fundamental to provide increasingly a wider variety of fruits and vegetables with extended shelf life and with appreciable quality (Brasil and Siddiqui, 2018). Chou and Chua (2001) reported that, nowadays, drying process research is mainly focused on its intensification. The drying process intensification should involve the mass transfer enhancement, which is related to energy consumption and cost reduction, together with the final quality of the product. In the literature, there have been significant developments in using novel techniques in the drying of agricultural crops in terms of pre-treatment or in combination with conventional techniques that will increase process efficiency and enhance the quality of the final dried products (Onwude, Hashim, and Chen, 2016). Solar drying has been used for the drying of vegetables (fruity and leafy), fruits, plants, seeds, fish, meat, wood and some forest, agricultural products. With the intention of benefit from the free and renewable energy sources provided by the sun, a number of efforts have been made in recent years to develop solar drying mainly for preserving fruits; vegetables and forest products. However, there are limitations for large-scale production through open-air drying. The limitations are the lack of skill to control the drying process, possible degradation due to microbiological or biochemical reactions, insect infestation, large area requirement and moderate labour costs. The required time for drying of a given material can be fairly long and result in post-harvest losses (more than 30 %).

Keywords – Solar Dry, Sun Dry, Antimicrobial, Vegetables, Shelf Life

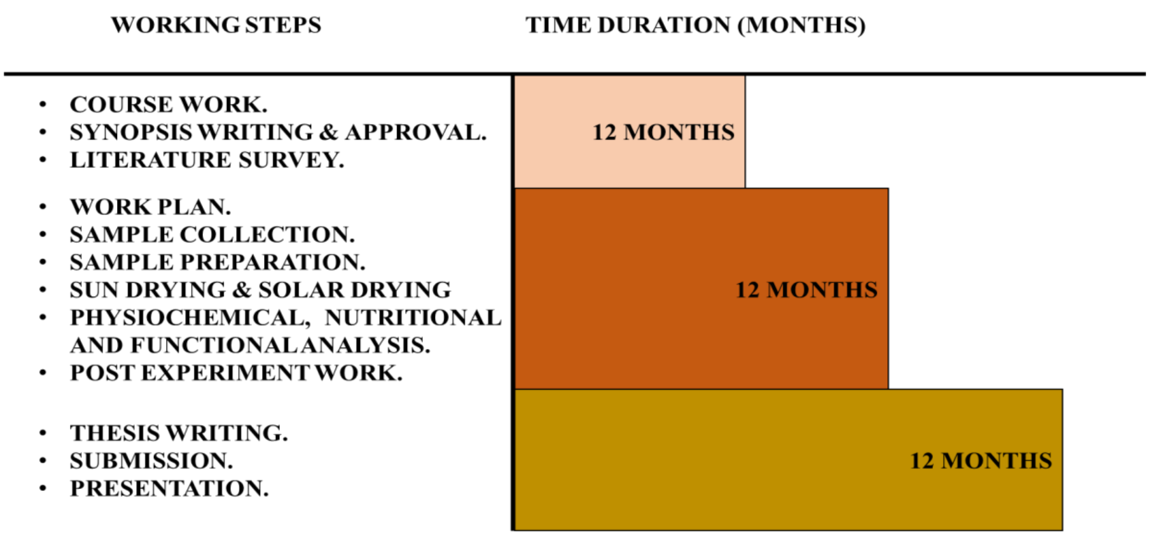
Objectives

- To examine nutritional and functional property of selected vegetables.
- To characterized solar dried vegetables on their nutritional and physio chemical properties.
- To evaluate dried vegetable colour by using UV-Visible Spectrophotometry.
- To study morphology of solar dried vegetables by using SEM and XRD.
- To examine microbial activity for shelf-life study of solar dried vegetables.
- To prepare packaging kit and create awareness among community people for acceptability of solar dried vegetable.

Methodology –

3.2. Period of the study

The total period of work was of 4 years in the starting and extensive literature review of the study was done by going through various papers in journals and online publications. The current research took place over the course of a year, from October 2020 to March 2021. The work was split into three phases over the course of its duration.



The present study was an experimental study. The current research was carried out using a various parameters to conceptualized phases of experiment work. These are:

1. Sample collection and preparation.

Cauliflower/ tomato/spinach/chinopodium/fenugreek

2. Sample drying by sun drying and solar drying.

SD-500 Solar Drier

3. Nutritional properties of raw and dried samples.

Iron/Calcium/B-carotene/Protein/Fat

4. Functional properties of raw and dried samples.

Water absorption /Water solubility index/Hydration capacity/Hydration index/Swelling capacity/Swelling power

5. Proximate analysis

Yield/pH/Moisture/Pigment/Ash

6. Microbial activities

Antibacterial activities/Antibiogram activities

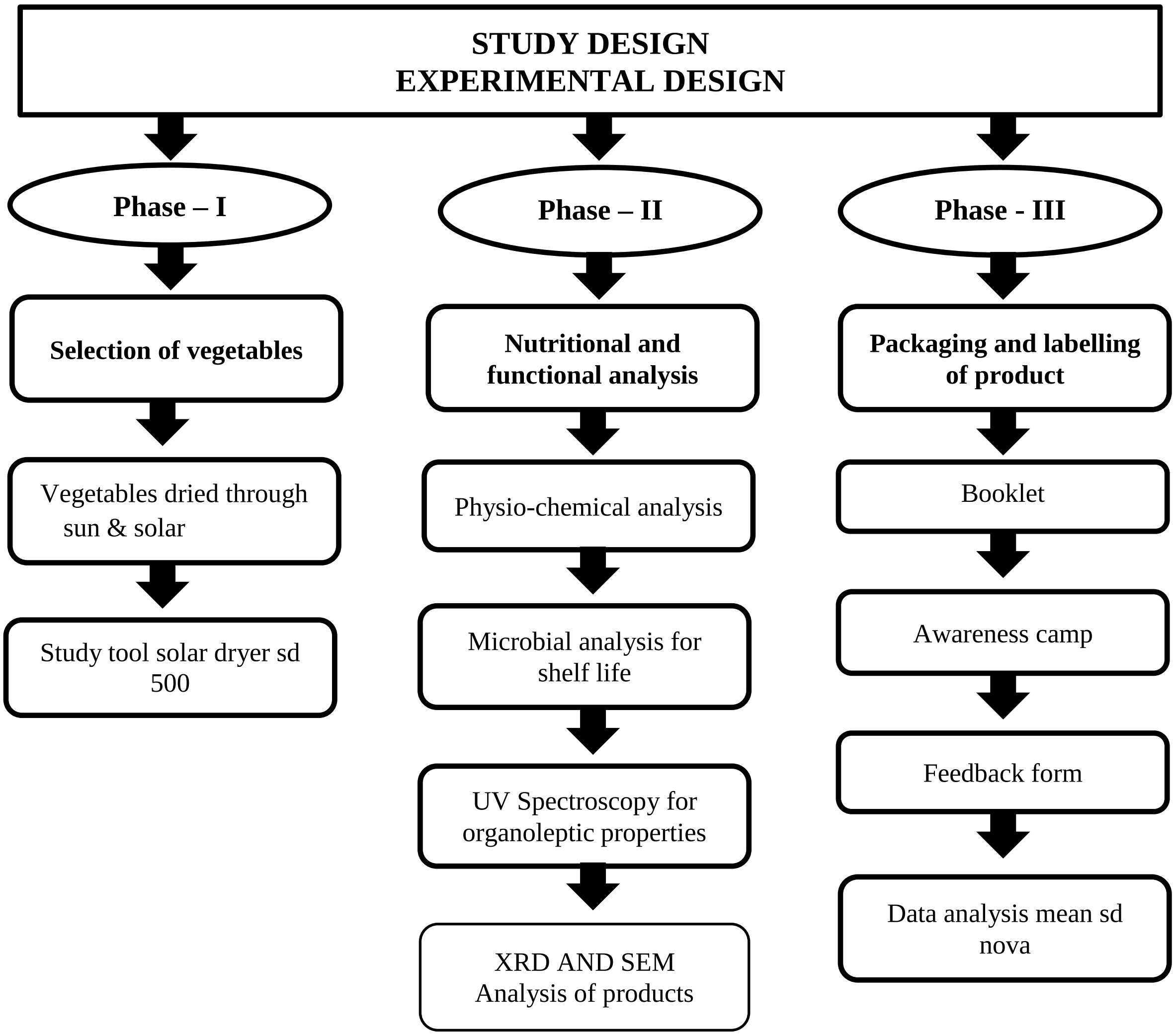
7. Organoleptic properties

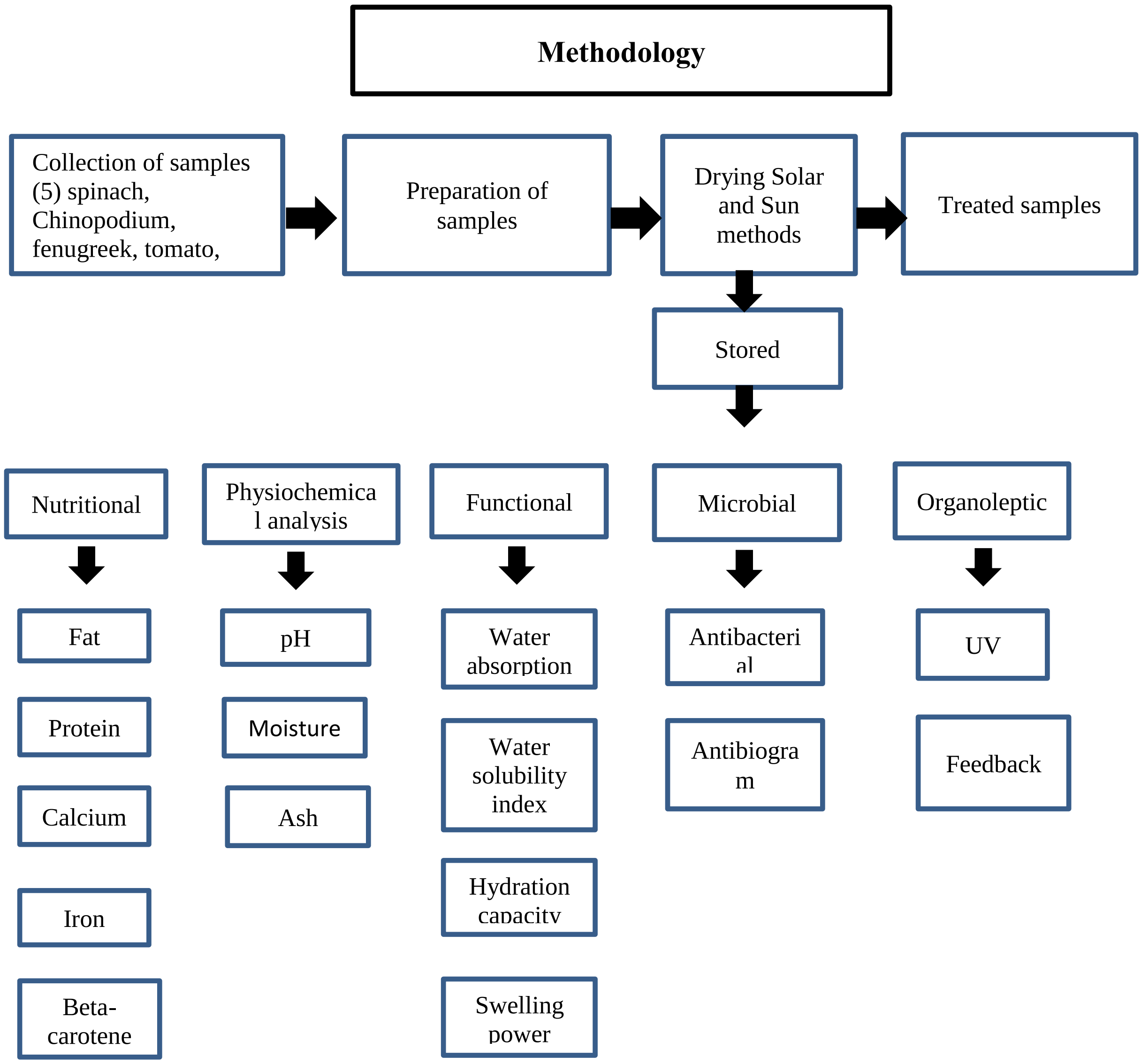
XRD for texture analysis/UV spectroscopy for colour analysis

8. Packaging.

SEM for morphological study/Moisture

The experiments were conducted to examine the nutritional properties of selected vegetables pre & post using the drying method. Also, to determine and compare functional properties of fresh vegetable versus dried vegetables in both the laboratories according to the requirement and the feasibility of the study. The conceptual experimental design were divided in three phases of study.


STUDY DESIGN
EXPERIMENTAL DESIGN
Phase – I
Phase – II
Phase - III
Selection of vegetables
Vegetables dried through sun & solar
Study tool solar dryer sd 500
Nutritional and functional analysis
Physio-chemical analysis
Microbial analysis for shelf life
UV Spectroscopy for organoleptic properties
XRD AND SEM Analysis of products
Packaging and labelling of product
Booklet
Awareness camp
Feedback form
Data analysis mean sd nova



RESULTS

All methods of drying found to significantly ($p<0.05$) lower fat, protein, chlorophyll, carotene, in compare to their fresh samples. In respect to density the bulk density and true density was quite low in sundried vegetable samples relative to solar dried vegetable samples. Fat level, protein content, carotene level, chlorophyll level, were seen reduced in sun dried vegetable samples rather than solar dried. Good antibacterial properties were also seen in solar drying vegetable samples in relative to sundry. Solar drying may be preferred method of drying the vegetable samples, as it is faster more hygienic preserve the nutrients better.

Five samples were collected namely, Spinach (*Spinacia oleracea)*, Fenugreek (*Trigonella foenum graecum)*, Cauliflower (*Brassica oleracea)*, tomato (*Solanum lycopersicum*), chenopodium (*Chenopodium album*) from vegetable market, Gomti Nagar

Lucknow, India. The research was done at Department of Biochemistry, MRD LifeSciences Pvt. Ltd., Gomati Nagar Lucknow, India.

Nutritional and functional property of selected vegetables.

- The moisture content of the fresh vegetables was 65.233, 89.800, 92.900, 97.600 and 66.467 % for spinach, fenugreek, cauliflower, tomato and chenopodium, respectively. The moisture content of the sun-dried vegetables was 3.853, 72.300, 55.373, 73.250 and 16.233 % for spinach, fenugreek, cauliflower, tomato and chenopodium, respectively. The moisture content of the solar dried vegetables was 8.457, 76.800, 62.827, 82.867 and 17.767 % for spinach, fenugreek, cauliflower, tomato and chenopodium, respectively. There was significant ($p<0.05$) difference in their moisture content. The maximum moisture content varies between individual vegetables because of their structural differences.
- Outcomes displayed that samples treated with sundry have less moisture content while samples treated with solar dry have enough content of moisture. There was a significant ($p < 0.05$) variation in moisture reduction between sundry and solar dry. In Spinach & Chenopodium, level of moisture was reduced after drying in respective to fresh sample. In compare to fresh and sun dry solar dried samples has highest decreased level of moisture.
- Protein content of the fresh vegetables was 60.00, 11.527, 35.737, 2.867 and 30.413% for spinach, fenugreek, cauliflower, tomato and chenopodium, respectively. Protein content of the sun-dried vegetables was 30.733, 4.250, 20.850, 1.090 and 16.963% for spinach, fenugreek, cauliflower, tomato and chenopodium, respectively. Protein content of the solar dried vegetables was 40.507, 5.120, 25.267, 1.493 and 16.963% for spinach, fenugreek, cauliflower, tomato and chenopodium, respectively. Both sundry and solar dry systems have reduced protein level in all treated sample in respect to fresh samples. Sundry method has highly reduced the protein content in treated sample rather than solar dry. Solar dried spinach had protein content significantly higher ($p<0.05$) than other vegetables while sun dried tomato had the least protein content.
- Fat content of the fresh vegetables was 1.200, 2.273, 7.150, 2.717 and 24.55% for spinach, fenugreek, cauliflower, tomato and chenopodium, respectively. Fat content of the sun-dried vegetables was 0.363, 0.937, 5.317, 1.100 and 5.013% for spinach,

fenugreek, cauliflower, tomato and chenopodium, respectively. Fat content of the solar dried vegetables was 0.439, 1.270, 5.710, 1.100 and 5.130% for spinach, fenugreek, cauliflower, tomato and chenopodium, respectively. Fat content ranged from 0.363-7.150% with dried cauliflower recording significantly higher ($p< 0.05$) was recorded in the fat content of dried spinach, fenugreek, tomato and scent chenopodium.

- These results are higher than the fat content of sun-dried spinach, fenugreek, cauliflower, tomato and chenopodium. The fat content of sun-dried tomato is similar to the fat content of solar dried tomato. Data demonstrated that sundried samples have low fat content in relative to solar dried.
- Ash content of the solar dried spinach (17.633%) and cauliflower (7.800%) were significantly ($p < 0.05$) higher than that of chenopodium (5.333%), fenugreek (3.333%) and tomato (2.003%). These values were high when compared to the ash content of sun-dried spinach (16.057%), cauliflower (6.573%), chenopodium (4.313%), fenugreek (3.233%) and tomato (1.013%). Maximum percentage of ash was achieved from sample treated with solar dry in relative to sundry. It was also higher than the ash content of dried cauliflower (5.98%).
- Obtained results depicted that sundry vegetable samples have low iron level while sample dried in solar dryer have high iron content in comparative to sundry. In spinach, cauliflower & tomato slightly variation of iron level was seen, but in Fenugreek, chenopodium huge effect of drying system on iron level was observed. Iron concentration was higher in all the vegetables and even crossed the permissible limits.
- The chemical analysis of iron content in fresh fenugreek leaves show maximum amount (40.483 ± 0.247 mg/100 gm) whereas its content in cauliflower is lower (1.353 ± 0.084 mg/100 gm). The content of iron in the fresh vegetable samples were in the order of fenugreek>spinach>chenopodium>tomato>cauliflower. The variation in concentration of iron in vegetable samples may be as a result of variation in absorption ability of iron from soil, water and atmosphere.
- Five vegetable samples were dried under the sundry and solar dryer. Outcomes illustrated that among the all-vegetable sample's calcium level went down under sundry relative to solar dry. The results of Ca2+ concentrations in the samples analysed is presented in Fig 4.3.2.6, from the results of the analysis, it was found that the mean concentration of calcium in fresh vegetables was found to be 3503.667 ± 3.786 mgdm-3 for spinach which is higher than 201.267 ± 0.306 mgdm-3 for

fenugreek, 86.700 ± 1.411 mgdm-3 for tomato, 28.633 ± 0.351 mgdm-3 for cauliflower and 14.333 ± 0.351 mgdm-3 .

- The mean iron concentration of sun-dried vegetables was found to be 2989 ± 5.568 mgdm-3 for spinach which is higher than 72.300 ± 0.436 mgdm-3 for fenugreek, 83.833 ± 0.666 mgdm-3 for tomato, 21.333 ± 0.379 mgdm-3 for cauliflower and 13.517 ± 0.275 mgdm-3 for chenopodium. The mean iron concentration of sun-dried vegetables was found to be 2999 ± 1.000 mgdm-3 for spinach which is higher than 79.503 ± 0.295 mgdm-3 for fenugreek, 85.467 ± 0.643 mgdm-3 for tomato, 25.533 ± 0.551 mgdm-3 for cauliflower and 14.200 ± 0.262 mgdm-3 for chenopodium. This may be due to a number of factors that influence the concentration of mineral elements on and within plants, these factors include climate, atmospheric deposition, nature of soil on which the plant is grown, irrigation with waste water.
- Outcomes depicted that both solar dry and sundry systems have lowered the bulk density in all treated samples. In comparative to solar dry, sundry has highly reduced the bulk density. In spinach, fenugreek and cauliflower the reduction level of bulk density was less while high reduction in bulk density was seen in Chenopodium and tomato. The variation in bulk density was significant at a significance level of 0.05.
- Results inferred that on drying under sundry and solar dry, true density was brought down in all treated samples. In comparison to solar dry, sundry has highly reduced the true density. In chenopodium true density reduction level was seen very low. In spinach and fenugreek, high reduction of true density was observed and in cauliflower and tomato, moderate reduction of true density was seen. The bulk and true density of vegetables definitely vary with decreasing moisture content. Therefore, porosity values of each sample are also variable.
- Outcomes displayed that samples treated with sundry have less moisture content while samples treated with solar dry have enough content of moisture. There was a significant ($p < 0.05$) variation in moisture reduction between sundry and solar dry. In Spinach & Chenopodium, level of moisture was reduced after drying in respective to fresh sample. In compare to fresh and sun dry solar dried samples has highest decreased level of moisture.
- Protein content of the fresh vegetables was 60.00, 11.527, 35.737, 2.867 and 30.413% for spinach, fenugreek, cauliflower, tomato and chenopodium, respectively. Protein content of the sun-dried vegetables was 30.733, 4.250, 20.850, 1.090 and 16.963% for

spinach, fenugreek, cauliflower, tomato and chenopodium, respectively. Protein content of the solar dried vegetables was 40.507, 5.120, 25.267, 1.493 and 16.963% for spinach, fenugreek, cauliflower, tomato and chenopodium, respectively. Both sundry and solar dry systems have reduced protein level in all treated sample in respect to fresh samples. Sundry method has highly reduced the protein content in treated sample rather than solar dry. Solar dried spinach had protein content significantly higher ($p<0.05$) than other vegetables while sun dried tomato had the least protein content. Protein is an essential component of human diet needed for the replacement of tissue and for the supply of energy and adequate amount of required amino acid. Protein deficiency causes growth retardation, muscle wasting, oedema, abnormal swelling of the body and collection of fluid in the body of children.

- Fat content of the fresh vegetables was 1.200, 2.273, 7.150, 2.717 and 24.55% for spinach, fenugreek, cauliflower, tomato and chenopodium, respectively. Fat content of the sun-dried vegetables was 0.363, 0.937, 5.317, 1.100 and 5.013% for spinach, fenugreek, cauliflower, tomato and chenopodium, respectively. Fat content of the solar dried vegetables was 0.439, 1.270, 5.710, 1.100 and 5.130% for spinach, fenugreek, cauliflower, tomato and chenopodium, respectively. Fat content ranged from 0.363-7.150% with dried cauliflower recording significantly higher ($p< 0.05$) was recorded in the fat content of dried spinach, fenugreek, tomato and scent chenopodium. These results are higher than the fat content of sun-dried spinach, fenugreek, cauliflower, tomato and chenopodium. The fat content of sun-dried tomato is similar to the fat content of solar dried tomato. Data demonstrated that sundried samples have low fat content in relative to solar dried.
- Ash content of the solar dried spinach (17.633%) and cauliflower (7.800%) were significantly ($p < 0.05$) higher than that of chenopodium (5.333%), fenugreek (3.333%) and tomato (2.003%). These values were high when compared to the ash content of sun-dried spinach (16.057%), cauliflower (6.573%), chenopodium (4.313%), fenugreek (3.233%) and tomato (1.013%). Maximum percentage of ash was achieved from sample treated with solar dry in relative to sundry. It was also higher than the ash content of dried cauliflower (5.98%) as reported by Baloch et al. (2015). Ash content in food is an indication of the presence of minerals and dried spinach, cauliflower and chenopodium could be considered as valuable sources of

minerals for alleviating micronutrient deficiency related to minerals in human nutrition.

- Obtained results depicted that sundry vegetable samples have low iron level while sample dried in solar dryer have high iron content in comparative to sundry. In spinach, cauliflower & tomato slightly variation of iron level was seen, but in Fenugreek, chenopodium huge effect of drying system on iron level was observed. Iron concentration was higher in all the vegetables and even crossed the permissible limits (Table 4.3.2.5 and Figure 4.3.2.5). The chemical analysis of iron content in fresh fenugreek leaves show maximum amount (40.483 ± 0.247 mg/100 gm) whereas its content in cauliflower is lower (1.353 ± 0.084 mg/100 gm). The content of iron in the fresh vegetable samples were in the order of fenugreek>spinach>chenopodium>tomato>cauliflower. The variation in concentration of iron in vegetable samples may be as a result of variation in absorption ability of iron from soil, water and atmosphere. Deficiency of iron is one of the most common non-communicable diseases that needs urgent, effective and corrective measures. Reports indicate that it is the major health challenge and the common nutrient deficiency which is prevalent across the globe and in which the world is facing. In addition, cognitive performance and physical growth of most children is greatly influenced by the amount of iron content in the food they consumed.
- In the bathua cauliflower. tomato, the fluctuations were not essential – from 8.99 ±0.60 7, 13.77 ±1.67, 15.47 ±1.38 mass %.
- The concentration of P was detected 9.13 ±1.18, 7.91 ±1.47, 14.35 ±1.10, 8.85 ±1.49, 8.85 ±1.49, 12.61 ±1.34 mass % at average in bathua, couliflower, methi, spinach, tomato wherein in the ash of methi the proportion of P is more than all vegetable.
- In vegetables the concentration of Mg has close values 2.56 ±0.15, 2.96 ±0.09, 3.39 ±0.10, 6.87 ±0.1, 2.88±0.245 mass % in bathua, cauliflower, methi spinach and tomato respectively orderly.
- The WAC of the spinach ranged from 1.27 – 2.596 gH20/sample, for the fenugreek samples it ranged from 0.25 – 1.78 gH20/sample, for the cauliflower samples it ranged from 1.53 – 9.36 gH20/sample, for the tomato samples it ranged from 9.3 – 0.11 gH20/sample and the chenopodium samples ranged from 0.66 – 1.79 gH20/sample.

- The vegetable powders exhibited high swelling index on solar drying. The results of the analysis of variance (ANOVA) at 0.05 level of significance, reveal significant differences in the % swelling index among the vegetables.
- Results obtained from experiments depicted that samples dried under the sun have lower hydration capacity while samples dried under the solar dryer have high hydration capacity. Chenopodium has high hydration capacity while tomato has lowest hydration capacity among the all-treated samples.
- The concentration of 14 basic elements (in mass %) contained in the vegetable’s mineral part was studied. Herewith the main proportion of the ash elements in the seeds belongs to Ca. Ca takes part in the processes of living organisms’ growth and development, goes into the composition of coenzymes and cells nucleuses, it also takes part in the most important processes for the organism such as metabolism, immunity, regeneration and others
- Our experimental results inferred moisture level is highly reduced in sundry rather than solardry. Angle of repose also depends on moisture level. It is clear from experiments that angle of repose is high in solar dry sample due to high moisture content in comparison to sundry sample
- Effects of drying process on swelling capacity of treated samples. Results depicted that sundried treated samples have low swelling capacity while solar dried samples have high swelling capacity. Among the all samples, Cauliflower has highest swelling capacity while tomato has lowest swelling capacity.
- Impact of drying procedures on swelling index of treated vegetable samples. Outcomes elaborated that samples dried under the solar dryer have high swelling index while samples dried under sundry have low swelling index.
- Outcomes of influence of drying systems on water absorption capacity. Obtained data inferred that samples those are dried in solar dryer have high water absorption capacity while samples dried under sun have low water absorption capacity. Tomato has high water absorption capacity among the all samples.
- Influence of drying process on hydration capacity. Results obtained from experiments depicted that samples dried under the sun have lower hydration capacity while samples dried under the solar dryer have high hydration capacity. Chenopodium has high hydration capacity while tomato has lowest hydration capacity among the all treated samples.

- Effect of drying systems on bulk density. Outcomes depicted that both solar dry and sundry systems have lowered the bulk density in all treated samples. In comparative to solar dry, sundry has highly reduced the bulk density. In spinach, fenugreek and cauliflower the reduction level of bulk density was less while high reduction in bulk density was seen in Chenopodium and tomato.
- Influence of drying process on true density. Results inferred that on drying under sundry and solar dry, true density was brought down in all treated samples. In comparison to solar dry, sundry has highly reduced the true density. In chenopodium true density reduction level was seen very low. In spinach and fenugreek, high reduction of true density was observed and in cauliflower and tomato, moderate reduction of true density was seen.
- Action of drying system on moisture content in treated sample with sundry and solar dry. Outcomes displayed that samples treated with sundry have less moisture content while samples treated with solar dry have enough content of moisture. In Spinach & Chenopodium, level of moisture was reduced after drying in respective to fresh sample.
- Influence of drying system on Ash content. Maximum percentage of ash was achieved from sample treated with solar dry in relative to sundry.
- Impact of drying process on fat quantity in dried samples. Data demonstrated that sundried samples have low fat content in relative to solar dried
- Action of drying process on protein content. Both sundry and solar dry systems have reduced protein level in all treated sample in respect to fresh samples. Sundry method has highly reduced the protein content in treated sample rather than solar dry.
- Vegetable samples were processed under the sun and solar drying system, vitamin concentration was detected. Outcomes depicted that in spinach & cauliflower, solar dryer has slightly reduced the vitamin level in comparison to sun dry. In Fenugreek, sundry sample has less vitamin concentration while solar dry sample has higher vitamin concentration in contrast to sundry. In tomato, very moderate effect was seen in level of vitamins and in chenopodium solar dryer bring down the level of vitamins in relative to Sundry.
- Influence of drying methods on quantity of Calcium. Five vegetable samples were dried under the sundry and solar dryer. Outcomes illustrated that among the all-vegetable sample’s calcium level went down under sundry relative to solar dry.

- Consequence of drying system on concentration of iron. Obtained results depicted that sundry vegetable samples have low iron level while sample dried in solar dryer have high iron content in comparative to sundry. In spinach, cauliflower & tomato slightly variation of iron level were seen, but in Fenugreek, chenopodium huge effect of drying system on iron level was observed.
- Five different samples were treated with solar dryer and under the sun, after the treatment carotene level were determined and it was found that carotene level was reduced under the sun dry in comparative to solar dry among the all-vegetable samples. Changes in β-carotene content of dried vegetables are presented in table 4.1.1.8. Initial carotene content was higher in solar dried vegetables than sun dried products. A steady loss in β-carotene content was observed with increase in storage time and losses were higher in ambient condition. Retort vaccum packaging reduced losses of β-carotene and in both type of sun dried and solar dried vegetables respectively packed in retort pouches retained statistically higher β-carotene throughout the storage. Retention of β-carotene was higher in cauliflower.
- Five vegetable samples were dried under the sundry and solar dryer. Outcomes illustrated that among the all-vegetable sample’s calcium level went down under sundry relative to solar dry. The results of Ca2+ concentrations in the samples analysed is presented.
- Collected all-vegetable samples were processed under the sun and solar drying system, vitamin concentration was detected. Outcomes depicted that in spinach & cauliflower, solar dryer has slightly reduced the vitamin level in comparison to sun dry. In Fenugreek, sundry sample has less vitamin concentration while solar dry sample has higher vitamin concentration in contrast to sundry. In tomato, very moderate effect was seen in level of vitamins and in chenopodium solar dryer bring down the level of vitamins in relative to Sundry. There was a continuous decline in ascorbic acid during storage. In general, ascorbic acid content was not significantly affected by drying, storage and packing conditions in all the vegetables. Higher ascorbic acid retention in solar dried products may be due to less time taken in drying of the products.

Characterized solar dried vegetables on their nutritional and physico-chemical properties.

- Samples were treated with solar dryer and under the sun, after the treatment carotene level were determined and it was found that carotene level was reduced under the sun dry in comparative to solar dry among the all-vegetable samples.
- In spinach & chenopodium pH was slightly elevated when treated in solar dry, in tomato, cauliflower and fenugreek pH was slightly reduced in relative to fresh samples. Among the all-treated samples, pH was high in solar dry in comparative to sundry. These findings illustrate that drying process lowers the hydrogen ion concentration in vegetable. Our findings are in agreement with that vegetables and fruits contains pH range from 4.0-6.2 units and the drying process influenced more in lowering pH content thus decreased when compared to fresh vegetables. Our findings are further authenticated that vegetables contain natural pH which is near to normal pH. Having normal pH indicates more suitability of the edible vegetables when intake does not affect the body pH. Our findings are significantly impact of pH on solar dried samples.
- It was observed that samples dried under the sun have lower angle of repose in comparison to solar dry. Cauliflower has high angle of repose among the all-vegetable samples. The angle of repose is a characteristic of bulk material that indicates the cohesion among the individual vegetables and the surface layer of moisture surrounding the individual vegetables holding the aggregates together by the surface tension. The solar dried showed significant impact on samples cauliflower, tomato compare to sun dried samples.
- Data inferred that among all vegetables maximum product yielding was seen in solar dry rather than sundry. Maximum product yielding was achieved in chenopodium. Fenugreek, Cauliflower, Spinach and tomato showed less product yielding showed in
- Chlorophyll is a group of compounds responsible for colour (such as green) intensity of plants (Rubinskiene et al., 2015). It shows the colour intensity of samples. Colour of vegetables of solar dried samples far better from sun dried samples. It shows highest impact of colour on green leafy vegetables. The results show that drying has a

significant impact on chlorophyll retention, however, the level of retention varied for each of the vegetable.

- The results depicted that the total chlorophyll content of the vegetables was 206.440, 198.117, 417.787, 45.593 and 750.767mg/1000g for fresh spinach, fenugreek, cauliflower, tomato and chenopodium respectively. For the sun dried vegetables, the total chlorophyll contents were 182.020, 176.083, 159.930, 15.713 and 508 mg/1000g for dried spinach, fenugreek, cauliflower, tomato and chenopodium respectively.
- Swelling power is a significant characteristic of high-quality powder. Swelling power in the solar dried ranged from 2.233 for the spinach to 12.223 for the chenopodium. There were significant differences in swelling power among sun dried and solar dried vegetables. The chemical composition and structural characteristics of the vegetables are having a major role in the kinetics of moisture uptake. Water may be trapped in the capillary structures of the fiber due to surface tension strength and could react with the molecular structure of fiber through hydrogen bonding or dipole forms. Other research work has also proven that the solar drying technique helps to improve. This property represents evidence of interaction between the amorphous and crystalline areas.
- Solar dried chenopodium had significantly ($P < 0.05$) higher hydration index followed by solar dried fenugreek and spinach. Sun dried fenugreek and tomato, had the minimum hydration index. Solar dried vegetables have the best proximate compositions because their hydration index is high and hence, they require less cooking time and should be preferred by food processors. Hence these dried vegetables have potential for incorporating in weaning mixtures and supplementary foods so as to combat the problem of malnutrition in developing countries.
- Comparative analysis of effect of drying system on angle of repose of treated samples. It was observed that samples dried under the sun have lower angle of repose in comparison to solar dry. Cauliflower has high angle of repose among the all-vegetable samples.
- Impact of drying system on product yielding. Data inferred that among all vegetables maximum product yielding was seen in solar dry rather than sundry. Maximum product yielding was achieved in chenopodium, Fenugreek, Cauliflower, Spinach, tomato showed less product yielding.

- Effect of drying on pH. In spinach & chenopodium pH was slightly elevated when treated in solar dry, in tomato, cauliflower and fenugreek pH was slightly reduced in relative to fresh samples. Among the all treated samples, pH was high in solar dry in comparative to sundry.
- Effect of drying system on chlorophyll concentration. Results elaborated, sundry reduce the chlorophyll level among the all treated samples in comparison to solar dry. Chenopodium has high chlorophyll level while tomato has less content of chlorophyll.

Dried vegetable colour by using UV-Visible Spectrophotometry.

- The UV Visible spectra of sun dried and solar dried samples described the presence of different phytochemicals which are responsible for their specific function.
- From the examined values of absorbance in sun dried and solar dried vegetable sample shows the presence of different pigments. Solar dried samples contains more plant pigment than the sun dried samples. Thus solar dried samples plays vital role in the daily operation of the body.

Morphology and crystallinity of solar dried vegetables by using SEM and XRD.

- The X-ray diffractometer (D8 Advance Eco X-ray diffractometer, Bruker Germany) was used to record the diffraction pattern. . The diffraction pattern shows well defined and the observed relative intensity peaks confirms the good crystalline nature and two amorphous nature that results for good texture analysis. The peaks positioned at 2Θ values (in degree) for Fig. 4.4.1.1 (I) (a,) of 26.68, 30.82, 50.28, 60, 68, (Fig. b) 26, 29,30 (Fig. c) 21, 26.30, 27.83, 36.5, 42.27, 50.51, 55, 57.6, (Fig. d) 14.7, 18.20, 24, 26, 28, 29, 31 and (Fig. e) 20.71. Due to the disordered arrangement of the molecules, which results in scattered bands, the diffused curve demonstrates that the two samples were amorphous in nature. The materials' organic, amorphous nature is revealed by the grinding. All five of the samples' curves were found to be quite similar.

- Elements such as carbon, oxygen, sodium, potassium, iron, magnesium, aluminium and silicone were detected in the samples by the method of energy dispersive spectrometry (ESD) on the analytical raster electron microscope JEOL JSM 6090 LA. The microscope resolution was at 4 nm at accelerating voltage 20 kV (secondary electrons image), zooming was from x 10 till x10000. While performing the elemental analysis the working distance (WD) was 10mm. Energy-dispersive spectrometer allows to carry out the quantitative X-ray microanalysis with the desired analyzing area: in a point or areally, and to receive the maps of elements allocation. X-ray microanalysis data are presented in the form of standard protocols which contain the microstructure picture of the sample under study, the table of the data in weighting and atomic correlation, spectra and histograms. Platinum was also detected as it was used as conductive material for the analysis. The percentage of mass of each element is shown in the result.

- The *Chenopodium album, Brassica oleracea, T.F. graecum, Spinacia oleracea* and *Solanum lycopersicum* powder surface morphology study indicated varied shaped particles with agglomerated cluster-like morphology. The SEM reveals that the drying procedure altered the micrograph of the leaves. Figure 4.3.1.8 (d) shows the micrographs of *Spinacia oleracea* powder. According to the images, porous, amorphous, and continuous zones have been obliterated. The sample of spinach exhibited disintegrated intercellular connections and damaged tissue structures with a shattered cell wall. The amorphous structure of the powder considerably improves its solubility with solvents, hence increasing its bioavailability.

5.5 Microbial activity for shelf-life study of solar dried vegetables.

- Results, after experiments concluded that in solar dried spinach has good antibacterial properties against *Bacillus subtilis* & *Klebsiella pneumonia* while against *Salmonella typhi,* has low antibacterial activity. Spinach dried under sundry has reduced antibacterial properties against *Bacillus subtilis* & *Klebsiella pneumonia* while against *Salmonella typhi,* has elevated antibacterial activity. In fenugreek, dried in solar dryer has good antibacterial properties against *Klebsiella pneumonia* while against *Bacillus subtilis* & *Salmonella typhi,* has lower antibacterial activity. Fenugreek dried under sundry has good antibacterial properties against *Klebsiella pneumonia & Bacillus subtilis* while against *Salmonella typhi,* has lower antibacterial activity. In cauliflower, samples dried under solar dryer & sundry have good antibacterial properties against *Klebsiella pneumonia & Salmonella typhi* while against *Bacillus subtilis,* has lower antibacterial activity. In tomato, samples dried under solar dryer & sundry have good antibacterial properties against *Bacillus subtilis & Salmonella typhi* while against *Klebsiella pneumonia,* has lower antibacterial activity. In Chenopodium, solar dry samples have good antibacterial properties against *Bacillus subtilis & Salmonella typhi* while against *Klebsiella pneumonia,* has lower antibacterial activity, in comparative to this, sun dry has elevated level of antibacterial activity against Klebsiella *pneumonia.*

- Consequences of drying strategies on action of antibacterial properties of treated samples. In solar dried spinach has good antibacterial properties against *Bacillus subtilis* & *Klebsiella pneumonia* while against *Salmonella typhi*, has low antibacterial activity.
- Results, after experiments concluded that in solar dried spinach has good antibacterial properties against *Bacillus subtilis* & *Klebsiella pneumonia* while against *Salmonella typhi*, has low antibacterial activity. Spinach dried under sundry has reduced antibacterial properties against *Bacillus subtilis* & *Klebsiella pneumonia* while against *Salmonella typhi*, has elevated antibacterial activity. In fenugreek, dried in solar dryer has good antibacterial properties against *Klebsiella pneumonia* while against *Bacillus subtilis* & *Salmonella typhi*, has lower antibacterial activity. Fenugreek dried under sundry has good antibacterial properties against *Klebsiella pneumonia & Bacillus subtilis* while against *Salmonella typhi*, has lower antibacterial activity.
- In cauliflower, samples dried under solar dryer & sundry have good antibacterial properties against *Klebsiella pneumonia & Salmonella typhi* while against *Bacillus subtilis*, has lower antibacterial activity. In tomato, samples dried under solar dryer & sundry have good antibacterial properties against *Bacillus subtilis & Salmonella typhi* while against *Klebsiella pneumonia,* has lower antibacterial activity.
- In Chenopodium, solar dry samples have good antibacterial properties against *Bacillus subtilis & Salmonella typhi* while against *Klebsiella pneumonia*, has lower antibacterial activity, in comparative to this, sun dry has elevated level of antibacterial activity against Klebsiella *pneumonia.*

5.6 Package kit and awareness among community people for acceptability of solar dried vegetable.

- According to the collected data in the awareness camp we found that female constituted 34 (85%) and male constituted 6 (15%) of all 40 participants. This implies female participation was higher than male participants and more females were aware about the drying techniques than males.

- According to the analysis larger proportion of the participants was in the age group of 30-39 which is 52.5% and the small proportion of the participants was in the age group of 60 years and above.
- The result of this study shows that 65% of the respondents forming majority had no formal education and remaining 22% had primary education. Only 3% respondents attained tertiary education.
- Self-employed and Unemployed were found to take part in awareness camp in large proportion about 35% & 28% respectively. Private sector employees were third highest having a percentage of 15%.
- The perceptions of respondents were mostly related to quality of the dried vegetables. The finding reveals that majority (75%) believe that awareness camp is important to make people aware about the importance of drying technique in preservation of vegetables. Results further indicate (67.5%) perceived that dried vegetables have nutritional values which are important in strengthening of body immunity.