

OSMO-CONVECTIVE DRYING ASSOCIATED WITH CONVENTIONAL DRYING OF TAPROOTS

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Technology degree in
Chemical Engineering

by

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**DEPARTMENT OF CHEMICAL ENGINEERING
SCHOOL OF BIO & CHEMICAL ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **SHAWANI SHOME** (37190037) and **CHAYANIKA DAS** (37190016) who carried out the project entitled "**OSMO-CONVECTIVE DRYING ASSOCIATED WITH CONVENTIONAL DRYING OF TAPROOTS**" under our supervision from September 2020 to March 2021.

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DATE: 16.03.2021

PLACE: Chennai



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DECLARATION

I CHAYANIKA DAS (37190016) hereby declare that the Project Report entitled **“OSMO-CONVECTIVE DRYING ASSOCIATED WITH CONVENTIONAL DRYING OF TAPROOTS”** done by me under the guidance of **Dr. S. Sathish, M.E., (Ph.D.)** is submitted in partial fulfilment of the requirements for the award of Bachelor of Technology degree in Chemical Engineering.

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ABSTRACT

This study aims to evaluate the effect of different concentrations of two different osmotic solutions viz. salt (3%, 6% & 9%) and apple cider vinegar (10%, 20% & 30%), oven drying temperatures (40°C, 50°C & 60°C) on water loss, solid gain & mass reduction of taproots (beetroot and radish). Owing to high energy requirement and quality degradation associated with conventional drying methods, industries are opting for combination techniques like osmotic treatment followed by oven (OTG) drying as it reduces drying time while ensuring adequate nutritional & sensory aspects. Taproots are selected for this experiment as it has valuable bioactive compounds like antioxidants, fibres but contains high water content as well which reduces its shelf life. Blanching the vegetables prior to osmo-convective drying increases the permeability of the outer cells of the taproots. The hypertonic solutions we have chosen for our study are salt & apple cider vinegar (ACV) for beetroot & radish respectively. The vegetable to solvent ratio is 1:2. Once the taproots are osmotically dehydrated in their respective hypertonic solutions for 90 minutes, they are dried in oven (OTG). The novelty of this study is the use of apple cider vinegar as the osmotic agent for radish.

Keywords: *osmo-convective drying, beetroot, radish, salt, apple cider vinegar (ACV), oven (OTG) drying, osmotic treatment, water loss, solid gain, mass reduction*

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ABBREVIATIONS:

ACV	Apple Cider Vinegar
Sol.	Solution
Conc.	Concentration

CHAPTER 1

INTRODUCTION

In today's world the need for some dietary foods has been increasing gradually and providing it for a longer period of time is not that easy. So we need some preservation methods for drying those vegetables to improve its shelf life along with its health benefits. Some methods that we have for preservation are freeze drying, hot air drying, and microwave drying.

Dried vegetables are easy for packaging, transportation and also improve the storage consistency. Some drying methods such as spray drying, osmotic dehydration, hot air drying, freeze drying etc. have chances of giving quality yields. While reducing the moisture content of the vegetables it also reduces its weight and volume which results in less expense on transportation and storage. Due to drying of food, it loses some of its nutritional values as well such as some vitamins; we can also find some changes in its taste and colour. At times the colour of the dried food may not be attractive. Other than conventional drying there are two more methods of removing water one is adding up of humectants. This method is usually avoided as it needs large amounts of sodium chloride, polyols or sugars polyols to be added to food resulting in toxicity and nutritional loss. The other method for removal of water is osmotic dehydration. In this method the solute entering retains on the epidermal tissues and only a little portion of solute goes in and conversely water is been partially taken out. In this experiment we have chosen osmotic dehydration and then followed by conventional drying using OTG. This reduces the drying time, saves energy, reduce nutrition and organoleptic property loss.

1.1 GENERAL PROCEDURE FOR DRYING:

Fresh vegetables should be always chosen for drying process. Initially the vegetables are to be washed to remove the adhering dirt. Then the epidermal tissues are to be removed and then cut into pieces. To avoid the browning of the vegetables it has to be pre-treated either in some citrus solution or blanched. Then the vegetables are to be kept in a spray dryer and when it is dried for a particular period it is taken out of the dryer. The samples are then

stored in a cool place. This process of drying also gives us dried vegetables/fruits but this method is having some disadvantages also. One of them is its energy intensive nature and other is the usage of chemicals like CaCl_2 in pre-treatment can be toxic in the long run. This method of drying may also result in reduction of some its nutritional values and attenuated loss in organoleptic properties.

1.2 SELECTION OF VEGETABLES

Availability of certain vegetables and fruits all around the globe throughout the year is tough. Canned foods contain preservatives to increase the shelf life and it also degrades the taste and freshness of the food product. We have taken taproots for this experiment, as taproots are high in water content and thus have less stability.

1.3 OSMOTIC DEHYDRATION:

Osmotic dehydration is a process to maintain equilibrium on both the sides of the membranes by reducing water content in one side and increasing the solute content by dipping the vegetables in an osmotic solution for the required time.. Oven drying after osmotic treatment does not affect much in the organoleptic properties. We have used Oven drying method in this experiment for drying and maintained a temperature range from 40°C to 60°C so that the nutritional values does get affected. This method also slows down the activities of polyphenol oxidase. Osmosis is completely a natural phenomenon which does not include any external force for the removal of water. The force used for the diffusion comes from the osmotic pressure of salt/ACV solutions due to high concentration of solute.

The osmotic dehydration depends on various following factors:-

1.3.1 OSMOTIC PRESSURE

It is the pressure which is required to attain the equilibrium between the solute particles and the water in the vegetables separated by a semi permeable membrane. It completely depends on the mass. If the mass is decreased by keeping the concentration same, the osmotic pressure

increases. Osmotic pressure difference of two surfaces totally depends on the amount of mass that can be transferred through the membrane. As the semi permeable membrane is that which only allows solvent but not solute particles, osmosis can be used in dehydrating the vegetables. The water comes out of the membrane of the vegetables and solute particles linger on the membrane of vegetables. Osmotic pressure is expressed as –

$$\text{Osmotic Pressure}(\pi) = i \times C \times R \times T$$

where, C → Molar solute concentration, i → Van't Hoff index,

R → Ideal Gas Constant, T → Temperature in Kelvin

1.3.2 PLANT TISSUE

Plant tissues have two major components: the cell wall and the protoplast. Cell wall permits the flow of water and lighter compounds. By stripping off the cell wall protoplast can be obtained. Vacuoles, plasmalemma (also known as cell membrane) etc. are present inside the protoplast. The plasmalemma is a 7.5–10 nm thick membrane permeable to water, and selectively permeable to other substances. A tissue is a collection of cells having a special role to perform. There are three types of tissues; the outer most tissue is called the epidermal tissue. It is thick in nature and in some fruits these tissues are roofed over with cutin. The second type parenchyma is also known as the store house of nutrients. The third type is called vascular tissue. It works as the transport hub due to the presence of xylem and phloem which helps in transferring amino acids, minerals and other nutrients to other parts of the body.

1.3.3 MASS TRANSFER

A solution in a vacuole has an osmotic pressure that pushes protoplasm and plasmalemma toward the cell wall and the pressure gradient between the cell and in its surroundings is called the turgor pressure. To achieve equilibrium, the turgor pressure must be equal to zero i.e.

same osmotic pressure outside and inside the cell. When a vegetable is immersed in hypertonic solution it starts losing water resulting in dehydration of protoplast and separation of plasmalemma. This phenomenon is called plasmolysis. Dehydration takes place in the entire vegetable instead of a single cell. While carrying out the osmotic treatment the peels (epidermal tissues) of the vegetables are removed thereby leaving the vegetables with only parenchyma and vascular tissues. These tissues allow other molecules inside and leave behind water.

1.3.4 OSMOTIC DEHYDRATION MODELLING:

In the design and optimization of any process the model plays a significant tool as it can be utilized in testing new experimental conditions with a view to decrease costs and time involved in conducting laboratory tests. Experimentally determining profiles of moisture content and osmotic agent are costly and time-taking. Yet they are necessary in the design and optimization of a convective-drying process as they influence the microbiological and sensorial attributes of the dried product. Taking into consideration that the model is based on a theoretical approach, it can be utilized for simulating osmotic dehydration and convective drying of various other food products with adequate adaptations like specific thermo-physical properties and coefficients of heat and mass transfer.

CHAPTER 2

LITERATURE SURVEY

- Osmotic dehydration is the phenomenon of removal of water from lower to higher solute concentration through semi permeable membrane and finally resulting in the equilibrium condition on both the sides of membrane (Tiwari 2005). Tiwari RB. Application of osmo-air dehydration for processing of tropical fruits in rural area. Indian Food Ind. 2005.
- Lerici et al. (1983) studied the influence of osmotic agents on drying behavior and quality of apple fruit. They reported that water loss of the final product depends on the amount of solids present in the sample. Additionally, quality of the final product also depends on solid gain, chemical composition of osmotic solution and shape of sample. They added that addition of NaCl increases the drying process.
- Jackfruit samples used in drying kinetic study when evaluated on the basis of color and drying time, the temperature of 60°C was found to be optimum in terms of product quality [Pragati Kaushal, 2014].
- The total color difference and hardness of the osmo-convective dried blueberries were related to sucrose concentration, temperature and contact time during osmotic pre-treatment. The rehydration ratios of the osmo-convective dried blueberries were lower than both conventionally air-dried and freeze-dried blueberries. The osmo-convective dried blueberries were therefore better suited for directly consuming without rehydration [F. Nsonzi, 2007].
- In osmotic dehydration, a simultaneous flux of water and solutes from and into the material takes place. This method can be used as a pretreatment before air drying in order to reduce from 30% to 70% of the water content of the food. Osmotic dehydration preceding air drying decreases colour changes and increases flavour retention in dried fruits and vegetables [Lenart and Lewicki, 1988].
- Dehydration of carrot slices were carried out by two different methods viz. hot air drying and osmo air drying after blanching. Hot air drying was done in cabinet drier and osmo air drying was carried out with the help of best cane sugar syrup. It was found that osmo air drying was better since carotene

retention was better and reducing sugar increased whereas total sugar decreased [Madan and Dhawan, 2005]. During osmotic dehydration 100–2,400 KJ/kg water elimination while in hot air drying it is 5,000 KJ/kg.

- Optimum solutions using numerical optimization obtained were 7.07 min blanching time and 60°C drying temperature to achieve maximum possible water loss, solid gain, and overall acceptability [R. Gupta et. al., 2012].
- For Carrot shreds, drying time reduced with increase in temperature from 50 to 70 °C [Hathan, B. S. and T. Malhotra. 2012].
- The major problem associated with the osmo-convective drying of grapes in fluidized bed of sugar was caking and stickiness caused by sugar on the fruit surface. According to a suggestion of Ponting et al. (7), this disadvantage could be corrected by suitable bed mixture with a lower osmotic pressure, since the caking is apparently caused by very rapid withdrawal of water from the grape at the beginning [S. Grabowski. Et. al., 2007]
- NaCl (salt) hypertonic solutions can be considered as good osmotic agents for red beetroot pretreatment. It gives a positive impact on product quality and also on drying kinetics [Stefan J. Kowalski, 2015].
- With the dietary concern of using sugar solutions as osmo-active agent, the gray area of research will be in the development of new osmotic solutions that will increase nutrient retention and infuse bioactive compounds that will confer health benefits. Additionally, the use of osmosed fruit or osmo-convective dehydrated fruits as a vehicle for drug delivery in the gastro-intestinal system is another is a gray area of research as well [Felix Akharume1, 2019].

CHAPTER 3

AIM AND SCOPE OF THE STUDY

3.1 AIM:

To compare the drying rate, moisture content and weight reduction within taproots in various hypertonic solutions (salt solution and apple cider vinegar) and calculating the optimized condition.

The objectives of this experiment are:

- To check the optimized combination of vegetable with the hypertonic solution and the parameters like solute concentration and oven drying temperature.
- To study the weight reduction of the vegetable at different immersion time and its moisture content.
- To keep the organoleptic properties unchanged as much as possible while carrying out the experiment.

3.2 SCOPE:

Osmotic dehydration followed with conventional drying (oven drying) is used in drying of taproots which are high in water content for increasing the shelf life and with very less or negligible amount of nutritional losses. We have taken only taproots in this experiment but this process can be used with other vegetables and fruits as well.

CHAPTER 4

MATERIALS AND METHODS

4.1 MATERIALS

4.1.1 Identification:

Fresh Beetroot (i.e. *Beta vulgaris*) and Radish (i.e. *Raphanus sativus*) were collected from the local market of Malda (West Bengal) and Silchar (Assam). While choosing taproots, we focussed on getting firm, hard beetroots with no obvious soft spots. We avoided sunken beets as it indicates that the beetroot has spoiled. Also for radish we have looked for crisp green leaves, vibrant colour, unblemished, firm.



Fig 4.1: Vegetables (beetroot and radish)

4.1.2 Vegetable description:

We have chosen some of the taproots for osmo convective drying as the water contents are too high in it and it has got so many health benefits.

Beetroot containing 88% water, 10% carbohydrates, 2% protein, and less than 1% fat is rich in folic acid, fiber, potassium and manganese. It is used for natural food coloring agents and also well known for weight loss due to its low calorie. It has the potential for cancer prevention and suppression due to its high content of antioxidants. It helps pregnant women in not having a premature baby. The beetroot is having origins throughout the coasts of Europe, India and Africa.

Radish consisting of 95% water, 3% carbohydrate and 1% protein, is high in potassium, manganese, Vitamin C, Folate (Vitamin B9) and Riboflavin (Vitamin B2). It helps to lower blood pressure, regularize brain and nerve function, increase oxygen supply to the blood, control red blood cell damage, support the generation of collagen keeping the blood vessels healthy. Radish is said to be originated from central and western China and India. It was cultivated for years by Egyptians and ancient Greeks & much later in Western Europe. Novelty of this project lies here as no study has been conducted with radish ever before.

4.1.3 Osmotic agents:

Osmotic agents (edible food grade) were used to enhance the partial removal of moisture content in the vegetable sample. Osmotic agents used in this present study are salt (Tata) and apple cider vinegar (American Garden). The osmotic agent used should be commercially accepted in terms of taste, non-reactive, nutritionally beneficial and easily soluble with the solvent (which is water in our study). Salt solution is commonly used osmotic agent for vegetables. If salt is used as osmotic agent, higher moisture content is allowed at the end of drying as salt uptake influences water sorption behavior of the product. Apple cider vinegar (ACV) has unbound goodness, including antimicrobial and antioxidant effects. It has health benefits, such as aiding weight loss, reducing cholesterol, lowering blood sugar levels, and improving the symptoms of diabetes. So, using ACV as osmotic solution will not only increase the nutritional value of the food but also preserve it for longer time as it is a fermented product itself.



Fig 4.2: Osmotic agent 1 (salt)



Fig 4.3: Osmotic agent 2 (ACV)

4.1.4 Apparatus Required:



Fig 4.4: Weighing machine



Fig 4.5: Temperature sensor

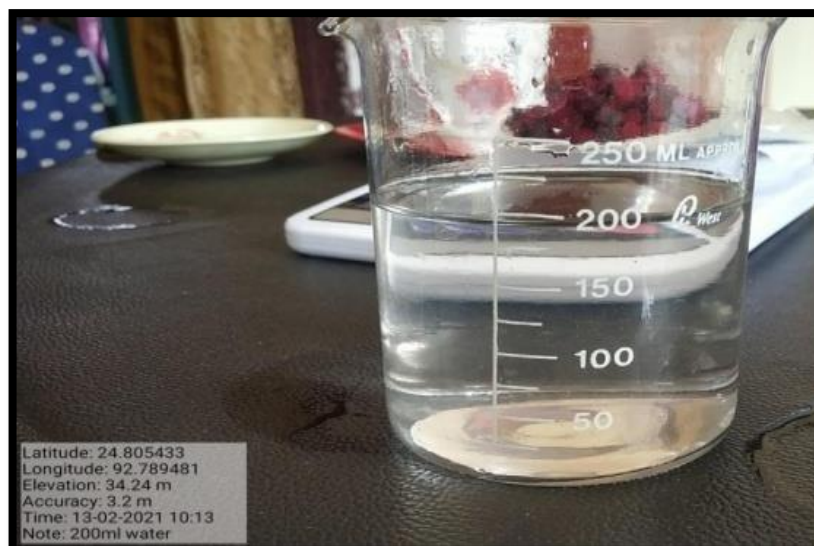


Fig 4.6: Beaker



Fig 4.7: Oven drier (OTG) (Bajaj 1000 T SS)

4.2 METHODS:

4.2.1 Preparation of raw materials:

Taproots bought from the market should be initially stored at 4 - 5°C in a refrigerator for around 6 hours prior to experiment.



Fig 4.8: Vegetables stored in refrigerator

4.2.2 Pretreatment of vegetables:

Washing it further and then blanching it by immersing it in hot water (95°C) first for 4 minutes and then immediately in cold water (20°C) is used to prevent enzymatic action. Peeling the taproots and cutting it into small cubes such that the width of each cube is around 1 cm.



Fig 4.9: Radish in hot water



Fig 4.10: Radish in cold water



Fig 4.11: Beetroot in hot water



Fig 4.12: Beetroot in cold water



Fig 4.13: 3 sets of beetroot (100g)



Fig 4.14: 3 sets of radish (100g)

4.2.3 Preparation of osmotic solution:

We made osmotic solutions of salt at the following solution concentrations – 3, 6 & 9% and apple cider vinegar at the following solution concentrations –

10, 20 & 30%. 200ml of water is used for making osmotic solutions each batch. 3% of 200ml salt solution includes 6g salt in 200ml water. Similarly, 6% & 9% of 200ml salt solution includes 12g & 18g salt in 200ml water respectively. Also, 10% of 200ml apple cider vinegar solution implies to 20ml of apple cider vinegar in 200ml of water. Similarly, 20% & 30% of 200ml apple cider vinegar solution implies to 40ml and 60 ml of apple cider vinegar in 200 ml of water respectively.



Fig 4.15: Salt (6, 12 , 18g) in 200ml water



Fig 4.16: ACV (20, 40, 60 ml) in 200 ml water

4.2.4 Osmotic treatment:

Eighteen batches of each beetroot & radish is made such that various comparative studies can be conducted on it keeping one parameter (either osmotic concentration or oven temperature) variable and others constant at a time. Weight of vegetables in each batch should be 100g. Further the taproots are immersed in each hypertonic solution. At room temperature, after every 30 minutes the sample is taken out with a strainer & its weight is measured. The reading is continued taking till the immersion time reaches 90 minutes. After 90 minutes the sample is wiped with tissue paper or towel to remove the adhering osmotic solution in the surface of the vegetable samples.



Fig 4.17: Radish in different concentrations of ACV



Fig 4.18: Beetroot in different concentrations of salt



Fig 4.19: Radish in different concentrations of salt



Fig 4.20: Beetroot in different concentrations of ACV

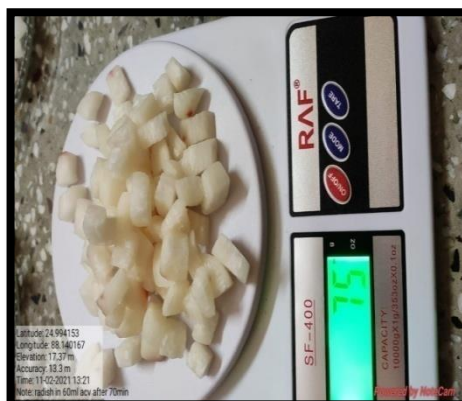


Fig 4.21: Weighing radish at intervals of time



Fig 4.22: Weighing beetroot at intervals of time



Fig 4.23: Beetroots after 90 minutes of Osmotic treatment



Fig 4.24: Radish after 90 minutes of Osmotic treatment

4.2.5 Oven Drying:

Further each batch of samples is processed at different temperatures in OTG (oven). At 40°C batches of Beetroot (3, 6, 9% salt), Beetroot (10, 20, 30% ACV), Radish (10, 20, 30% ACV) & Radish (3, 6, 9% salt) are processed separately. After every 10 minutes the samples are taken out and the weight of the vegetables is measured. Processing is continued till the weight reaches a constant value. Similarly, at 50°C & 60°C batches of Beetroot (3, 6, 9% salt), Beetroot (10, 20, 30% ACV), Radish (10, 20, 30% ACV) & Radish (3, 6, 9% salt) are processed separately in the same manner. Here we have processed it for 70 minutes as the organoleptic properties were getting negatively affected on drying it beyond that time.



Fig 4.25: Beetroot kept in OTG for Oven drying for 70 minutes



Fig 4.26: Radish after oven dry at 40°C



Fig 4.27: Beetroot after oven dry at 40°C



Fig 4.28: Radish after oven dry at 50°C



Fig 4.29: Beetroot after oven dry at 50°C



Fig 4.30: Radish after oven dry at 60°C



Fig 4.31: Beetroot after oven dry at 60°C



Fig 4.32: Radish after 70 minutes of oven dry



Fig 4.33: Beetroot after 70 minutes of oven dry

4.2.6 Dry matter weight calculation:

The dry matter weight is also calculated by putting 100g of the two types of vegetables (i.e. Beetroot and Radish) separately in an oven and dried till the weight does not reduce further. The dry matter weight as per the experiment conducted for Beetroot is 18g & Radish is 10g.



Fig 4.35: Dried radish for dry weight calculation



Fig 4.36: Dried Beetroot for dry weight calculation

4.3 DEFINATIONS AND FORMULAE FOR OSMO-CONVECTIVE DEHYDRATION PARAMETER CALCULATION:

4.3.1 Moisture Content (kg / kg wet basis):

Moisture content is the amount of water contained in the sample in a given point of time. There are two ways to express the moisture content- wet basis and dry basis. If the percentage is calculated relative to the wet weight, it is called the wet basis moisture content and if the percentage is calculated relative to the dry matter weight, it is called the dry basis moisture content.

$$\text{Moisture Content (wet basis)}(\%) = \frac{\text{mass of water}}{\text{mass of moist sample}} \times 100$$

$$\text{Moisture Content (dry basis)}(\%) = \frac{\text{mass of water}}{\text{mass of dry sample}} \times 100$$

The two above equations are related to each other as -

$$\text{Moisture Content (wet basis)}(\%) = \frac{\text{Moisture Content (dry basis)}(\%)}{\text{Moisture Content (dry basis)}(\%) + 1} \times 100$$

As the moisture content (dry basis) can exceed 100 but moisture content (wet basis) ranges between 0-100, we have expressed our moisture content in terms of wet basis to avoid confusion.

The current moisture content and initial moisture content can be expressed through the following equations-

$$\begin{aligned} \text{Current moisture content (\%)} \\ = \frac{[\text{current sample weight} - \text{dry matter weight}]}{\text{initial weight}} \times 100 \end{aligned}$$

$$\text{Initial moisture content (\%)} = \frac{[\text{initial weight} - \text{dry matter weight}]}{\text{initial weight}} \times 100$$

As per our experiment conducted,

$$\text{Initial moisture content for Beetroot(\%)} = \frac{[100 - 18]}{100} \times 100 = 82\%$$

$$\text{Initial moisture content for Radish (\%)} = \frac{[100 - 10]}{100} \times 100 = 90\%$$

4.3.2 Drying Rate:

Dry matter is the amount of solids which are left after drying. It is expressed in terms of percentage. Drying rate is a function of various factors like oven drying temperature, humidity, air flow rate, transport properties like Reynolds' number and Schmidt number. The drying rate is expressed here as the weight of water lost per unit time. Here, the unit of drying rate is kg/hr.

$$\text{Drying rate} = \frac{\text{initial weight} - \text{current weight}}{\text{time taken}}$$

The effectiveness of osmotic dehydration is determined by the following three parameters:

4.3.3 Weight Reduction:

Percent Weight reduction is the amount of weight of water reduced with time based on the initial sample weight. Weight Reduction is expressed as the ratio of the difference between the initial and current sample weight to the initial weight.

$$\text{Weight Reduction (WR)\%} = \frac{(\text{Initial Weight} - \text{Weight at time 't'})}{\text{Initial Weight}} \times 100$$

4.3.4 Water Loss:

Percent water loss (%WL) is defined as the net loss of water from the fresh beetroot or radish during osmotic treatment based on the initial sample weight. Water loss is expressed as the ratio of the difference between the initial and current moisture content to the initial weight.

$$\text{Water Loss(WL)\%} = \frac{(\text{Initial Moisture} - \text{Moisture at time 't'})}{\text{Initial Moisture}} \times 100$$

4.3.5 Solid Gain:

Percent Solid gain (%SG) was defined as the net uptake of salt by the osmosed beetroot or apple cider vinegar by radish based on the initial sample weight. It can be calculated by subtracting the water reduction (%) from the water loss (%).

$$\text{Solid Gain (SG)\%} = \text{Water Loss(\%)} - \text{Water Reduction(\%)}$$

CHAPTER 5

TABULATION AND GRAPHICAL REPRESENTATION

5.1 OSMOSIC TREATMENT

5.1.1 Beetroot

Table 5.1: Beetroot-Salt solution-Osmosis

Sl. No.	Osmotic sol. Conc. (%)	Immersion time (min)	Weight (g)	Moisture content (%)	Weight Reduction (%)	Water loss (%)	Solid gain (%)
1	3	30	90	72	10	12.195	2.195
2	3	60	87	69	13	15.854	2.854
3	3	90	85	67	15	18.293	3.293
4	6	30	74	56	26	31.707	5.707
5	6	60	71	53	29	35.366	6.366
6	6	90	68	50	32	39.024	7.024
7	9	30	73	55	27	32.237	5.927
8	9	60	68	50	32	39.024	7.024
9	9	90	65	47	35	42.683	7.683

Table 5.2: Beetroot-Apple cider vinegar-Osmosis

Sl.No.	Osmotic sol. Conc. (%)	Immersion time (min)	Weight (g)	Moisture content (%)	Weight Reduction (%)	Water loss (%)	Solid gain (%)
1	3	30	97	79	3	3.66	0.66
2	3	60	93	75	7	8.54	1.54
3	3	90	89	71	11	13.41	2.41
4	6	30	87	69	13	15.85	2.85
5	6	60	84	66	16	19.51	3.51
6	6	90	78	60	22	26.83	4.83
7	9	30	86	68	14	17.07	3.07
8	9	60	79	61	21	25.61	4.61
9	9	90	76	58	24	29.27	5.27

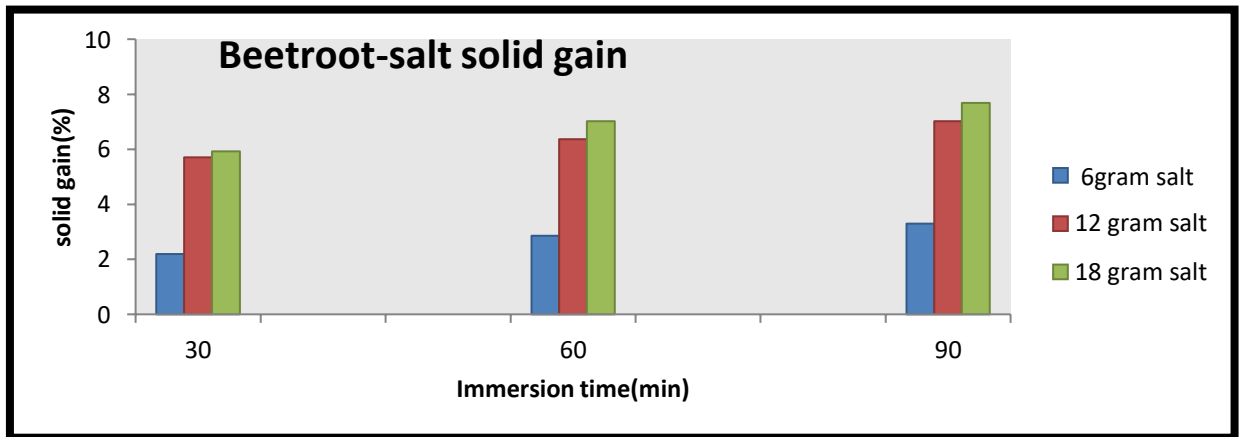


Fig 5.1: Graph of beetroot-salt-osmosis solid gain calculation

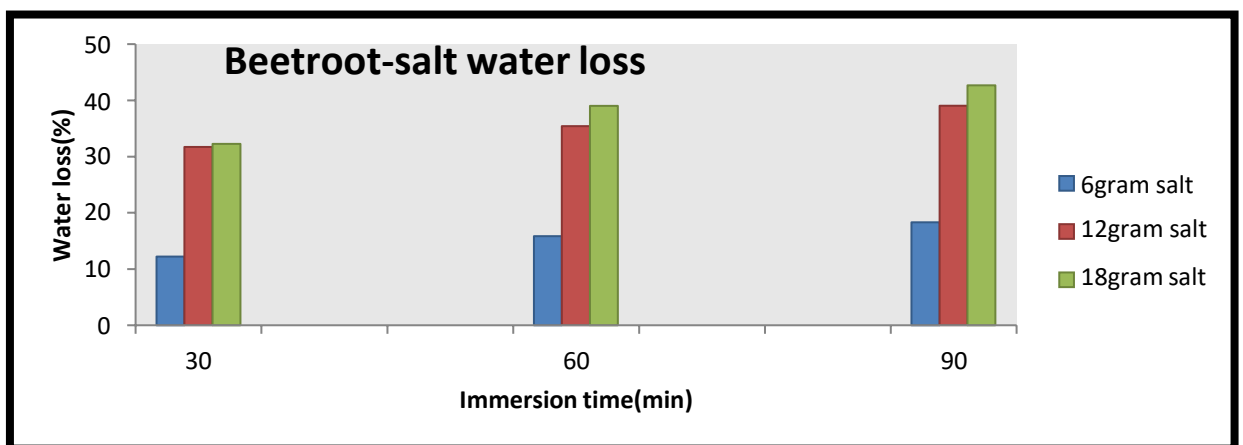


Fig 5.2: Graph of Beetroot-salt- osmosis water loss calculation

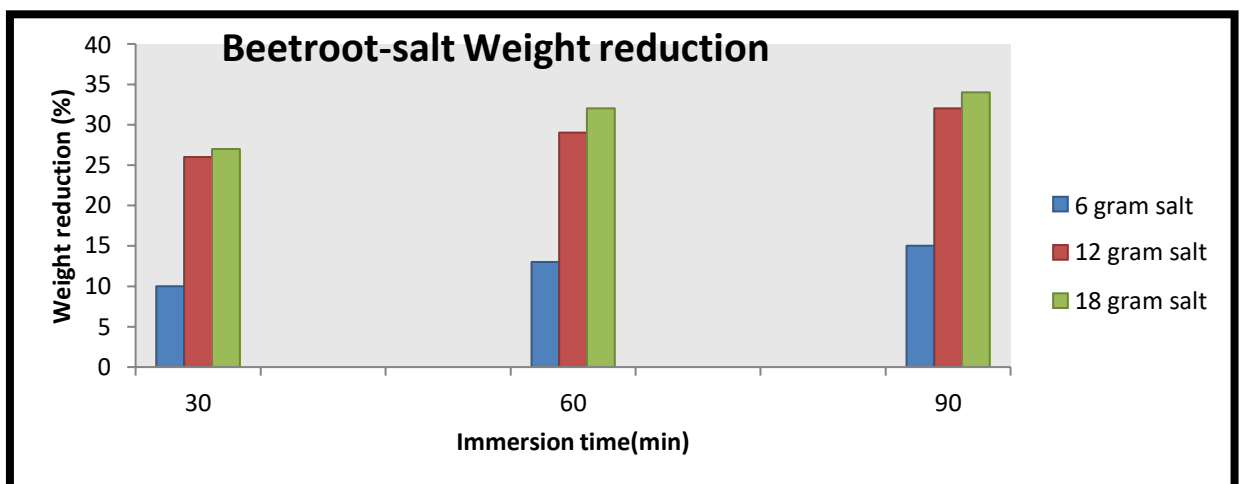


Fig 5.3 Graph of Beetroot-salt-osmosis weight reduction calculation

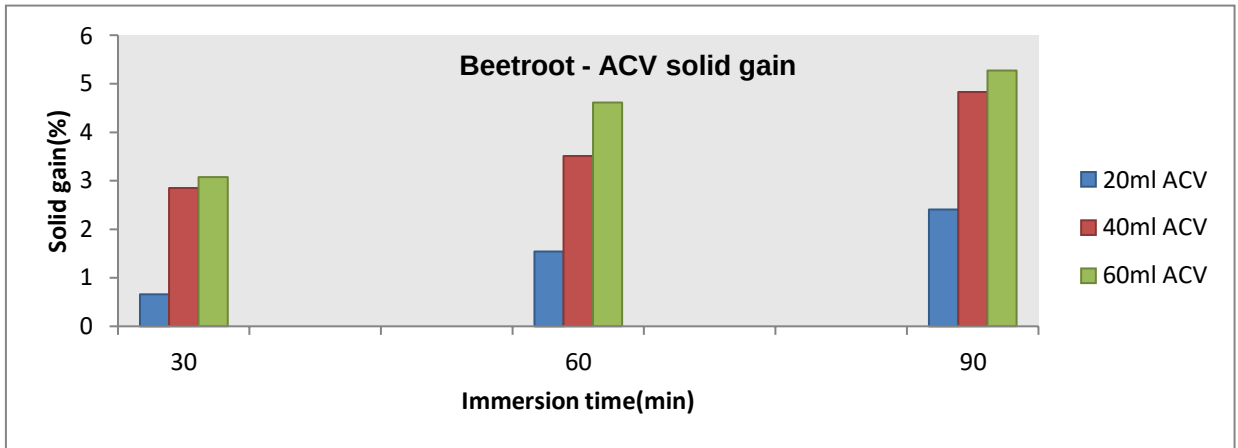


Fig 5.4: Graph of Beetroot-ACV-osmosis solid gain calculation

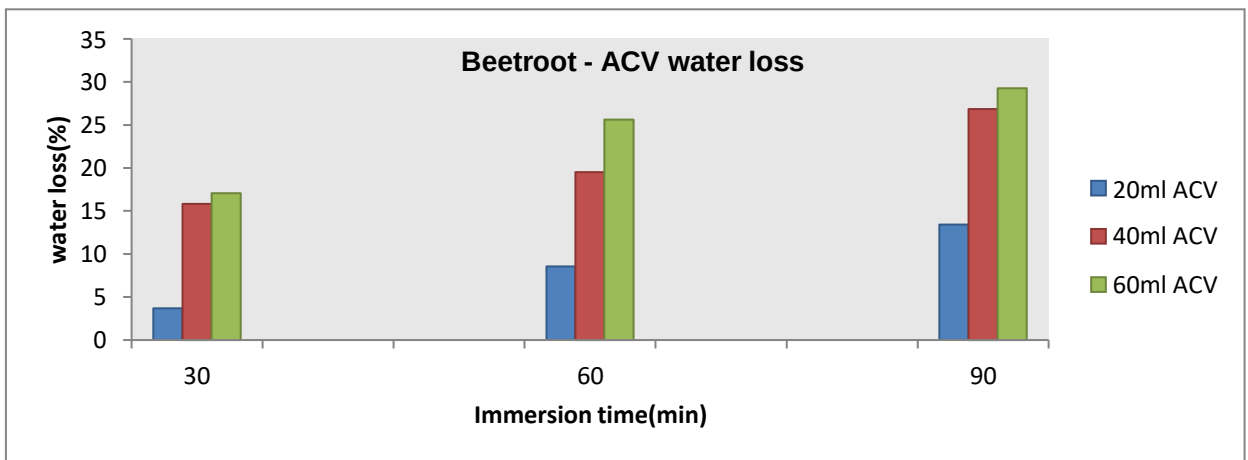


Fig 5.5: Graph of Beetroot-ACV-osmosis water loss calculation

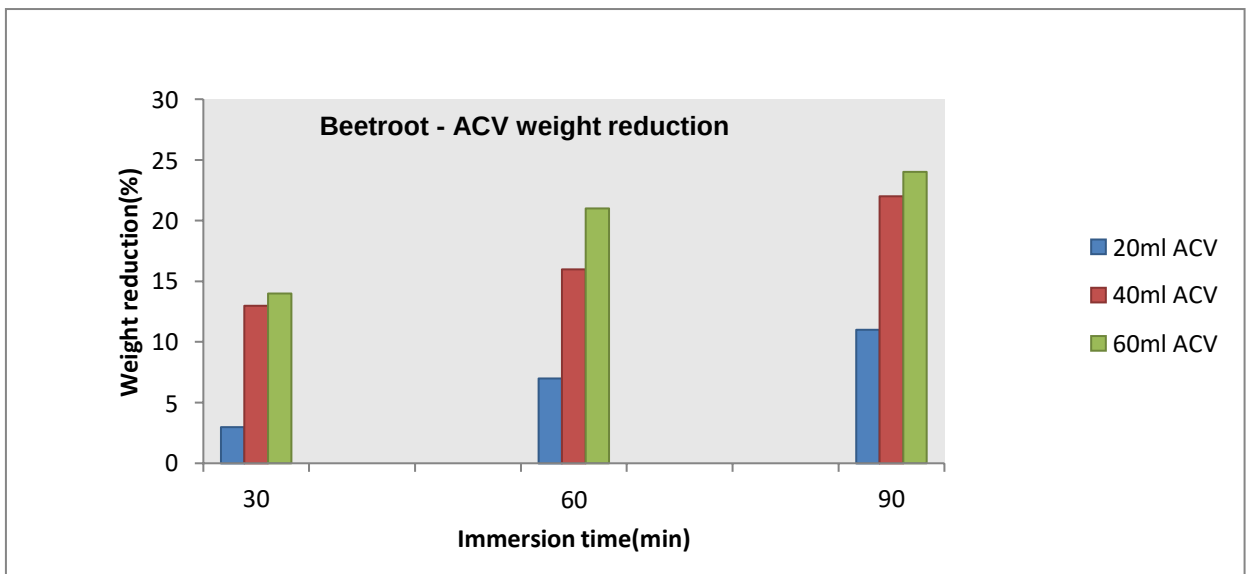


Fig 5.6: Graph of Beetroot-ACV-osmosis weight reduction calculation

5.1.2 Radish

Table 5.3: Radish in salt solution-osmosis

Sl.No.	Osmotic sol. Conc. (%)	Immersion time (min)	Weight (g)	Moisture content (%)	Weight Reduction (%)	Water loss (%)	Solid gain (%)
1	3	30	95	85	5	5.55	0.55
2	3	60	92	82	8	8.88	0.88
3	3	90	88	77	12	14.44	2.44
4	6	30	82	72	18	20	2
5	6	60	79	69	21	23.33	2.33
6	6	90	75	65	25	27.77	2.77
7	9	30	80	70	20	22.22	2.22
8	9	60	78	68	22	24.44	2.44
9	9	90	75	65	25	27.77	2.77

Table 5.4: Radish in Apple cider vinegar-osmosis

Sl.No.	Osmotic sol. Conc. (%)	Immersion time (min)	Weight (g)	Moisture content (%)	Weight Reduction (%)	Water loss (%)	Solid gain (%)
1	3	30	91	81	9	10	1
2	3	60	87	77	13	14.44	1.44
3	3	90	85	75	15	16.66	1.66
4	6	30	83	73	17	18.88	1.88
5	6	60	79	69	21	23.33	2.33
6	6	90	75	65	25	27.77	2.77
7	9	30	82	72	18	20	2
8	9	60	77	67	23	25.55	2.55
9	9	90	74	64	26	28.88	2.88

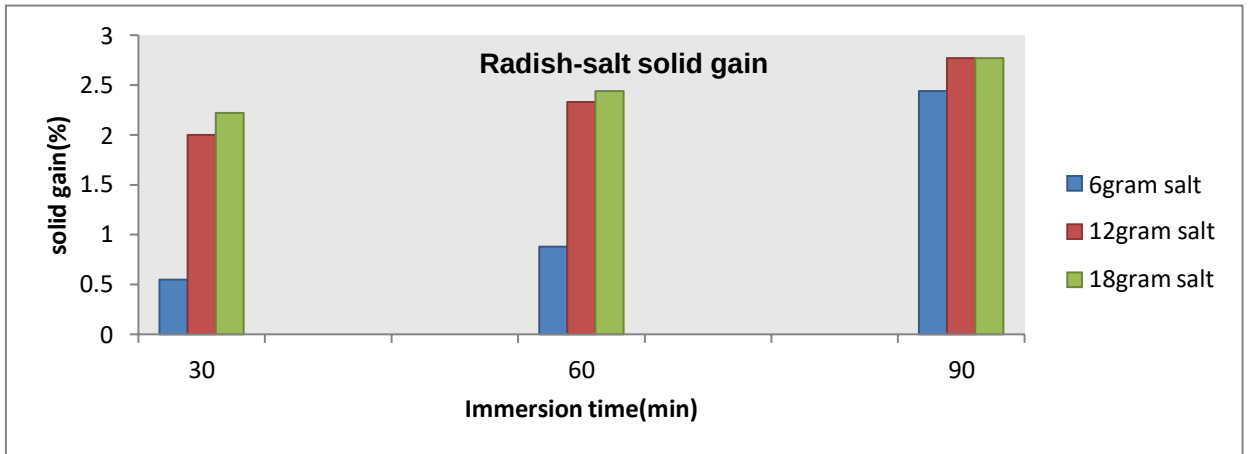


Fig 5.7: Graph of Radish-salt-osmosis solid gain calculation

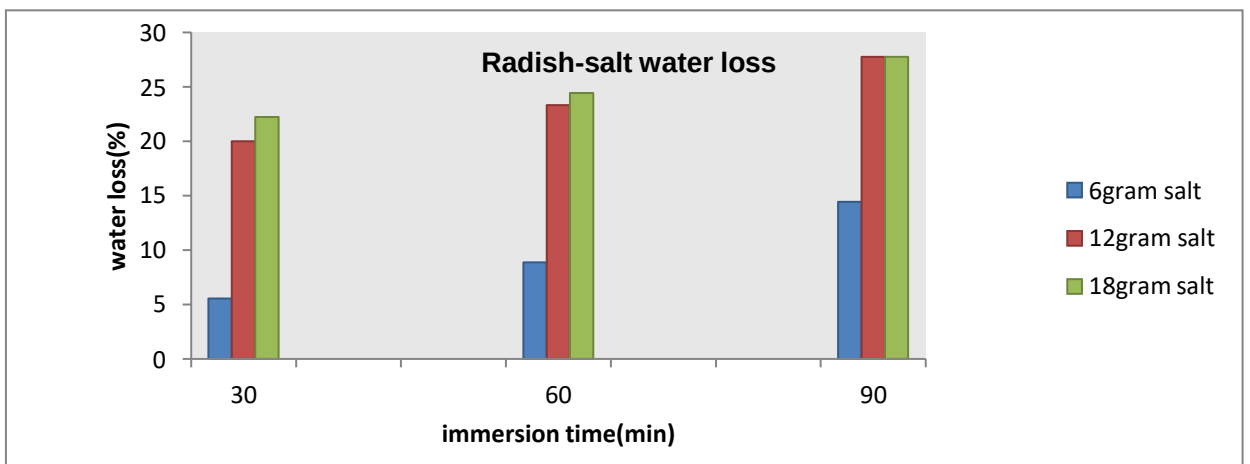


Fig 5.8: Graph of Radish-salt-osmosis water loss calculation

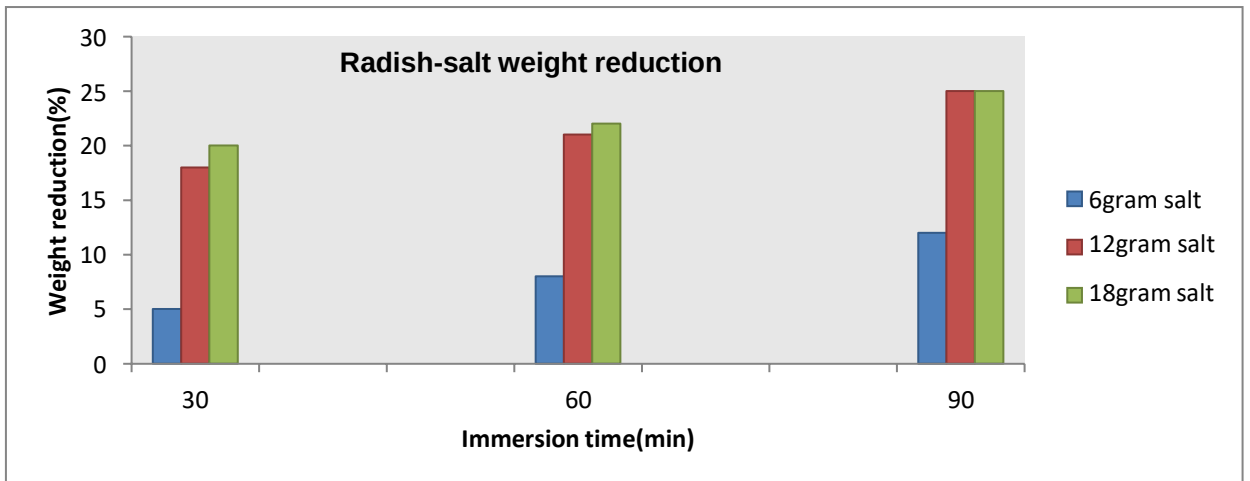


Fig 5.9: Graph of Radish-salt-osmosis weight reduction calculation

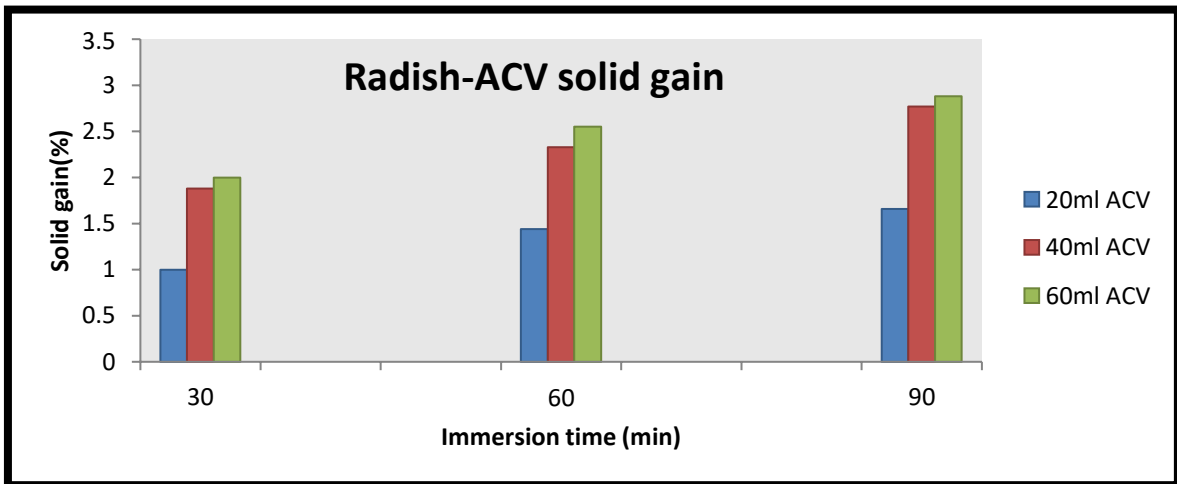


Fig 5.10: Graph of Radish-ACV-osmosis solid gain calculation

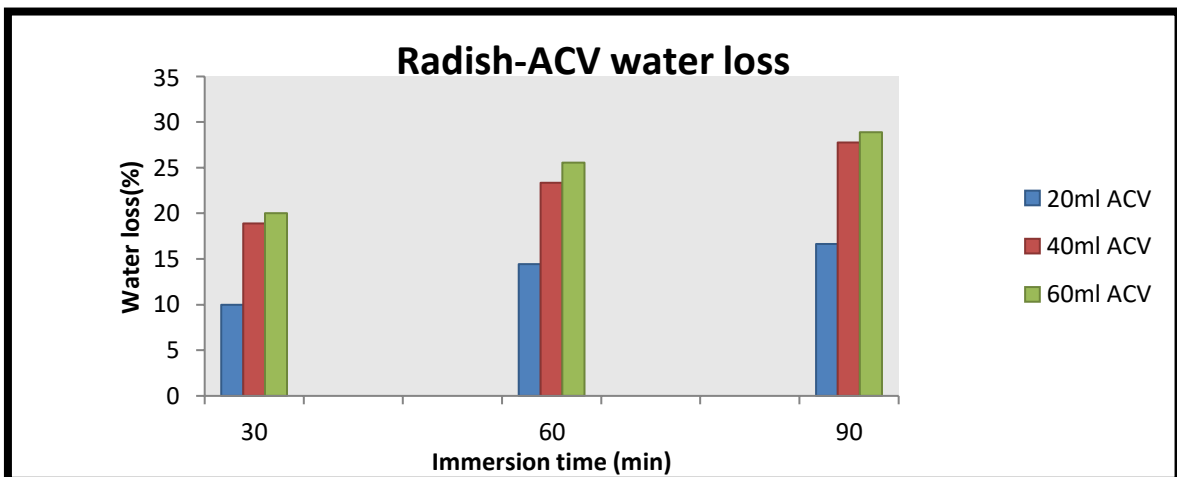


Fig 5.11: Graph of Radish-ACV-osmosis water loss calculation

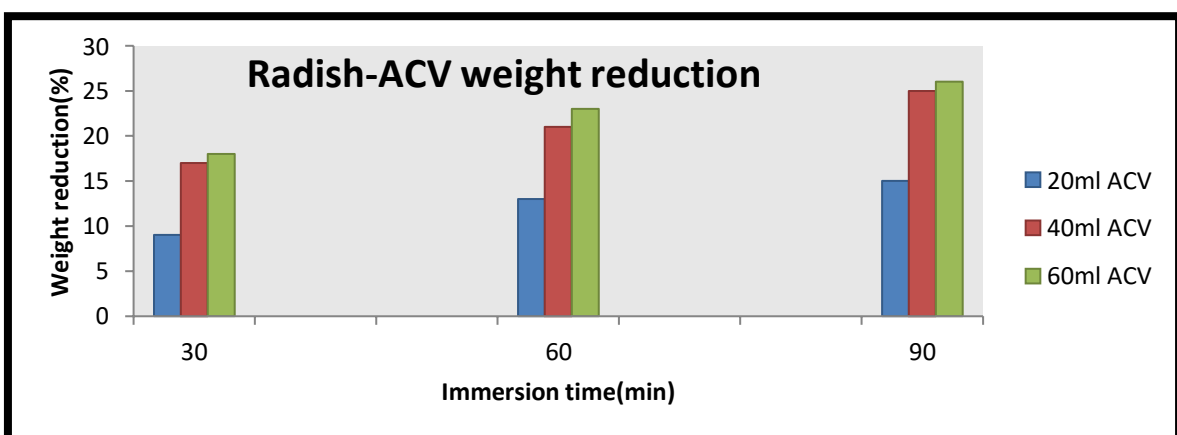


Fig 5.12: Graph of Radish-ACV-osmosis weight reduction calculation

5.2 OVEN DRYING

5.2.1 Salt Solution

5.2.1.1 3% salt solution

Table 5.5: Beetroot and Radish oven drying at 40°C after 3% salt solution osmotic treatment

TIME (min)	Beetroot			Radish		
	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)
0	85	78.82	-	88	88.64	-
10	83	76.47	0.012	87	87.5	0.006
20	81	74.12	0.012	86	86.36	0.006
30	75	67.06	0.02	72	70.45	0.032
40	69	60	0.024	67	64.77	0.032
50	65	55.29	0.024	65	62.5	0.028
60	62	51.76	0.022	64	61.36	0.024
70	60	49.41	0.021	63	60.23	0.021

Table 5.6: Beetroot and Radish oven drying at 50°C after 3% salt solution osmotic treatment

TIME (min)	Beetroot			Radish		
	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)
0	85	78.82	-	88	88.64	-
10	84	77.65	0.006	87	87.5	0.006
20	83	76.47	0.006	85	85.23	0.009
30	74	65.88	0.022	72	70.45	0.032
40	69	60	0.024	61	57.95	0.041
50	65	55.29	0.024	58	54.55	0.036
60	64	54.12	0.021	57	53.41	0.031
70	63	52.94	.019	56	52.27	0.027

**Table 5.7: Beetroot and radish oven drying at 60°C after 3% salt solution
osmotic treatment**

TIME (min)	Beetroot			Radish		
	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)
0	85	78.82	-	88	88.64	-
10	84	77.65	0.006	87	87.5	0.006
20	82	75.29	0.009	86	86.36	0.006
30	76	68.24	0.018	73	71.59	0.03
40	72	63.53	0.020	61	57.95	0.041
50	67	57.65	0.022	60	56.82	0.034
60	66	56.47	0.019	59	55.68	0.029
70	65	55.29	0.017	58	54.55	0.026

5.2.1.2 6% salt solution

**Table 5.8: Beetroot and Radish oven drying at 40°C after 6% salt solution
osmotic treatment**

TIME (min)	Beetroot			Radish		
	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)
0	68	73.53	-	75	86.67	-
10	67	72.06	0.006	74	85.34	0.006
20	60	61.76	0.024	72	82.67	0.009
30	51	48.53	0.034	64	72	0.022
40	47	42.65	0.032	52	56	0.035
50	45	39.71	0.028	50	53.34	0.03
60	43	36.76	0.025	49	52	0.026
70	42	35.29	0.022	48	50.67	0.023

**Table 5.9: Beetroot and radish oven drying at 50°C after 6% salt solution
osmotic treatment**

TIME (min)	Beetroot			Radish		
	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)
0	68	73.53	-	75	86.67	-
10	65	69.12	0.018	74	85.34	0.006
20	63	66.18	0.015	73	84	0.006
30	54	52.94	0.028	70	80	0.01
40	45	39.71	0.035	58	64	0.026
50	41	33.82	0.032	53	57.34	0.026
60	38	29.41	0.03	52	56	0.023
70	36	26.47	0.027	51	54.67	0.021

**Table 5.10: Beetroot and radish oven drying at 60°C after 6% salt solution
osmotic treatment**

TIME (min)	Beetroot			Radish		
	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)
0	68	73.53	-	75	86.67	-
10	67	72.06	0.006	73	84	0.012
20	66	70.59	0.006	70	80	0.015
30	50	47.06	0.036	61	68	0.028
40	45	39.71	0.035	57	62.67	0.027
50	42	35.29	0.031	55	60	0.024
60	38	29.41	0.03	54	58.67	0.021
70	37	27.94	0.027	53	57.34	0.019

5.2.1.3 9% salt solution

Table 5.11: Beetroot and radish oven drying at 40°C after 9% salt solution osmotic treatment

TIME (min)	Beetroot			Radish		
	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)
0	65	72.31	-	67	85.07	-
10	64	70.77	0.006	66	83.58	0.006
20	58	61.54	0.021	65	82.09	0.006
30	56	58.46	0.018	59	73.13	0.016
40	50	49.23	0.023	57	70.15	0.03
50	48	46.15	0.020	55	67.16	0.014
60	46	43.08	0.019	54	65.67	0.013
70	45	41.54	0.017	53	64.18	0.012

Table 5.12: Beetroot and Radish oven drying at 50°C after 9% salt solution osmotic treatment

TIME (min)	Beetroot			Radish		
	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)
0	65	72.31	-	67	85.67	-
10	64	70.77	0.006	66	83.58	0.006
20	62	67.69	0.009	65	82.01	0.006
30	59	63.08	0.012	63	79.1	0.008
40	53	53.85	0.018	60	74.63	0.011
50	49	47.69	0.019	57	70.15	0.012
60	43	38.46	0.022	51	61.19	0.016
70	42	36.92	0.02	50	59.7	0.015

**Table 5.13: Beetroot and radish oven drying at 60°C after 9% salt solution
osmotic treatment**

TIME (min)	Beetroot			Radish		
	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)
0	65	72.31	-	67	85.07	-
10	63	69.23	0.012	65	82.09	0.012
20	61	66.15	0.012	64	80.6	0.009
30	47	44.62	0.044	62	77.61	0.01
40	45	41.54	0.03	55	67.16	0.018
50	39	32.32	0.031	49	58.21	0.022
60	37	29.23	0.028	44	50.75	0.023
70	35	26.15	0.026	43	49.25	0.021

5.2.2 Apple cider vinegar (ACV)

5.2.2.1 10% ACV solution

**Table 5.14: Beetroot and radish oven drying at 40°C after 10% ACV solution
osmotic treatment**

TIME (min)	Beetroot			Radish		
	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)
0	89	79.78	-	85	88.24	-
10	88	78.65	0.006	83	85.58	0.012
20	85	75.28	0.012	79	81.18	0.018
30	75	64.04	0.028	55	60.81	0.04
40	61	48.31	0.042	53	58.12	0.048
50	57	43.82	0.038	51	48.24	0.041
60	56	42.7	0.033	49	45.88	0.036
70	55	41.57	0.029	44	40	0.035

**Table 5.15: Beetroot and radish oven drying at 50°C after 10% ACV solution
osmotic treatment**

TIME (min)	Beetroot			Radish		
	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)
0	89	79.78	-	85	88.24	-
10	88	78.65	0.006	84	87.06	0.006
20	86	76.40	0.009	82	84.71	0.009
30	80	69.66	0.018	72	72.94	0.026
40	63	50.56	0.039	67	67.06	0.027
50	56	42.7	0.04	62	61.18	0.028
60	55	41.57	0.034	58	56.47	0.027
70	54	40.45	0.03	57	55.29	0.024

**Table 5.16: Beetroot and radish oven drying at 60°C after 10% ACV solution
osmotic treatment**

TIME (min)	Beetroot			Radish		
	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)
0	89	79.78	-	85	88.24	-
10	88	78.65	0.006	84	87.06	0.006
20	87	77.53	0.006	81	83.53	0.012
30	69	57.30	0.04	71	71.76	0.028
40	58	44.94	0.047	62	61.18	0.035
50	53	39.33	0.043	59	57.65	0.016
60	52	38.20	0.037	58	56.47	0.027
70	51	37.08	0.032	57	55.29	0.024

5.2.2.2 20% ACV solution

Table 5.17: Beetroot and radish oven drying at 40°C after 20% ACV solution osmotic treatment

TIME (min)	Beetroot			Radish		
	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)
0	78	76.92	-	75	86.67	-
10	77	75.64	0.006	74	85.33	0.006
20	75	73.08	0.009	73	84	0.006
30	64	58.97	0.028	61	68	0.028
40	60	53.85	0.027	54	58.67	0.032
50	57	50	0.025	49	52	0.031
60	56	48.72	0.022	48	50.67	0.027
70	54	46.15	0.021	47	49.34	0.024

Table 5.18: Beetroot and radish oven drying at 50°C after 20% ACV osmosis

TIME (min)	Beetroot			Radish		
	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)
0	78	76.92	-	75	86.67	-
10	77	75.64	0.006	72	82.67	0.018
20	74	71.79	0.012	70	80	0.015
30	63	57.69	0.03	57	62.67	0.036
40	58	51.28	0.03	45	46.67	0.045
50	56	48.72	0.026	42	42.67	0.04
60	54	46.15	0.024	39	38.67	0.036
70	53	44.87	0.021	37	36	0.033

Table 5.19: Beetroot and radish oven drying at 60°C after 20% ACV osmosis

TIME (min)	Beetroot			Radish		
	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)
0	78	76.92	-	75	86.67	-
10	77	75.64	0.006	74	85.53	0.006
20	76	74.36	0.006	73	84	0.006
30	60	53.85	0.036	60	66.67	0.03
40	54	46.15	0.06	55	60	0.03
50	53	44.87	0.03	53	57.34	0.026
60	52	43.59	0.026	52	56	0.023
70	51	42.31	0.023	51	54.67	0.021

5.2.2.3 30% ACV solution

Table 5.20: Beetroot and radish oven drying at 40°C after 30% ACV osmosis

TIME (min)	Beetroot			Radish		
	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)
0	76	76.32	-	74	86.49	-
10	75	75	0.006	73	85.14	0.006
20	73	72.37	0.009	71	82.43	0.009
30	59	53.95	0.026	59	66.22	0.03
40	50	42.11	0.039	52	56.76	0.033
50	43	32.89	0.04	49	52.70	0.03
60	42	31.58	0.034	48	51.35	0.026
70	41	30.26	0.028	47	50	.023

**Table 5.21: Beetroot and radish oven drying at 50°C after 30% ACV solution
osmotic treatment**

TIME (min)	Beetroot			Radish		
	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)
0	76	76.32	-	74	86.49	-
10	75	75	.006	73	85.14	.006
20	73	72.37	.009	70	81.08	.012
30	58	52.63	.036	61	68.92	.026
40	51	43.42	.038	53	58.12	.032
50	47	38.16	.035	47	50	.032
60	46	36.84	.03	46	48.65	.028
70	45	35.53	.027	45	47.3	.025

**Table 5.22: Beetroot and radish oven drying at 60°C after 30% ACV solution
osmotic treatment**

TIME (min)	Beetroot			Radish		
	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)	WEIGHT (g)	MOISTURE CONTENT wet basis (%)	DRYING RATE (kg/hr)
0	76	76.32	-	74	86.49	-
10	75	75	0.006	72	83.78	0.012
20	72	71.05	0.012	67	77.03	0.021
30	57	51.32	0.038	53	58.12	0.032
40	49	40.79	0.041	36	35.14	0.057
50	45	35.53	0.037	34	32.43	0.048
60	43	32.89	0.033	32	29.73	0.042
70	42	31.58	0.029	31	28.37	0.037

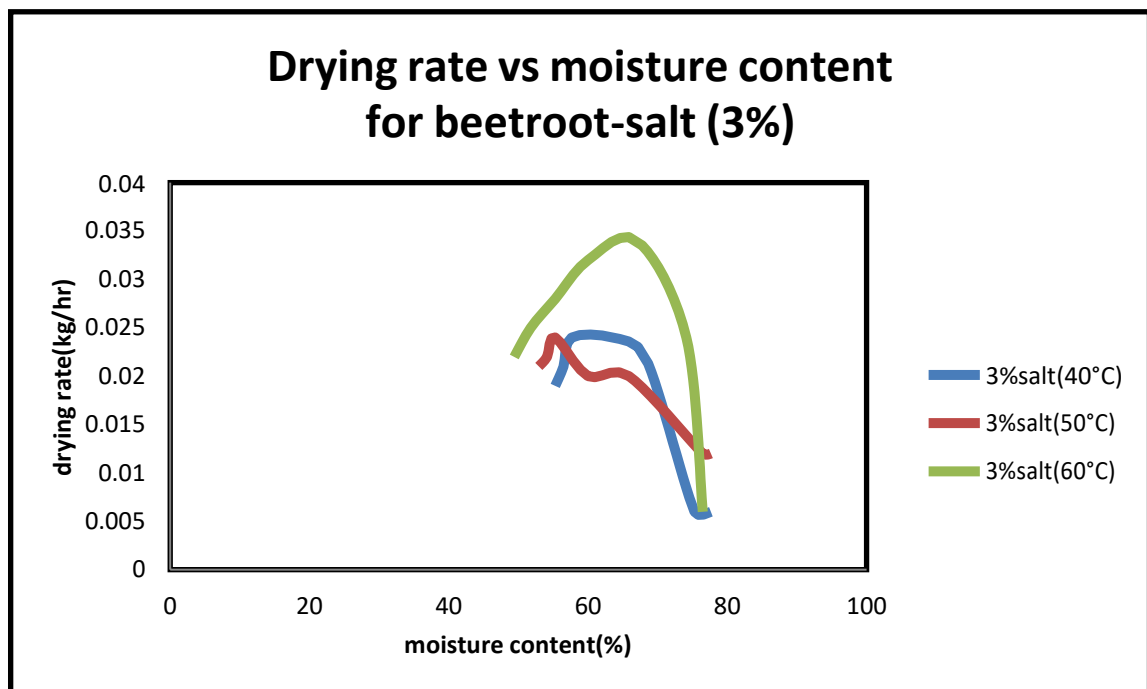


Fig 5.13: Graph of drying rate vs. moisture content of beetroot-salt (3%)

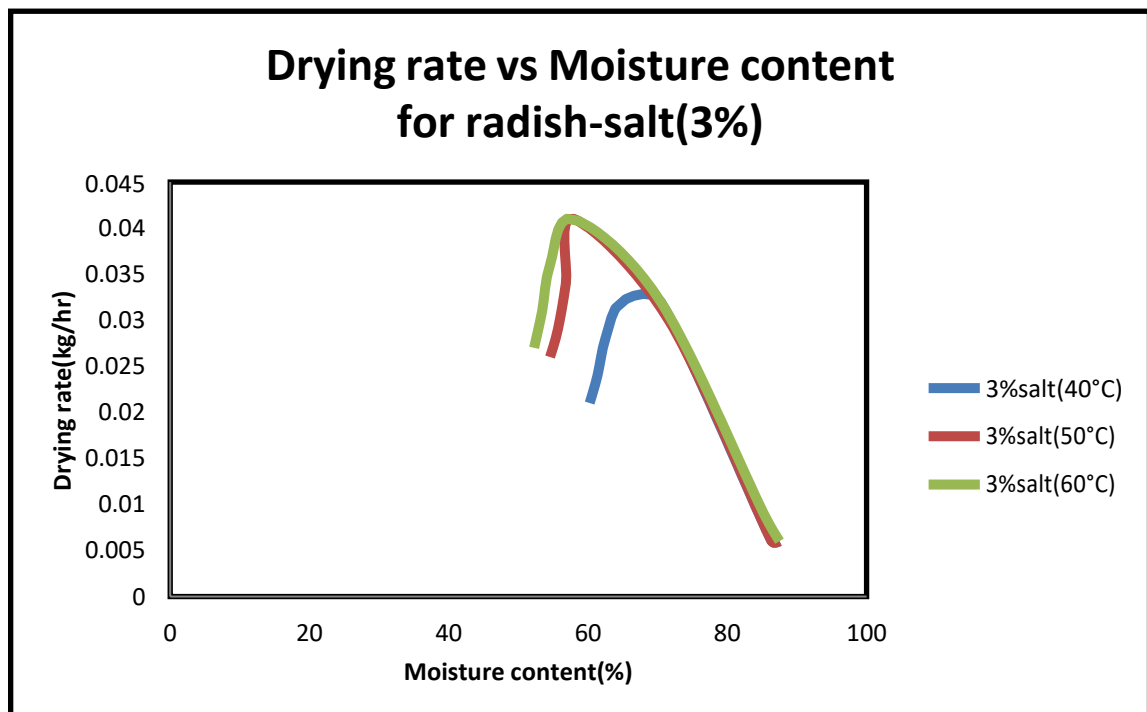


Fig 5.14: Graph of drying rate vs. moisture content of radish-salt (3%)

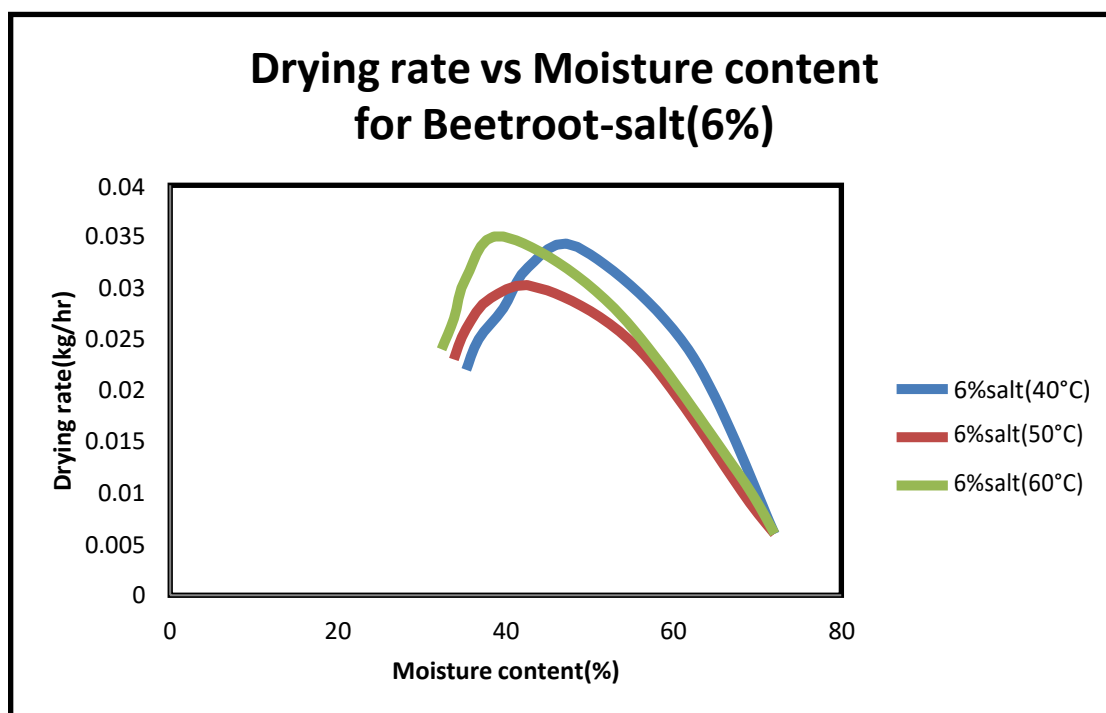


Fig 5.15: Graph of drying rate vs. moisture content of beetroot-salt (6%)

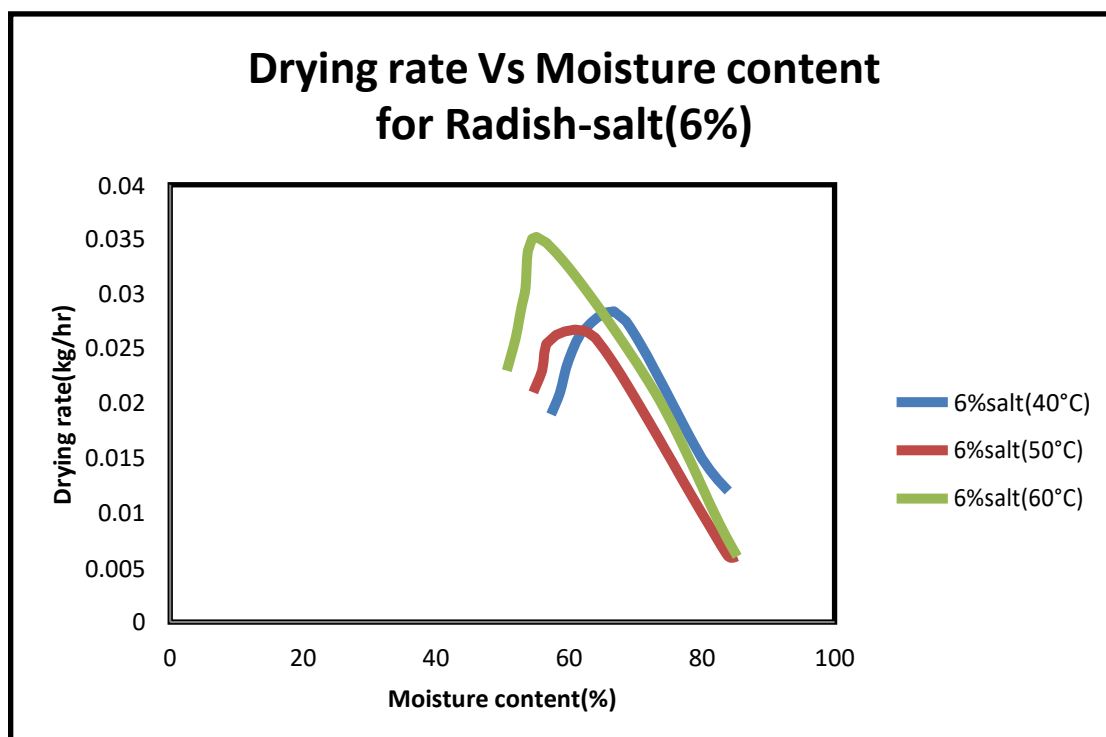


Fig 5.16: Graph of drying rate vs. moisture content of radish-salt (6%)

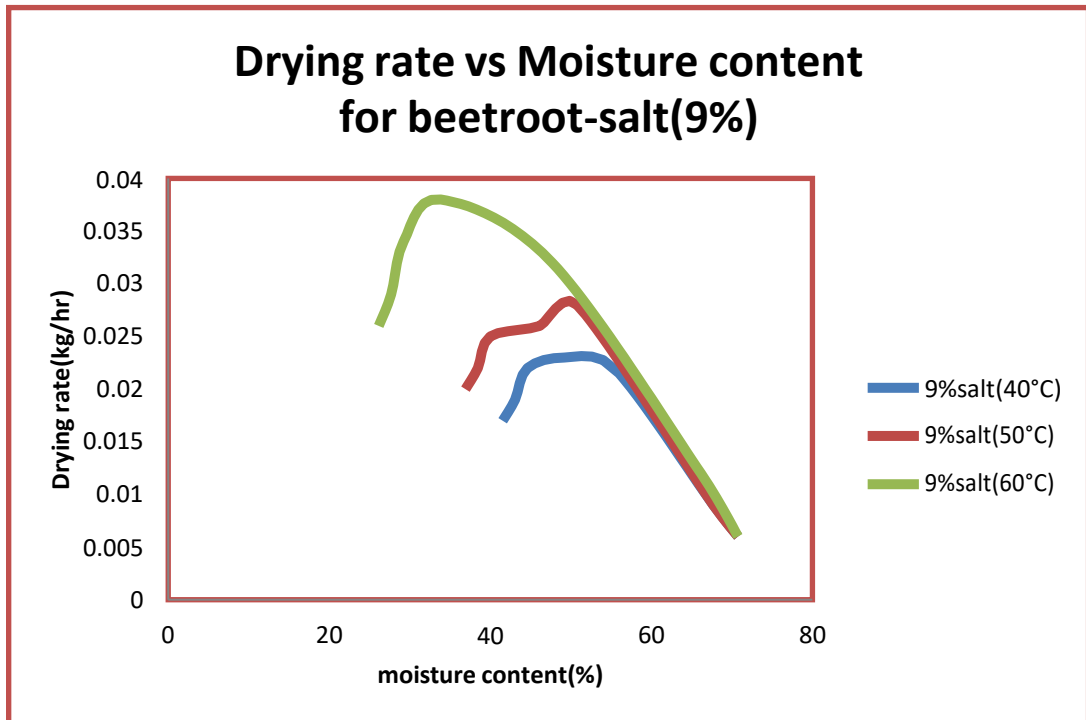


Fig 5.17: Graph of drying rate vs. moisture content of beetroot-salt (9%)

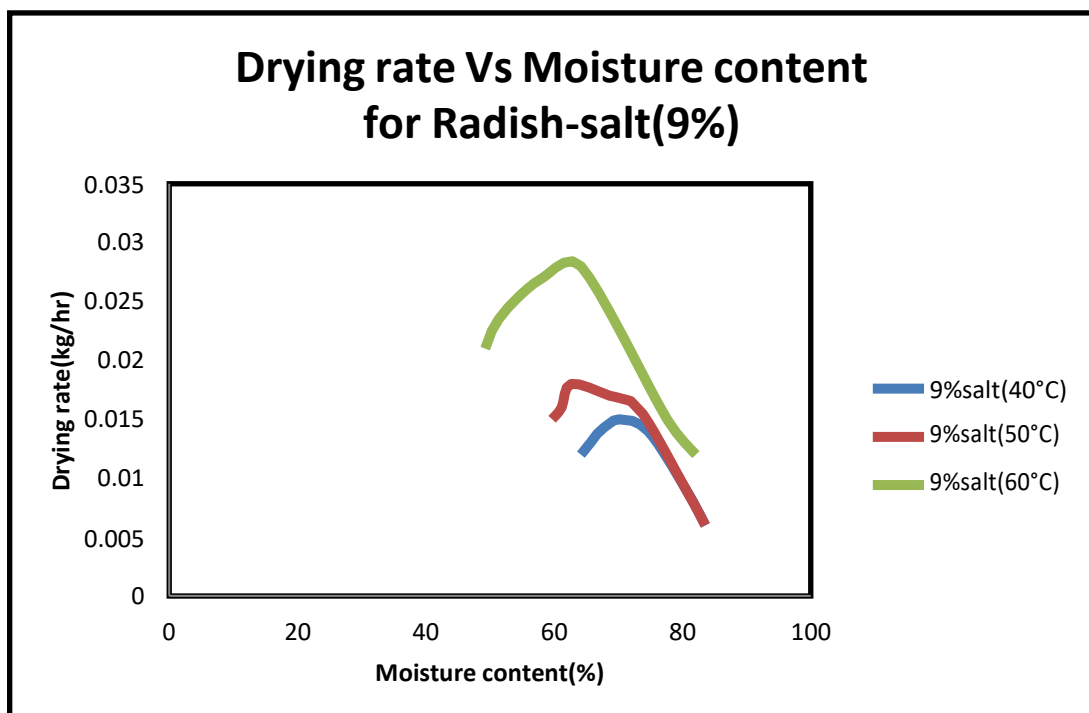


Fig 5.18: Graph of drying rate vs. moisture content of radish-salt (9%)

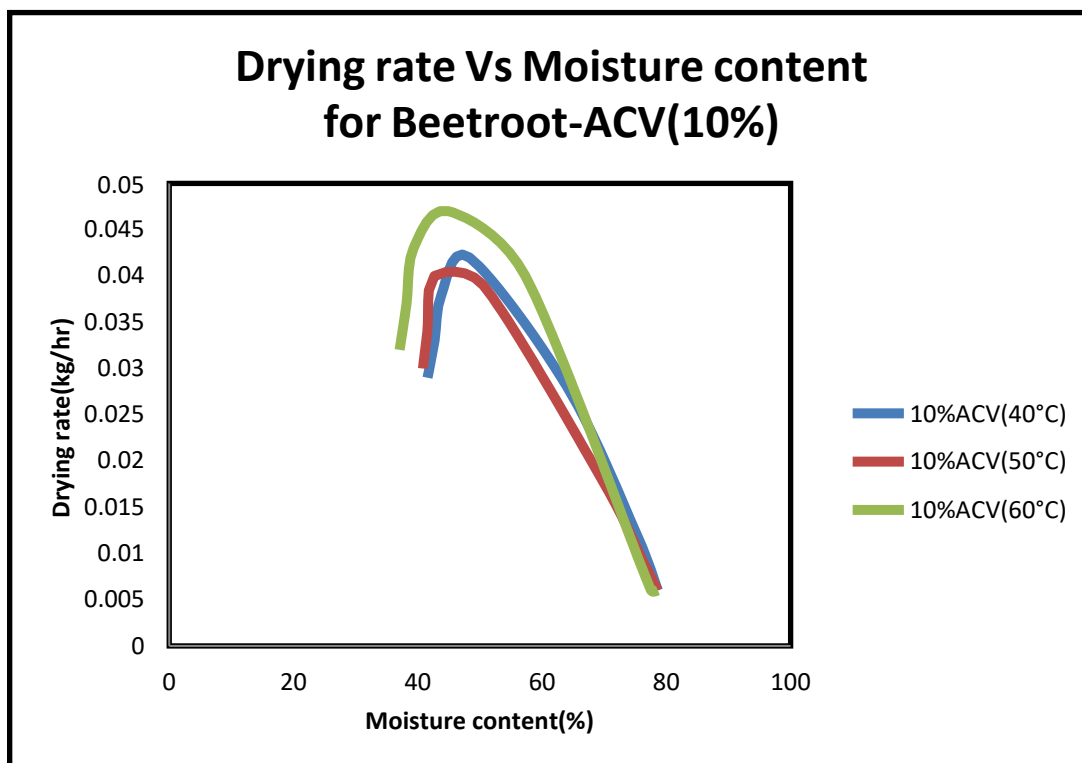


Fig 5.19: Graph of drying rate vs. moisture content of beetroot-ACV (10%)

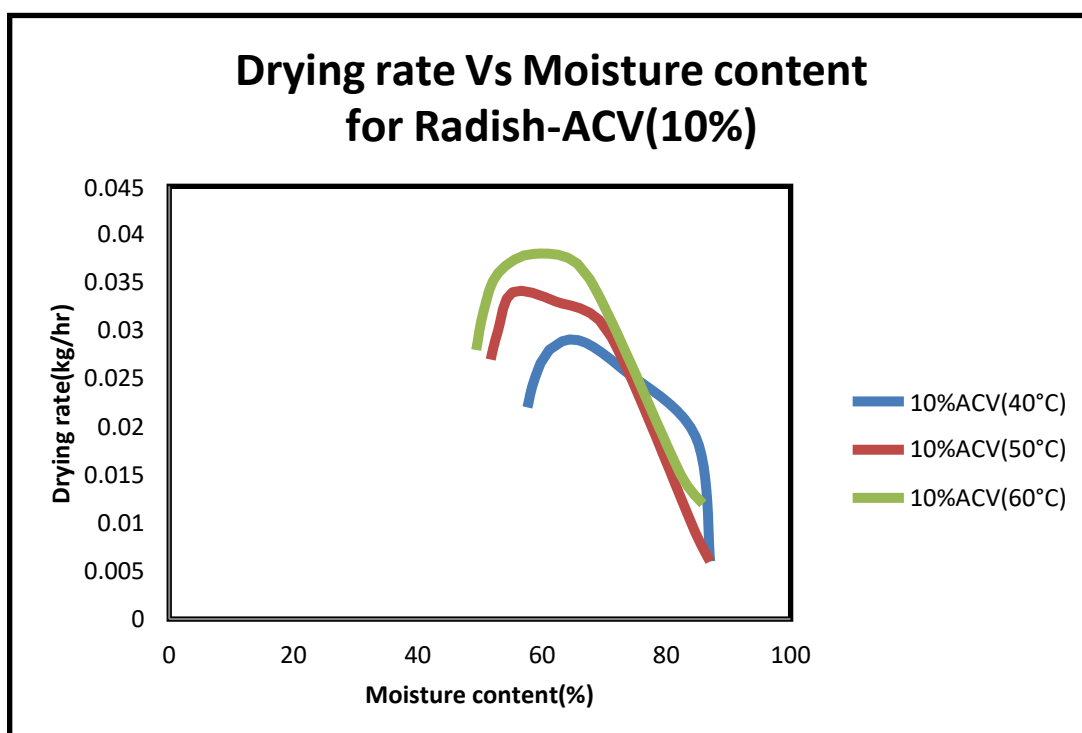


Fig 5.20: Graph of drying rate vs. moisture content of radish-ACV(10%)

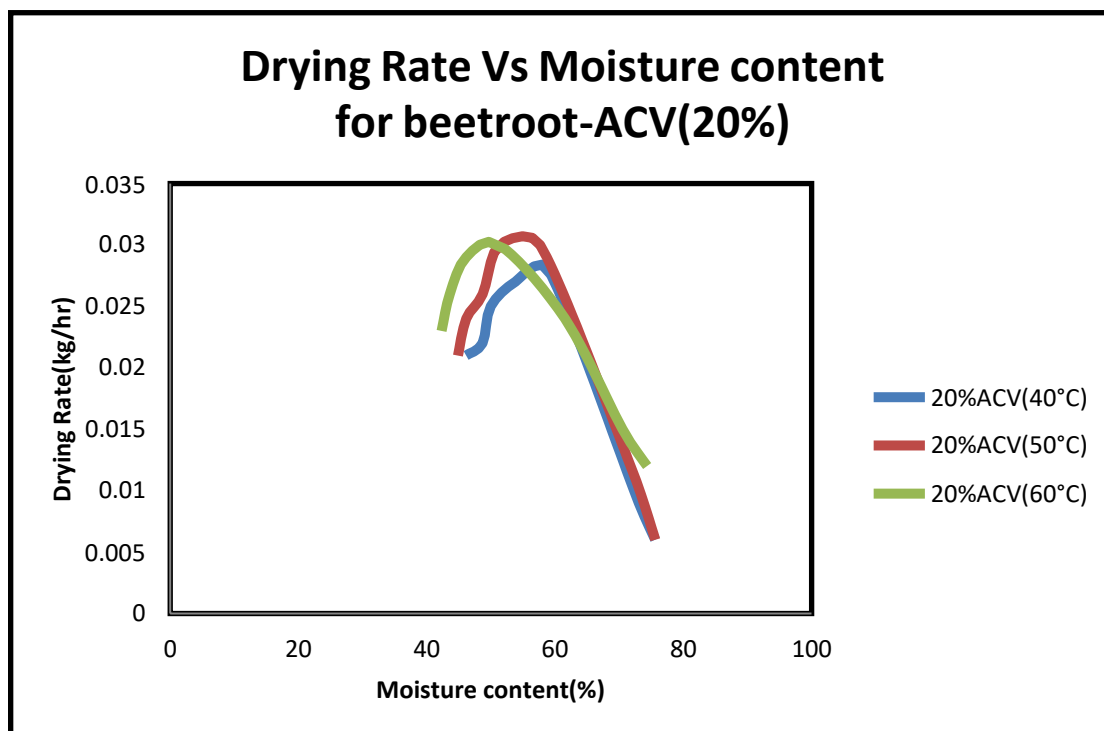


Fig 5.21: Graph of drying rate vs. moisture content of beetroot –ACV (20%)

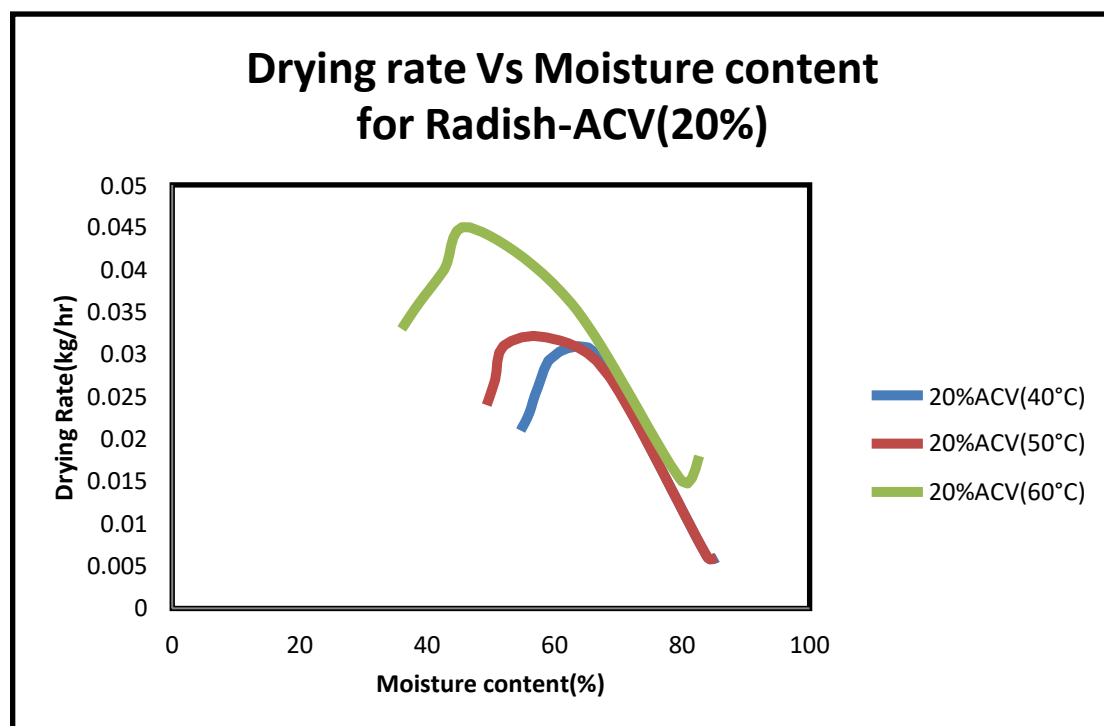


Fig 5.22: Graph of drying rate vs. moisture content of radish-ACV (20%)

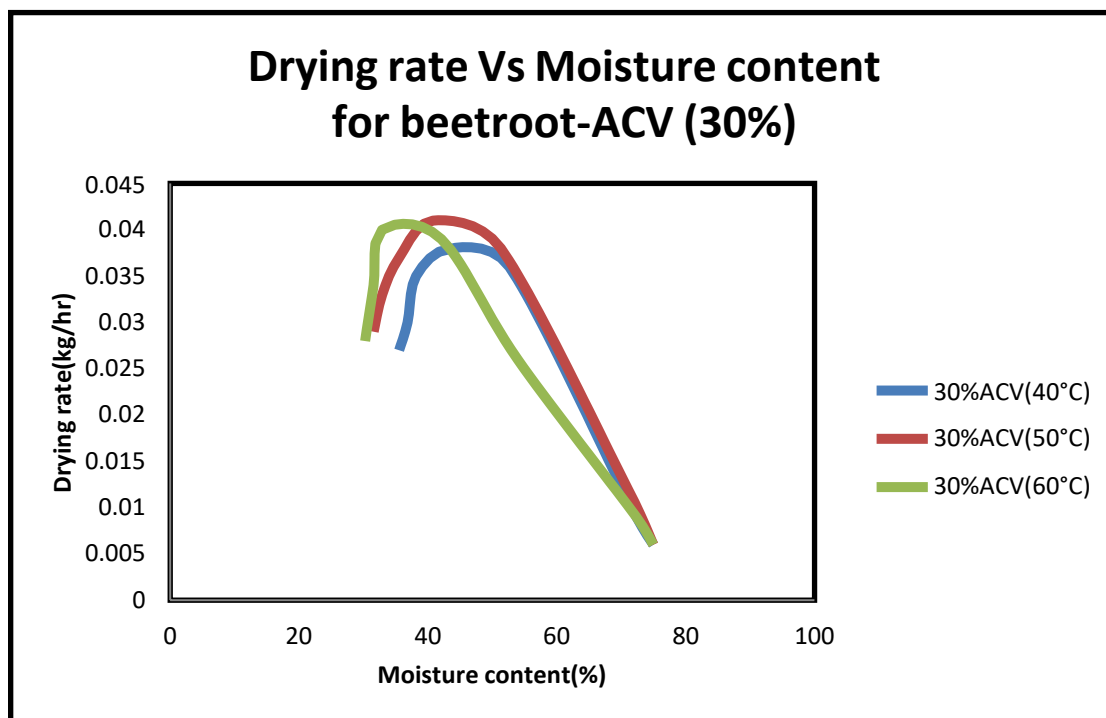


Fig 5.23: Graph of drying rate vs. moisture content of beetroot-ACV (30%)

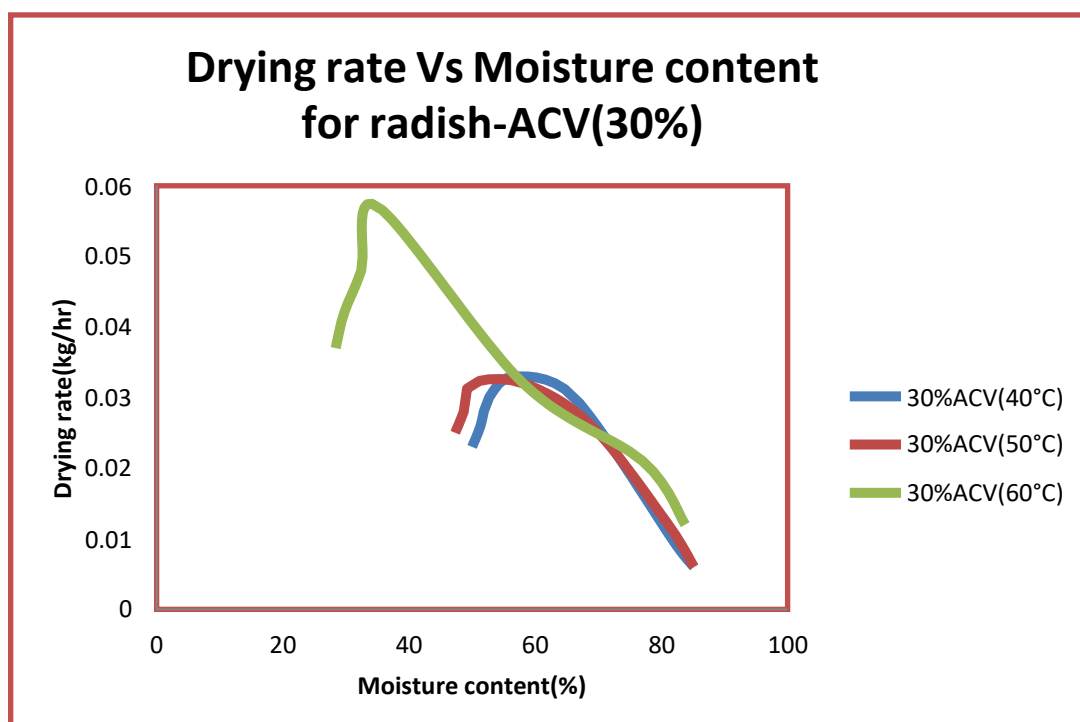


Fig 5.24: Graph of drying rate vs. moisture content of radish-ACV (30%)

5.3 ORGANOLEPTIC EVALUATION

The optimal conditions for Beetroot is found to be - Salt solution as osmotic agent, concentration – 9%, oven drying temperature - 60°C & that for Radish is found to be – Apple Cider Vinegar as osmotic solution, concentration - 30%, oven drying temperature - 60°C.

Quality characteristics of osmotically dehydrated samples were determined based on the organoleptic evaluation of the optimized sample. The overall acceptability of osmo-dehydrated samples at optimized condition was evaluated by ten trained panel members with all age groups. The samples were served to the panelists in plastic plates and mentioned with three-digit randomly selected code numbers. All the panel members appraised the odour and taste of the samples using the technique of quantitative descriptive analysis (QDA) with a hedonic scale (9-1), from extremely likeable (9) to extremely dislikeable (1). The maximum acceptability was observed for salty beetroot under process conditions of 9 w/w% concentration, 60°C temperature and sour radish under process conditions of 30 w/w% concentration, 60°C temperature.

5.4 NUTRITIONAL ANALYSIS

The samples are submitted to the Chennai Testing Laboratory Private Limited- Guindy for undergoing nutritional analysis.

Table 5.23: Sample details 1

Sample description by customer	Beetroot-Osmotic dried		
Quantity Received	35g	Sampled by	Customer
Date of receipt	03.03.2021	Sample condition	Good & received in packed condition
Analysis starting date	04.03.2021	Analysis completion date	10.03.2021

Table 5.24: Test details of Beetroot

Sl.No	PARAMETERS	METHOD	UNITS	RESULTS
1	Carbohydrate(by difference)	CTL/SOP/FOOD/262-2014	g/100g	21.9
2	Protein	AOAC 20 th Edn.2016,986.25	g/100g	5.70
3	Dietary fiber	AOAC 20 th Edn.2016,985.29	g/100g	12.1
4	Calcium as Ca	IS 5949:1990(RA.2003)	mg/100g	44.7
5	Magnesium as Mg		mg/100g	66.3
6	Iron as Fe	AOAC 20 th Edn.2016,999.11	mg/100g	8.72

Table 5.25: Sample details 2

Sample description by customer	Radish-osmotic dried		
Quantity Received	37g	Sampled by	customer
Date of receipt	03.03.2021	Sample condition	Good & received in packed condition
Analysis starting date	04.03.2021	Analysis completion date	10.03.2021

Table 5.26: Test results of Radish

Sl.No	PARAMETERS	METHOD	UNITS	RESULTS
1	Carbohydrate(by difference)	CTL/SOP/FOOD/262-2014	g/100g	13.1
2	Protein	AOAC 20 th Edn.2016,986.25	g/100g	2.03
3	Dietary fiber	AOAC 20 th Edn.2016,985.29	g/100g	7.30
4	Calcium as Ca	IS 5949:1990(RA.2003)	mg/100g	91.4
5	Magnesium as Mg		mg/100g	51.2
6	Iron as Fe	AOAC 20 th Edn.2016,999.11	mg/100g	6.53

CHAPTER 6

CONCLUSION

The present study involved the preparation of products from beetroot & radish which has greater shelf life using osmo-convective drying method. This method is basically two major subjects in Chemical engineering. The first one is a membrane separation process – “osmosis” & the second one is a unit operation – “drying”. In this research, we have dehydrated taproots by osmosis using two different osmotic agents (salt and ACV), followed by oven drying at three different temperatures - 40, 50, 60°C. Taproots were chosen as per the percentage of moisture present in them and their health benefits. Beetroot and Radish have high water content and they are fibrous vegetables. Although salt is a common osmotic solution but ACV is a novel one to be used as osmotic agent. Solutions of different concentration were taken to carry out the experiment. Initially, increase in osmotic solution concentration enhanced the mass transfer properties (weight reduction, solid gain and water loss). This is due to the fact that lighter solute particles vigorously penetrate into the semi permeable membrane (taproot outer layer) and enhanced the outflow of water from the inner tissue rapidly to the osmotic solution.

The moisture content of the samples decreased with the increase of drying temperature. The reduction in moisture content was fast initially and then decreased slowly. This is due to the presence of free and unbound moisture present in the samples. As the drying process continues, the inner pores occupied by the infusion of solutes give resistance for the water outflow and hence slows down the water removal. The coating of the osmotic agent has enabled a better taste, texture, flavour and colour of the vegetable as compared to the conventional dried taproots or the ones undergoing enzymatic browning. This has increased the overall acceptability of the product.

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