

**Effect of pretreatment, drying method and cooking medium on
yield, quality and storability of potato sticks**

**THESIS
SUBMITTED TO THE**

**Sardar Vallabhbhai Patel University of Agriculture and
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Dedicated

To

My beloved parents

Mr. Patram Singh

&

Mrs. Maya Devi



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CERTIFICATE

This is to certify that the thesis entitled “**Effect of pretreatment, drying method and cooking medium on yield, quality and storability of potato sticks**” submitted in partial fulfillment of the requirements for the degree of **Master of Technology** with major in **Agricultural Process and Food Engineering** and minor in **Agriculture Biotechnology** of the College of Post Graduate Studies, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, is a record of *bonafide* research carried out by **Mr. Rahul Kumar, Id. No. 3695**, under my supervision and no part of the thesis has been submitted for any other degree or diploma.

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(Vivak Kumar)

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CHAPTER-I



INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the unique and most potential crops having high productivity, supplementing major food requirement in the world. It is rich in carbohydrates, proteins, phosphorus, calcium, vitamin C, β -carotene and has high protein calorie ratio. Among the world's important food crops, Potato is the fourth important food crop after wheat, rice and maize because of its great yield potential and high nutritive value. India ranks fourth in area with 14 lakh hectares and the third largest country in the world in production of potato after China and Russian federation with a production of 294.94 million tonnes and productivity of 17.86 tonnes per hectare. The major commercial variety grown in Kashmir is "Kufri Jyoti" which is very suitable for instant flacks and chips. So there is a huge scope for the processing industries of potato in kashmir. It is a high moisture food which is rich in enzyme namely peroxidases and cannot be sun-dried, as the traditional sun drying is a slow process and makes such food materials susceptible to fungal growth. It may also result in the loss of product quality from color degradation, microbial growth and poor rehydration etc (Faisal *et al.*,2013)

Potato is one of the major crops, being ranked second after grain in our country and worldwide. Potato is the staple food for many people and has a high percentage in the economic balance of many countries, and it is considered as the second bread. In food industry, it is used to obtain potato flour, flakes, dehydrated potatoes (which are used for purees and bread), and chips. Potato is used in starch industry, alcohol and chemical industry. Also, potato is used in animal feed as such or as draff from the production of starch and alcohol. It has become an integral part of breakfast, lunch and dinner among

the larger population. Being a short duration crop, it produces more quantity of dry matter, edible energy and edible protein in lesser duration of time compared to cereals like rice and wheat. Hence, Potato is considered to be an important crop to achieve nutritional security of the nation. It can be processed into variety of products such as cubes, chips, flakes, granules, powder, French fries and dehydrated dice. In India, Potato processing industry mainly comprises four segments: Potato chips, French fries, Potato flakes/powder and other processed products such as dehydrated chips, AluBhujia, Samosa, and Tikkis. **(Fao, 2017)**

Drying is a process of removing water from food and agricultural products and constitutes a significant portion of the processing activity for persons working in the food and agricultural processing industries. Potato tuber is a living organism, whose physiological activity does not stop even during storage. Due to its high water content, losses during storage are quite high. Drying is the process of removal of water from a solid, semi-solid or liquid material. It is a thermo-physical and physico-chemical process whose dynamic principles are governed by heat and mass transfer laws, both inside and outside the products. In the most common cases, a gas stream, like air stream, applies the heat by convection and carries away the vapor as humidity. The medium used for drying the food i.e. hot air in convective drying has a low value of water vapor pressure at high temperature; which creates a vapor pressure gradient. Drying is generally carried out for two main reasons, one to reduce the water activity which eventually increase the shelf life of food and second to reduce the weight and bulk of food for cheaper transport and storage. **(Chavhan et al, 2018).**

Potatoes are the fourth most important vegetable crop for human nutrition in the world. Food drying is the most important process for preserving agricultural products since it has a great effect on the quality of the dried products **(Doymaz, 2004)**. Potato chips have been popular snacks for more than a century **(Pedreschiet *al.*, 2005)** and its production is indeed a more competitive industry than other snack productions **(Garayo and Moreira, 2002)**.

Drier process improves the food stability, since it reduces considerable the water and microbiological activities of the material and minimizes physical and chemical changes during its, storage **(Hatamipour, 2007)**. Drying is the most energy intensive process in food industry. Therefore, new drying techniques and dryers must be designed and studied to minimize the energy cost in drying process **(Kocabiyik and Tezer, 2009)**.

During the frying process, physical, chemical and organoleptic properties of food are changed, The main goal of deep fat frying is to maintain tenderized and crispy shapes. Oil content is one of the important quality attributes in fried products. Fried potato products with low fat content have a hard and unfavorable texture. On the other hand high oil consumption is not cost effective. For manufacturers and consumers, products with high oil content are high fatty acid and tasteless. Today, consumers demand food products with lower fat content. Oil absorption during deep fat frying is controlled by parameters including oil quality, frying temperature and time. Deep -fat frying is one of the oldest processes of food preparation which consists basically immersion of food pieces in hot vegetable oil. The high temperature causes partial evaporation of the water, which moves away from the food and through the surrounding oil. **(Santis *et al.*, 2007)**

Frying time, food surface area, moisture content of food, types of breading or battering materials, and frying oil influence the amount of absorbed oil to foods (**Moreira et al., 1997**). The oil contents of potato chips, corn chips, tortilla chips, doughnuts, french fries, and fried noodle (ramyon) were in the range 33% - 38%, 30% -38%, 23% - 30%, 20% - 25%, and 10% - 15% (**Moreira et al., 1999a**), and 14% (**Choe et al., 1993**), respectively.

Frying can be considered a dehydration operation in which a simultaneous heat and mass transfer occurs giving two counter-fluxes, i.e., a water outlet from the food to the hot oil and an oil inlet by the food (**Krokida et al., 2000**), leading to series of physical and chemical changes in the final product. Despite undergoing the large gain of oil during processing of the product, frying is a widely used domestic and industrial cooking technique because of its ability to generate, in the final product, a combination of texture, color, and unique flavor that makes it a more palatable and desirable food for the consumer (**Mestdagh et al., 2008; Shaker, 2015**).

Deep fat frying is a simultaneous heat and mass transfer process which leads to a succession of physical and chemical changes in the product (**Hindra and Baik 2006**).The fried products have an attractive colour (golden brown), distinctive mouth feel, pleasant taste as well as fried flavour and unique textural properties (crispy crust formation). Deep frying is a cooking method in which the food is submerged in hot oil or fat. This is normally performed with a deep fryer or chip pan. Industrially, a pressure fryer or vacuum fryer may be used (**Peluola et al., 2015**).

Frying is often selected as a method for creating unique flavours and texture in the processed foods that improve their overall palatability (**Moyano and Pedreschi 2006**).

With starchy products, water and some soluble materials escape from the products and oil enters in the food (**Blumenthal 1991**). Sometimes, even fat can escape from the product in the oil bath during the frying of raw material presenting a significant fat content such as meat or fish (**Oroszvari et al. 2005**). During deep-fat frying, starch gelatinisation and swelling occur very rapidly, thus making the potato cells with a dense starchy interior capable of supporting dehydration with shrinkage (**Ziaifar et al. 2008; Huang et al., 2014**)

Potatoes are the most important ones from a point of view of market share. Frying may be seen as a high temperature drying process in a liquid fat medium. A dry surface crust is formed and a 103°C isotherm evolves towards the centre (**Pravisan and Calvelo, 1986**). Fat absorption into the voids created by the release of vapour occurs when the slice is removed from the frying medium as a result of a pressure drop, caused by the cooling of the product (**Ufheil and Escher, 1996; Gamble and Rice, 1987**). Thus some fundamental models were however reported in literature (**Farkas, 1994; Ngadi, Watts and Correia, 1997**) considering internal diffusion as the controlling step. These models provide a greater scientific insight, yet they are still based on oversimplified assumptions and the use of complex numerical methods, thus having high requirements in terms of computer software and time.

Deep-fat frying is a multifunctional operation of food transformation. This process may be defined as cooking food by immersion in edible oil or fat at a temperature above the boiling point of water (**Hubbard and Farkas, 2000**).

Deep-fat frying remains a complex operation because of the two mass transfers in opposite directions within the material being fried: for starchy products, water and some

soluble material escape from the products and oil enters the food (**Blumenthal and Stier, 1991**). Sometimes, even fat can escape from the product in the oil bath during frying of raw material presenting a significant fat content, such as meat or fish (**Oroszvari et al., 2005; Aman et al., 2007**).

High oil content is a major factor affecting consumer acceptance of oil-fried products today and the low fat food products are becoming more popular (**Bunger et al., 2003; Mai Tran et al., 2006**). Oil consumption especially saturated fat is considered a major factor increasing health risks such as coronary heart disease (CHD), cancer, diabetes and hypertension, and even linked to increased causes of deaths. The most common sequence is cutting / blanching / drying / pre-frying / freezing / chilling – packing / thawing. Each step may be important for the final product quality. The fat uptake varies with the pre-treatment of the potato. Blanching reduces the subsequent cooking time. Blanching also makes the colour more uniform after frying and it forms a layer of gelatinized starch that limits oil absorption and improves texture (**Moreira, 1999; Kampuse et al., 2014**).

Consumers today are more interested in health related food products, and the interest in functional foods continues to grow, powered by progressive research efforts. The recent trend in reducing the fat content in fried foods is leading to the development of low-fat products. Many attempts have been made to reduce oil uptake during deep-fat frying. There are several prefrying procedures have been proposed to reduce the amount of absorbed oil in fried potatoes to make such products more acceptable to health conscious consumer (**Pedreschi and Zuniga 2009**).

An alternative to reduce oil uptake in fried foods is the use of edible films or coatings. The application of hydrocolloid coatings allows reducing oil content of deep-fat fried products due to its lipid barrier properties; the most widely studied are coating materials were gellman and cellulose derivatives (**Mellema 2003, Williams and Mittal, 1999**). Frying oil influences many qualities of the finished product such as flavor, texture, shelf life and nutritional attributes (**Ali et al., 2012**).

Importance of the study:

India is one of the largest snack markets in the Asia-Pacific region contributing three per cent to the total Asia-Pacific snack market share. There is a huge potential for processed potato products such as Potato chips, Wafers, Potato flakes, Potato Powder, Frozen Potatoes, and Frozen French Fries etc in India. To meet the burgeoning demand, Potato processing is emerging as a fastest growing industry with the entry of numbers private players.

Objectives:

1. To study the effect of pretreatments on drying characteristics of the potato sticks.
2. To study the effect of pretreatments and drying on fried potato sticks.
3. To study the effect of packaging on fried potato stick during storage.

CHAPTER-II



***REVIEW
OF
LITERATURE***

Potato (*Solanum tuberosum* L) is a nourishing food that has sustained civilizations for centuries in South America and Europe. Potato production has significantly increased in recent years in many countries, particularly in Asia where it has become more important as a food and industrial crop. In terms of the number of producing countries, potato is fourth after wheat, rice and maize. About one half of the world's potato production is being used as human food. Though India is the third largest producer in the world after China and Russian Federation, Today, a wide variety of potatoes and potatoes products are consumed in the home and at workplace. In this chapter, an attempt has been made to review the research work done in India and abroad related to the present investigation on **“Effect of pretreatment, drying method and cooking medium on yield, quality and storability of potato sticks”** and presented under following heads:

Costa et al., (1997) reported the dependence of the heat transfer coefficient (h) on the water loss rate of potato during frying. An indirect method was used where a metal piece with the same geometry of the potato pieces was placed on top of various potato samples at different frying times, and its temperature was recorded for 20 ± 30 s. Another method consisted of direct recording of the temperature within a potato slice, close to the surface. Water loss rate was estimated by image analysis of bubbles. After immersion in hot oil, the potato temperature increases and water starts vapourising, leaving the surface in the form of bubbles that flow through the oil. The water loss rate increases until complete drying of the potato surface and then decreases till the end of frying.

Garayo (2002) evaluated oil temperature and vacuum pressure had a significant effect on the drying rate and oil absorption rate of potato chips. Potato chips fried at lower vacuum pressure and higher temperature had less volume shrinkage. Color was not significantly affected by the oil temperature and vacuum pressure. Hardness values increased with increasing oil temperature and decreasing vacuum levels. Potato chips fried under vacuum (3.115 kPa and 144⁰C) had more volume shrinkage, were slightly softer, and lighter in color than the potato chips fried under atmospheric conditions (165⁰C). It was concluded that vacuum frying is a process that could be a feasible alternative to produce potato chips with lower oil content and desirable color and texture.

Supardan and Satriana (2007) were fried may be a good alternative for the production of dehydrated fruit and vegetable slices. In this study a relationship between water losses with frying time during vacuum frying process of potato chips was developed. A first order kinetic model was used, in which drying rate constant is a function of the main process variables i.e. oil temperature, sample thickness and vacuum pressure.

Seidu *et al.*, (2012) conducted on the suitability of processing sweet potato tubers into chips using locally constructed solar panels within the semi forest and the transitional climatic zone of Ghana. The study was done during the months of November, 2010 and January, 2011 and seven designed solar panels were used. The panels were constructed using hard wood, binding materials (nails), chicken mesh, nylon net and black and white polythene sheets. Drying was observed to be faster in the panels with their drying platforms covered with the chicken mesh and nylon net (5 and 6 days) than those with their drying platform lined with the black polythene sheets (2 and 3 days) for

October, 2010 and January, 2011 respectively. The chips dried on the chicken mesh and nylon drying platforms looked whiter and more appealing to the eye than those dried on the black polythene sheet platform due to moisture condensation that encouraged mould growth before drying. The open air dried cassava appeared darker since the sweet potato got mouldy before drying.

Chayjan (2012) revealed the high moisture potato slices with initial moisture content of about 4.06 (db) under thin layer fixed, semi fluidized and fluidized bed conditions were studied. Drying air temperatures of 40, 50, 60 and 70°C were applied in experiments using a laboratory fluidized bed convective dryer. In order to predict the drying behavior of potato slices, seven thin layer drying models were applied from where finally **Midilli *et al.*, (2002)** model was selected as the suitable one, based on comparative indices. Effective moisture diffusivity of the potato slices varied between 4.29×10^{-9} and 15.70×10^{-9} m² s⁻¹ for fixed and fluidized bed conditions, respectively. Moisture diffusivity values of the slices were increased as the drying air temperature levels increased.

Truong *et al.*, (2010) evaluated operations involved in these technologies and their effects on quality, storability, nutritional values and rheological properties of sweet potato purees and powders/flours. For purees, the processing steps include peeling, cutting/grinding, and pre-cooking finish-cooking with temperature-time program suitable for starch conversion by endogenous amylolytic enzymes to obtain the products with targeted maltose levels and viscosities. frozen products and limited package sizes of these preserved forms are the main hurdles for widespread applications of sweet potato purees in the food industry. These problems can be overcome by a new process using a

continuous flow microwave system for rapid sterilization and aseptic packaging to produce shelf-stable purees with consistently high quality.

Chavhan *et al.*, (2018) reported that drying is an important technique to remove the moisture of the product. Various drying techniques are employed to dry different agricultural products. Each technique has its own advantage and limitation. So, choosing the right drying techniques is very important in the process of drying. The raw agricultural products with 80-90% moisture content are brought down to equilibrium moisture content for keeping in the short or long term storages. Present works involves the study of the effect of various process parameters on drying behavior of Potato.

2.1 Pretreatments:

2.1.1 Blanching:

Smith (1977) studied that blanching improves in the reduction of oil adsorption French fries that had been blanched, then dried with air at 2% relative humidity (RH), showed a lower fat uptake than the undried fries. They concluded that when drying with air, at 2% RH, a skin was formed that reduced the ability of fat to penetrate into the product.

Toma *et al.*, (1986) found that partial surface freezing (-20 °C for 25 min) of ‘Russet Burbank’ chips resulted in more oil absorbed during pre-frying but less oil during finish- frying, compared with untreated samples. The overall oil content was lower in the partially frozen French fries and they contained less reducing sugar and ascorbic acid and were lighter in color than the untreated samples.

Anderson *et al.*, (1994) investigated the synergistic effect of de-oiling process and pretreatments with blanching in hot water and soaking in NaCl solution. In the

commercial production of French fries, blanching helps control the color, the texture and some extent, the flavor of the final product. The heat treatment step of blanching affects the typical potato cell by membrane so water enter the cells and the intercellular spaces, expelling gases and other volatiles, and there is also a loss of water soluble nutrients (sugars, vitamins, and minerals) to the blanch water. There are also profound changes that occur during blanching at temperatures between 66-73 °C to alterations of the pectin material in the potato.

Pedreschi *et al.*, (2009) studied the kinetics of color development in blanched and blanched-NaCl impregnated potato slices during frying by using the dynamic method and also to evaluate the effect of NaCl in reducing acrylamide formation in potato chips. The measurement of color was done by using an inexpensive computer vision technique which allowed quantifying in a more precise and representative way the color in units of complex surfaces such as those of potato slices during frying. The effect of potato slice soaking in NaCl was evaluated not only for color change but also for acrylamide formation. Prior to frying, potato slices (Desiree variety, diameter: 37 mm, width: 2.2 mm) were blanched in hot water at 85 C for 3.5 min; these slices were considered as the control.

Arya *et al.*, (2017) were conducted to develop the potato French fries using five pre-treatments (blanching with 3%Nacl, 0.5% KMS, 3% NaCl+0.5% KMS and 0.5% CaCl₂) and frying with three type of oil (mustard oil, refined oil & sunflower oil,) for 50-200 sec. then packed into aluminum foil packaging. Mass transfer phenomena, water loss and oil uptake take place during frying of potato strips can be described by an empirical first order kinetic model. Water loss and oil uptake phenomena are getting more intense

at higher temperatures and thinner sample. The rates of both mass transfer phenomena that take place during the frying of potato strips decrease due to the drying or pretreatment before frying. French fries soaked in a 3% NaCl solution usually resulted in the reduction of oil uptake by at least 10% compared to the non-pre-treated samples. Blanching in hot water usually decreased the yellowness of final products, compared to non-pretreated samples. In overall study and sensory evaluation, the treatment viz. 3% NaCl + 0.5% KMS at 90 °C for 3 min gives best result among other.

2.1.2 Soaking:

Sandhu and Parhawak (2002) studied that the various pre-treatments given to potato cubes, the soaking in 0.2 per cent metabisulphite, blanching in two percent brine for two minutes, blanching in two per cent brine for two minutes followed by soaking in 0.2 per cent KMS treatment produced dehydrated potato cubes with high rehydration ratio (3.49:1) and low non enzymatic browning of 0.36 OD.

Bunger *et al.*, (2003) observed that Soaking in NaCl can also decrease fat content and improve the quality of French fries. The soaking the solid food in a NaCl solution before frying is a simple pretreatment to control the surface of the potato so that the solute penetrates into the surface preventing water loss by osmotic dehydration. Soaking potato strips in NaCl solution under the best conditions (3% w/w NaCl concentration and 50 min soaking time) decreased oil uptake and increased hardness of French fries, without changing color, moisture content, and sensory acceptability. Many approaches to reduce oil absorption in fried products have been reported in the literature. For instance, soaking of potato strips in NaCl solutions reduced oil uptake in French fries.

Faisal *et al.*, (2013) were conducted to characterize the drying behavior of Potato cubes at various temperatures, potato cube sizes and blanching chemical treatments. The various drying models were evaluated for their suitability and Midilli's model was found to be best describing the drying characteristics of Potato cubes. A full second order model was developed for all the response variables, viz. Rehydration ratio, shrinkage percentage and mean sensory scores of overall acceptability and found to be significant at 1% level of significance.

Velescu *et al.*, (2013) Studied the drying parameters of the potato, as regards to the temperature of the drying and how partitions (slices, cubes) without any pre-treatment. The parameters of drying agent were temperature of the drying was (50°C, 60 °C and 70 °C), the initial moisture content of the air was (30 to 35%), the rate of drying agent was kept constant at (2.0 m/s). The time was set so that at the end of the drying the moisture content of the product to have a value of 14%. Data drying was determined experimentally using a vertical laboratory dryer. Potatoes in the form of cubes and dried at 70 °C were reached at a moisture content of 14% in a shorter time than the products being divided in the form of rings.

Arya *et al.*, (2015) were conducted to develop the potato French fries using five treatments and different types of oil for frying. Pre-treatments are blanching with 3%NaCl, 0.5% KMS, 3% NaCl+0.5% KMS and 0.5% CaCl and frying with three different type of oil (mustard oil, refined oil, sunflower oil,) frying at 50-200 sec. The fried French fries packed into aluminum foil, HDPE packaging. On the basis of results revealed the following conclusions were drawn. Mass transfer phenomena, water loss and oil uptake take place during frying of potato strips can be described by an empirical first

order kinetic model. Water loss and oil uptake phenomena are getting more intense at higher temperatures and thinner sample. The rates of both mass transfer phenomena that take place during the frying of potato strips decrease due to the drying or osmotic pretreatment before frying.

2.2 Frying

Frying is the process where food is placed in hot oil, the surface temperature rises rapidly and water is vaporised as steam. During frying, water & water vapour are removed from the larger capillaries & replaced by hot oil. Moisture moves from the surface of the food through a boundary film of oil. The thickness controls rate of heat and mass transfer

Pinthus *et al.*, 1993; and Reeve and Neel (1960) studied that the process of frying involves the loss of water and the absorption of oil; strongly associated with this loss of water and oil absorption is the formation of a crust.

Farkas *et al.*, (1996) studied that during frying, the surface of potato heats up to water boiling temperature and water starts to vaporize. As frying progresses, the crust/core interface moves towards the center of the product. The crust becomes thicker and the core decreases in thickness.

Gamble *et al.*, (1987) studied that the frying oil is then absorbed by the food, replacing the lost water. When the potato slices are submerged in hot oil, moisture is rapidly evaporated in a stream of bubbles and the moisture content reduces rapidly. The dry outer surface provides a diffusion gradient, and the inner moisture is converted to steam causing a pressure gradient. The steam is attracted to selective weakness in the cellular adhesion and escapes through these areas. On the surface of the chips, steam

evaporates in a discontinuous manner through a small number of major sites and a larger number of minor sites. Thereafter, the areas surrounding moisture-escape sites lose their hydrophobicity due to the dryness of the areas. As a result, oil may adhere to the slices and place in damaged areas. The outer surface of the slice is the first area to take up oil and has more oil than average since the area has a greater exposed surface in contact with the oil. The high temperature results in the evaporation of water, which moves away from the food and through the surrounding oil. Frying oil is then absorbed by the food, replacing the lost water. When the potato slices are submerged in hot oil, moisture is rapidly evaporated in a stream of bubbles and the moisture content reduces rapidly. The dry outer surface provides a diffusion gradient, and the inner moisture is converted to steam causing a pressure gradient. The steam is attracted to selective weakness in the cellular adhesion and escapes through these areas. On the surface of the chips, steam evaporates in a discontinuous manner through a small number of major sites and a larger number of minor sites. Thereafter, the areas surrounding moisture-escape sites lose their hydrophobicity due to the dryness of the areas. As a result, oil may adhere to the slices and place in damaged areas. The outer surface of the slice is the first area to take up oil and has more oil than average since the area has a greater exposed surface in contact with the oil.

Costa *et al.*, (1996) were fried process impairs the developed the of mechanistic models to describe water losses. Empirical models, though lacking a theoretical basis, may provide a suitable and simpler alternative. In this work it was found that a two parallel compartments model (core and edge compartments), with a time-dependent boundary condition, could be successfully applied for this purpose. The model showed a

good fit to the experimental data for a variety of experimental conditions tested: potato geometry and size, temperature, oil type and oil use.

Mirzaei *et al.*,(2015) Studied the main quality parameters of fried potato products such as the most popular French fries and potato crisps. They are formed during the frying conditions were taken under investigation. Quality of frying oils as well as fatty acid composition and degree of degradation affect fat uptake and texture of fried potato products such as French fries and potato crisps are discussed. The kind and quality of frying medium as well as frying parameters (temperature) influence fat uptake and texture of fried potato. Texture of products correlated with fat content and composition of frying medium. Higher frying temperature decrease hardness of French fries and potato crisps which exhibit more crispy and delicate texture in composition with products fried at lower temperature. In this research, the effect of frying temperature at temperatures 180°C and 160°C for less of oil uptake of French fries.

Shaker (2015) evaluated air-frying process as a new technique for frying process. The potato strips were fried in both air-frying machines at 180°C±5°C for 40 min and traditional frying process at 180°C for 40 min, 6 min/batch. After frying process the moisture and oil uptake were determined moisture content and oil uptake in fried potato strips by air frying process were significantly lower than fried potato strips by traditional frying process. Generally, the air frying processes was more suitable for frying process and produce healthy fried foods than other traditional frying method.

Arya *et al.*, (2017) Studied the moisture loss and oil uptake at different treatment of sample and time during deep-fat frying of French fries was investigated in this study. French fries samples were diced and fried at different oil (Mustard oil, Soybean refined

oil, Sunflower oil,) in a fryer for periods varying from 50 to 200 sec. The relationship between moisture loss and oil uptake during the frying was erratic and appeared to be independent of frying oil. The relationship Oil uptake was positively to moisture loss in the range of frying times 50 sec. to about 200 sec. After 100 sec, oil uptake tended to decrease while moisture loss continued. The relationship between moisture loss and oil uptake is an important phenomenon in the context of characterizing the physical properties of French fried.

2.3 Type of frying:

2.3.1 Deep fat frying

Deep fat frying is one of the most common methods of cooking is widely used in chain fast restaurants as well as the household level. Deep fat frying yields desirable characteristics such as crispness, appealing flavor and color in foods in a relatively short cooking time. This explains the popularity of fried food products such as French fries, donuts, extruded snacks,

Deep fat frying (or immersion frying) is a process where the food product is immersed in hot oil bath for a certain period of time. Oil temperatures are usually kept above the boiling point of water, hence frying result in moisture loss from the food product by evaporation. The moisture loss is accompanied by oil uptake from the frying medium.

Typically deep fat frying result in the formation of the crust at the surface of the food due to the fast evaporation of water from the peripheral parts of the food the crust is one of the characteristic that gives fried their desirable texture.

Deep fat frying is a very popular and widely utilized in food preparation because it is fast and convenient. Frying is still considered to be more an art than a science because it is an extraordinarily complex process involving various factors; some of which are dependent on the process itself and others on the food and the types of frying medium used.

Deep fat frying of foods is considered everywhere in the world to be the most common unit operation used in food preparation. Therefore, to produce, preserve, and market fried food optimally, it is essential to understand the frying mechanism, the factors affecting the oil uptake, and the changes of frying oil during frying. In addition, this chapter briefly introduces the measurements of oil quality used widely in the frying industries.

Pinthus *et al.*, 1993; Reeve and Neel (1960) reported that the process of frying involves the loss of water and the absorption of oil; strongly associated with this loss of water and oil absorption is the formation of a crust.

Adel-aal and Karara (1986) reported that moisture content was negatively affected by oil temperature, and fixed frying temperature, moisture decreased with frying time that affect the oil absorption during deep fat frying are the quality of the oil in which the food is being fried.

Gamble *et al.*, (1987a) Observed that the moisture content of the product is decreased during frying, resulted in an increase in oil content. The loss of moisture during frying exhibited a classic drying profile. At higher temperatures, there was an initial rapid fall followed by a continuous drying period. The moisture content decreased sharply by as much as 20% over a 3 min frying time and then more slowly to the final moisture

content. They found that the loss of moisture and the uptake of oil were interrelated and recommended reducing the initial moisture content by drying to decrease the fat uptake into the potatoes.

Farkas (1994) categorized the frying process into four distinct stages: initial heating, surface boiling, falling rate, and the bubble end-point. During the initial heating stage, which lasts a few seconds, the surface temperature of food in the oil reaches the elevated boiling point of the liquid. The mode of heat transfer between the food and the oil is natural convection. During the surface boiling stage, which is signaled by the vaporization of water, the convective mode of heat transfer varies from natural to forced convection due to the presence of considerable turbulence in the oil surrounding the food. The Deep-fat frying can be defined as a process of cooking food by immersing them in edible oil at a temperature above the boiling point of water, and therefore, may be classified as a dehydration process.

Pinthus and Saguy (1994) and Pinthus *et al.*, (1995) Observed the oil penetrates mainly the cellulosic walls and to some extent the gelled starch contents of crust cells. Oil penetration is influenced by oil type and oil quality. Some oil is absorbed into cell wall surfaces of the interior voids developed during frying. Cells tend to separate when steam is evolved from the strips during frying. Oil uptake during deep fat frying of products, such as potatoes, which initially contain little or no fat take place at the surface of the product.

Bauman and Escher (1995) reported that drying or moisture removal was accelerated at higher oil temperature during deep fat frying of potato chips. The final oil content was lower at higher oil temperatures due to shorter residence time of the food in

the frying oil. The effect of frying temperature on oil uptake during deep fat frying is still a subject of controversy. .

Erdogdu and Dejmek (2010) reported that Frying is a process of immersing food products in oil or fat heated to temperatures well above the boiling point of water. During frying, the heat is transferred from the heated oil to the food product.

Kampuse *et al.*, (2014) explained the French fries are very popular product in many countries. But this product together with potato chips is included in the group of unhealthy products due to high content of fats, acrylamide, and peroxide value. Therefore the aim of this research was to evaluate the pre-treatment methods for reducing the fat content, and improving other quality parameters. Before frying the potato strips were blanched in hot water at 85 °C, and dried in microwave-vacuum dryer for 3, 6 and 8 min, and in conventional dryer with air ventilation for 15 min at 60 and 80 °C, and 10 min at 100 °C temperature. The frying was done at 170 °C for 1.5–2 min. The colour, texture (with texture analyser), the moisture content, the total fat content, and the ascorbic acid content were analysed for all prepared sample.

Ufheil and Escher (1996) studied oil uptake during deep fat frying of potato slices. They introduced a fat- soluble and heat stable dye into the oil at different times before the end of frying in order to determine the dynamics of oil uptake throughout the process. The author concluded that oil does not penetrate the potato slices during frying, but it is taken up by considered to be a function of the equilibrium between adhesion and drainage of oil after removing the sample from the frying medium.

Farkas *et al.*, (1996) proposed that during frying, the surface of potato heats up to water boiling temperature and water starts to vaporize. As frying progresses, the

crust/core interface moves towards the center of the product. The crust becomes thicker and the core decreases in thickness. The Deep-fat frying is one of the oldest and most common unit operations used for cooking foods by immersing them in an edible oil or fat heated above the boiling point of water.

Moreira *et al.*, (1999) explained that the Deep-fat frying is one of the oldest methods to prepare foods with unique texture and flavor. Some of the products produced by deep-fat frying include potato chips, French fries, extruded snacks, doughnuts, fish sticks, and fried chicken products. The purpose of deep-fat frying is to seal the food by immersing it in hot oil so that all the flavors and the juices are retained in a crisp crust. Also, oil imparts nutrients and flavor when entering the food as well as provides a heat transfer medium. During deep-fat frying, heat and mass transfer mechanisms are coupled. Heat transferred from the hot oil to the product surface by convection moves to the center of the food by conduction. The commercial deep-fat frying, the major chemical reaction that takes place is hydrolysis a result of interactions between the food and the oil. Vapor reacts with triglycerides to form free fatty acids, monoglycerides, diglycerides, and glycerol. The free fatty acids cause the oil and the fried product to develop off flavors. During frying heat is transfer from the oil to the surface of the product by convection and then from the surface to the center of the product by conduction, which causes an increase in temperature until the boiling temperature is attained and water starts evaporating. The Deep-fat frying can be defined as the process of drying and cooking food by contact with hot oil. The Deep-fat frying can be accomplished under three different pressure conditions: atmospheric pressure, low pressure (vacuum), and high pressure.

Bouchon *et al.*, (2003) reported that the Deep-fat frying is a complex unit operation involving high temperatures, significant microstructure changes both to the surface and the body of the chip, and simultaneous heat and mass transfer resulting in flows in opposite directions of water vapor (bubbles) and oil at the surface of the piece.

Choe (2007) studied that the process of deep-fat frying produces either a desirable or undesirable flavor. The combination of heat and mass transfer of oil, the food and air produce the desirable qualities of fried foods. Linoleic acid, commonly found in vegetable oils, is responsible for the desirable fat flavor. The chemical reactions most common in the frying of oil are hydrolysis, oxidation and polymerization

Ali *et al.*, (2012) Concerned with the oil uptake reduction of French fried potatoes through application of some prefrying treatments. These treatments comprised blanching, coating with different hydrocolloids and heating before deep frying process by three different processes, namely, heating in a laboratory convection oven and microwave oven at 50% and 100% power level. It was found that high oil uptake reduction was achieved when French fried potato strips were blanched in 0.5% calcium chloride solution and coated with a mixture of carboxy methyl cellulose (1%) and (0.5%) guar gum followed by heat with microwave or oven treatment before deep frying in cotton seed oil. It was found that, these treatments helped in minimizing oil uptake to 53.21%.

Alruz (2013) investigated the interaction effect of pre drying treatments and using hydrocolloids mixture as an edible coat, as a packaging material and for better frying results for fried potato. Pre drying treatments used were heating samples at 69°C for 3 and 25 min. Hydrocolloid system used was MA-1 type, Hydrocolloid texturizer contains; methylcellulose, carrageenan and potassium chloride. Treatments were evaluated by

measuring oil content, moisture content, cutting force, color and mold growth. The result showed a great effect for the hydrocolloid system in combination of pre drying treatment (69°C for 25 min) in both prolonging the fried product shelf-life through retarding and decreasing mold formation and in enhancing the frying characteristics and texture.

Reshi *et al.*, (2017) reported the Potato vegetable crop and can be used for preparing various food products like chips, cubes, flour, slices, french fries, granules, powder etc. India having tropical climatic conditions the packaging and storage of above processed products for longer period is posing a big problem. An investigation was carried out to study the effect of different packaging and anti-browning chemical pre-treatments on storability of potato products. Results indicated that potato slices and cubes pre-treated with citric acid 0.10% + KMS 0.5% and packed in 300 gauge polyethylene bag had longer storability and good organoleptic qualities.

Akhtar *et al.*, (2015) studied the effect of different drying methods on drying behaviour of potato to evaluate the quality and drying performance parameters of potato dehydrated in microwave assisted fluidized bed drying system. Drying of potatoes were also carried out in a fluidized bed drying at 50°C, 60°C and 70°C for comparison of drying behaviour and quality parameters of dehydrated potatoes obtained with those of microwave assisted fluidized bed drying experiments. The optimum values of these responses in the experimental range of microwave power, inlet air temperature and inlet air velocity were: apparent density ratio 44.42%; rehydration ratio 2.27; browning index 0.06; drying time of 62 min; moisture content 6.4 %(db); volumetric shrinkage ratio 24.30; bulk density 0.25 g/cc and colour 11.08.

Sobol *et al.*, (2017) reported the effects of time and temperature during the pre-treatment in hot water semi-products obtained from potatoes. This treatment results in leaching of reducing sugars and influences on the texture of fried potato products. Studies were carried out on samples of potatoes in the form of slices (having a diameter of 57 mm and a thickness of 4 mm) and sticks having a cross section of 10×10 mm and a length of 100 mm. The semi-products formed had a comparable weight of ca. 10 g. Prepared semi-product were immersed in demineralized water at temperature 20°C, 30°C, 40°C. The product shape, temperature of water for washing sugars and treatment time are statistically significant for product texture. Lower texture values are found in the slices.

Kita *et al.*, (2004) studied the effect of blanching or soaking in different acid solutions on the acrylamide content in potato crisps. Furthermore, the effects of a shorter frying time and a lower frying temperature combined with a post drying were investigated. Soaking or blanching of potato slices in acidic solutions decreased the pH of potato juice and increased the extraction of amino acids and sugars. Potato crisps obtained after such pretreatments were characterized by lower acrylamide content. Furthermore, the post drying treatment gave a decrease in acrylamide content of 70% when potato slices were fried at 185 °C and ~80% when potato slices were fried at 160 °C. Effective ways of decreasing acrylamide content in crisps production have been found.

2.4 Qualitative study of potato sticks fries oil content.

Moreira *et al.*, (1997) studied that the total oil content of fried products can be separated into two regions: the oil on the core of the product (internal oil) that is absorbed during frying, and the surface oil which is absorbed during cooling. Measured oil content on the surface (surface oil) and the core (internal oil) of tortilla chips to determine oil distribution during frying and cooling. The surface oil was extracted by dipping the

tortilla chips for 1 second in a beaker with petroleum ether immediately after frying. The petroleum ether was evaporated and the oil left on the beaker was defined as surface oil. It was observed that only 20% of the oil content was absorbed during frying and 80% of the total oil content was surface oil.

Moreira and Barrufet (1998) proposed that the oil uptake by tortilla chips can be described in terms of capillary forces and described the mechanism of oil uptake using the percolation theory.

Moreira et al., (2001) considered the amount of surface oil present at the moment of pressurization as a determining aspect for the final oil content of the product, and established that a de-oiling process must be used to remove surface oil under vacuum after the product is fried. They determined the internal and structural oil absorption kinetics during vacuum frying of potato chips, and found that 14% of the total oil content was located in the core (internal oil) and the remaining 86% of the oil content was surface oil. The de-oiling mechanism (centrifuging system) used in the study removed surface oil before the pressurization step and was able to reduce the total oil content from 80 to 90%. The influence of various parameters of the pressurization and cooling stage on the final oil content of fried potato using different geometries, and explained that oil absorption during the cooling stage is greatly influenced not only by the difference in temperature, but also by the vacuum break conditions as the system is restored to atmospheric pressure. They found that the volume of oil absorbed by the product is inversely proportional to the pressurization velocity meaning that lower velocities favors oil absorption showing an increase of 70% for potato chips compared to the oil content when the vacuum breaks abruptly.

A decorative border resembling a scroll, with a vertical line on the left and horizontal lines at the top and bottom. The corners are rounded, and there are grey circular accents at the top-left and top-right corners.

***MATERIALS
AND
METHODS***

Experiments were carried out to develop potato sticks in process and Food Engineering Laboratory of the Department of Agricultural Engineering and Technology, Sardar Vallabhbhai Patel university of Agriculture and Technology, Modipuram, Meerut. Studies were also carried out to evaluate the physical chemical parameter of potato sticks and fried after 45-50 Sec. potato sticks fries sample were packed in room temperature. Materials and methods of the present investigation are described in following section.

3.1 Materials

Raw materials i.e. potatoes were procured from the Central Potato Research Institute (CPRI) Campus, Modipuram, Meerut (UP) India. Chemicals (control, citric acid, potassium meta-bisufite, citric acid + potassium meta-bisufite, blanching with 95 °C) and frying oil with mustard oil and other raw materials including low density polyethylene (LDPE) poly bag and were procured from the local market (Meerut) for the present study.

3.2 Experimental plan

Experimental plan for effect of pretreatment and cooking medium on quality of potato sticks and their oil uptake kinetics is given in Table 3.1.

Table 3.1 Experimental layout for drying and frying of potato sticks

Experimental Parameters	Levels	Description	Measuring Parameters
Product	1	Potato sticks	Physico-chemical analysis Moisture content, Ascorbic acid, Ash content. Process parameters: Mass reduction, Drying rate, water loss and weight gain, oil content Sensory evaluation: Colour, texture, Flavour, and overall acceptability
Pre-treatments	5	T ₁ – Control T ₂ - Citric acid @ 0.5% T ₃ - Potassium-meta-bisulphate @ 0.5% T ₄ - Citric acid @ 0.5% + Potassium-meta-bisulphate @ 0.5% T ₅ - Blanched (3-4 min) at 95 °C	
Sample weight	1	400gm	
Solution product ratio	1	5:1	
Drying methods	2	Open Sun, Cabinet tray dryer (60 ⁰ C)	
Packaging Material	1	LDPE (poly bag)	
Storage	1	Room temperature	
Frying oil	1	Mustard oil	
Storage Period	4	0, 15, 30 and 45days	
Replication	3		
Design	1	RBD	

Experimental Details:

Pretreatments - (05)

Factor (A)

1. T₁ – Control
2. T₂ - Citric acid @ 0.5%
3. T₃ - Potassium meta-bisulphate @ 0.5%
4. T₄ - Citric acid @ 0.5% + Potassium meta-bisulphate @ 0.5%
5. T₅ - Blanching (3-4 min) at 95 °C

Drying Methods - (02)

Factor (B)

1. Open Sun
2. Cabinete Tray Dryer 60° C

Factor (C)

Cooking Method – (01)

1. Mustard Oil

Sample size : 400g

Packaging Material : LDPE (Low Density Poly Ethylene) poly bags

Storage : Room temperature

Storage Period : 0, 15, 30, and 45 days

Replication : 3

Design : RBD

Observations recorded:

1. Moisture content
2. Drying rate

3. Water Loss
4. Weight Gain

Chemical Observations recorded:

1. Ash content
2. Ascorbic acid

Sensory Observations recorded:

1. Color
2. Texture
3. Flavor
4. Overall acceptability

3.3 Experimental set-up

The entire studies were conducted in the Department of Agricultural Engineering, S.V.P. University of Agric. & Tech., Meerut (U.P.), Instruments / equipments used were knife, trays, electronic balance, hot air oven, gas burner, frying pan. Salient feature of the major equipments are describes below.

3.4 Processing method

3.4.1 Development of potato sticks

Potato was collected from CPRI then washed with clean water to remove dust and dirt, then potatoes were peeled manually with the help of knife, follow by cutting with the help of sticks fries cutter, and blanched in different treatments (control, citric acid, KMS, Citric acid + Potassium meta-bisulphate, blanching).

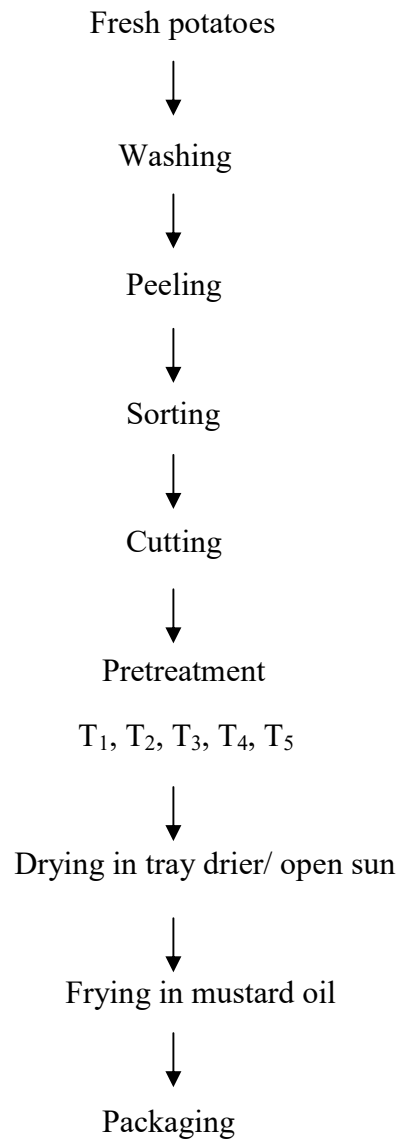


Fig. 3.1: Flow chart of potato sticks development

The blanched samples were pre dried in tray drier/ oven sun and then the pre-dried samples were fried in mustard oil.

3.5 Pretreatments

3.5.1 Control/untreated

The potato were peeled and sliced (0.7 mm average thickness) using a French fries cutter. Then potato slices were dipped in fresh water to prevent color changes due to the Maillard reaction in the French fries during frying. The potato French fries were then bloated with paper towels and then packed in aluminum foil to avoid any moisture loss before further treatments.

3.5.2 Blanching

The potato sticks samples were treated with four different treatments namely, (i) 0.5% citric acid solution at 95°C for 3 min (ii) 0.5% KMS solution at 95°C for 3 min, (ii) 0.5% citric acid + 0.5% KMS solution at 90°C for 3 min, and (iv) only blanching in water at 95 °C for 3 min. After blanching, the samples were cooled for 30 min at room temperature.

3.6. Frying oil

Dried potato sticks samples were fired in mustard oil. Smoke point of mustard oil (250°C).

3.6.1. Frying Process

Frying is a process in which heat is transferred from the oil to the food, water is evaporated from the food and oil is absorbed in it. The main aspects, as far as oil and moisture contents are concerned, is to control the product oil and moisture content in order to produce products of low fat level (**Erdogdu and Dejmek, 2010**).

3.7 Tray dryer:

A cabinet type mechanical tray dryer was used to conduct drying experiment on 60 °C. The dryer had drying chamber, heating unit and a fan. Drying chamber was an insulated box with a single door opening at front. Six aluminum trays were placed in drying chamber.

Six heating units were provided to increase the temperature inside the drying chamber. The effect of pretreatment and cooking medium of potato sticks samples were spread uniformly for thin layer drying in the dryer, the drying tray temperature 60 °C and the air velocity kept as constant 28 m/s.



Plate 1: Tray drying of samples

3.8 Sun Drying

Sun drying is one of the applications of solar energy. Drying means moisture removal from the product. Drying is helpful in preserving food product for long time; it prevent product from contamination. Direct solar drying, indirect solar drying, and mixed mode solar drying these are different solar drying methods. Primarily open to the sun or direct sun drying.



Plate 2: Sun drying of samples

3.9 Electronic balance

Electronic balance of high accuracy (M/s Eagle Instruments Pvt., New Delhi) with 0.0001g least count and 150 g capacity was used for measuring mass of the samples and chemicals. Another electronic balance (Samson S300) with least count of 0.10 g having capacity of 5 kg was also used for weighing of potatoes and other raw material. A top pan electronic balance of high accuracy was also used which is provided with digital display. It has capacity of 4000g and least count 0.1g. it is used to weight sample of potato sticks.

3.10 Hot air oven

Hot air oven (Instron IN-301 model) was a double walled chamber of size 78cm x27cm x 116cm. Outer chamber was made of mild steel while the inner chamber was made of stainless steel. Glass wool insulation (65 cm) was provided between two walls. Heating elements were evenly placed in ribs on both side walls and rear wall for uniform heating. Air ventilators were provided on the side walls of the oven. A digital display was placed in

front of the oven to measure the temperature. The temperature was controlled by thermostat. The perforated shelves were made of stainless steel provided for the placement of samples over them. Oven was used for drying of samples, so as to determine the moisture content of raw materials and their products



Plate 3. A view of Hot air oven

3.11 Desiccators:

Desiccators were used to keep the hot Petri plates in it for cooling as keeping the hot Petri plates in it avoids fluctuation in measuring the weight. Desiccators are sealable enclosures containing desiccants (silica gel) used for preserving moisture-sensitive items. The common use of desiccators is to protect materials and chemicals which are hygroscopic or which react with humidity.



Plate.4: Desiccator

3.12 Determination of physico-chemical attributes of potato sticks

3.12.1 Moisture content: Initial moisture content of samples was determined by hot air oven drying method as recommended by **AOAC (2000)**. A brief description of method is presented below:

- Dry the empty dish and lid in the oven at 105°C for 3 h and transfer to desiccators to cool. Weigh the empty dish and lid.
- Weigh about 3 g of sample to the dish. Spread the sample to the uniformity.
- Place the dish with sample in the oven. Dry for 3 h at 105°C .
- After drying, transfer the dish with partially covered lid to the desiccators to cool. Reweight the dish and its dried sample.

The moisture content of sample was calculated using following equation.

$$\text{Moisture}(\%) = \frac{W_1 - W_2}{W_1} \times 100$$

Where,

W_1 = weight (g) of sample before drying,

W_2 = weight (g) of sample after drying,

3.12.2 Ash content:

Total ash was determined gravimetrically by taking known weight of samples (5 g) in tarred silica crucibles. The dried samples after moisture determination were slowly heated over hot plate until the bulk of organic matter was burnt. The crucibles were then placed in a muffle furnace for ash at 550°C to obtain a carbon free white ash with a constant weight (**Ranganna, 2010**). Ash content of sample was then calculated and expressed as per cent on fresh weight basis.

$$\text{Ash content} (\%) = \frac{\text{final weigh of ash}}{\text{initial weight of sample}} \times 100$$

3.12.3 Determination of water loss (WL) and weight gain (WG)

Dried samples was blotted with tissue paper and later on weighed for determination of WL and WG as shown by the following equation (**Aktas *et al.*, 2007**):

$$WL = \frac{W_{wo} - W_w}{W_o} \times 100$$

$$WG = \frac{W_s - W_{so}}{W_o} \times 100$$

Where,

WL and WG are water loss and weight gain in %, respectively.

W_{wo} is the initial water mass,

W_w is the mass of water at time t,

W_S is the solid mass at time t,

W_{so} is the initial solid mass

3.12.4 Oil content

- **Total oil content-** Total oil content is defined as the oil content of the product after frying of the product without any de-oiling process.

3.12.5 Determination of ascorbic acid (Vitamin C) (mg/100gm)

Ascorbic acid was determined by the procedure proposed by (**Rangana, 1986**).

Standardization of dye: 5 ml of standard ascorbic acid solution was taken and 5 ml of HPO₃ was added. Fill a micro burette with the dye. Titration was done with the dye solution to pink color which should persist for 15 sec. Determination of dye factor i.e. mg of ascorbic acid per ml of the dye, using formula proposed by (**Rangana, 1986**).

$$\text{Dye factor} = \frac{0.5}{\text{Titre}}$$

Preparation of sample:

10 gm of sample was taken, then blend with 3% HPO₃ and make up to 100 ml with HPO₃ followed by Filter or Centrifuge.

3.13. Sensory Evaluation

To test these organoleptic characteristics, sensory evaluation was done on the basis of 9 points hedonic scale. The sensory evaluation was carried out for taste, color and overall acceptability. A sample of dehydrated product was served for the evaluation to a 10

panelists at a time. The score sheet was provided with product and of all the panelists was computed on 9 point hedonic scale.

Table 3.2 Nine Point hedonic scale for sensory evaluation

Sl. No.	Feeling	Rating
1	Like extremely	9
2	Like very much	8
3	Like moderately	7
4	Like slightly	6
5	Neither like nor dislike	5
6	Dislike slightly	4
7	Dislike moderate	3
8	Dislike very much	2
9	Dislike extremely	1



Plate 5: Sensary evaluation

A decorative border resembling a scroll, with rounded corners and a vertical strip on the left side. The scroll is outlined in black and has a light gray shadow effect on its top and left edges.

***RESULTS
AND
DISCUSSION***

The present investigation were carried out to determine the drying and frying characteristics of potato sticks treated with Control (T₁), blanched Citric acid @ 0.5% (T₂), blanched Potassium meta-bisulphate@ 0.5% (T₃), blanched Citric acid 0.5% + Potassium meta-bisulphate@ 0.5% (T₄), Blanched (3-4 min) at 95 °C (T₅) and dried under open Sun and tray drying and also to study the frying kinetics and sensory evaluation during storage.

4.1 Drying kinetics of potato sticks

Results of potato sticks drying with tray dryer and open sun with five different treatments are presented in following heads. The dimensions parameter like length, width and thickness of potato sticks samples were about 6.8 mm, 0.75 mm and 0.85 mm, respectively. Samples were dried until they stop loosing moisture. Water removed (g), moisture content (db%), average drying rate, mass reduction and water loss were measured.

4.1.1 Drying kinetics of potato sticks under open sun

Experiments were conducted to develop the potato sticks using five pretreatment viz. Control (T₁), blanched Citric acid @ 0.5% (T₂), blanched Potassium meta-bisulphate @ 0.5% (T₃), blanched Citric acid 0.5% + Potassium meta-bisulphate @ 0.5% (T₄), Blanched (3-4 min) at 95 °C (T₅) then dried under open sun.

4.1.1.1 Drying kinetics of untreated (control) potato sticks under open sun

The experimental data of drying kinetics of untreated (control) potato sticks under open sun is presented in Table 4.1. The line chart showing the difference in moisture

content (db %) during the period of drying is given in Fig. 4.1(a). The line chart showing the changes in drying rate during the period of drying is given in Fig. 4.1(b). According to data moisture content (db %) was ranged from 497.01 to 8.67 and drying rate was ranged from 1.33 to 0.14. It took about 10 hour to dry the samples. Similar pattern was observed by (Agarry *et al.*, 2005)

Table 4.1: Open sun of untreated (control) potato sticks

Time (h)	Sample weight(g)	Water Removed	M.C%(db)	Drying Rate (g of water removed/ h / g of dry matter)
0	400	0	497.01	0.00
1	311	89.12	364.00	1.33
2	253	57.62	278.00	0.86
3	212	41.54	216.00	0.62
4	180	32.16	168.00	0.48
5	152	27.47	127.00	0.41
6	131	20.77	96.00	0.31
7	112	19.32	67.16	0.29
8	95	16.86	42.00	0.25
9	82	13.14	22.39	0.20
10	73	9.19	8.67	0.14

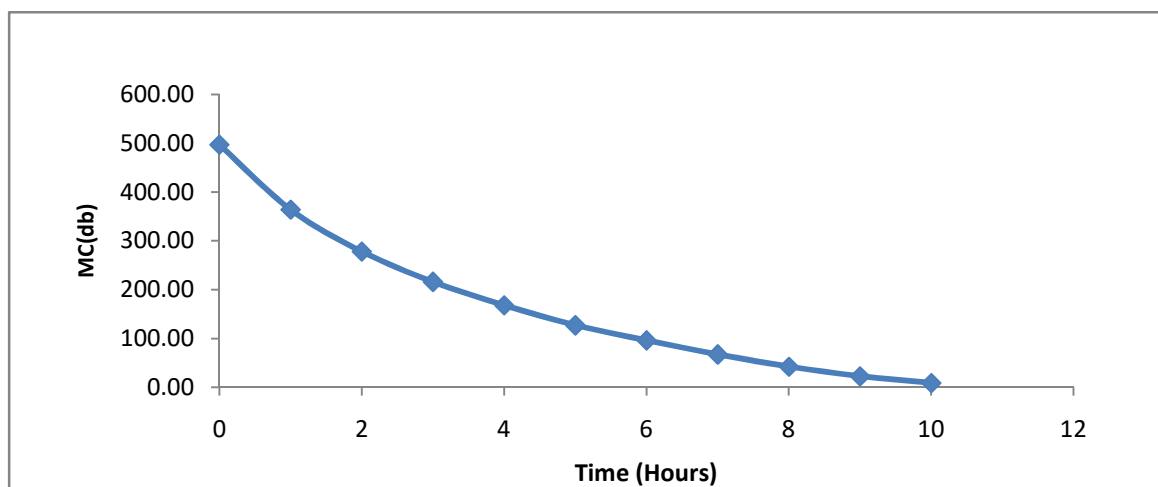


Fig 4.1(a): Change in moisture content (% db) of samples (T₁) under open Sun.

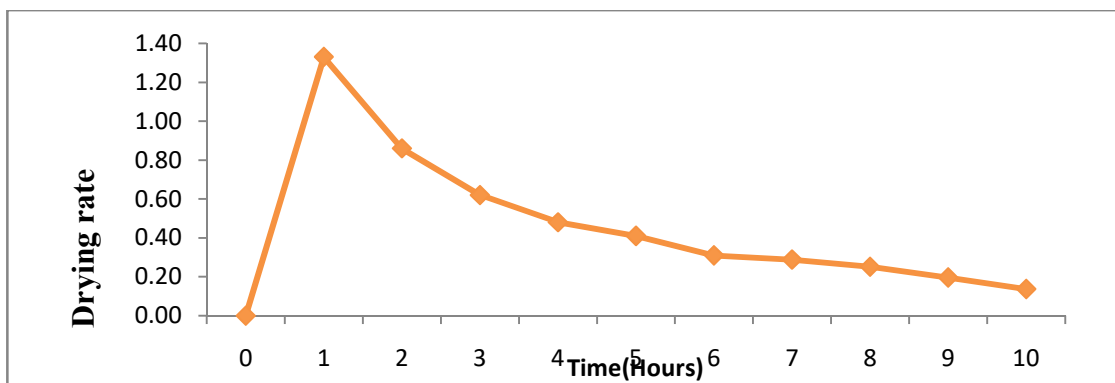


Fig 4.1(b): Change in drying rate of samples (T₁) under Open Sun.

4.1.1.2 Drying kinetics of citric acid treated potato sticks (T₂) under Open Sun

The experimental data of drying kinetics of citric acid treated potato sticks under open sun is presented in Table 4.2. The line chart showing the difference in moisture content (db %) during the period of drying is given in Fig. 4.2(a). The line chart showing the changes in drying rate during the period of drying is given in Fig. 4.2(b). According to data moisture content (db %) was ranged from 497.01 to 6.67 and drying rate was ranged from 1.32 to 0.04. It took about 660 min to dry the samples.

Table 4.2: Open Sun of citric acid treated potato sticks.

Time (h)	Sample weight(g)	Water Removed (g)	M.C.%(db)	Drying Rate (g of water removed/ h / g of dry matter)
0	400	0	497.01	0.00
1	312	88.45	365.00	1.32
2	249	62.31	272.00	0.93
3	204	45.24	204.48	0.68
4	171	33.00	155.22	0.49
5	144	27.00	114.93	0.40
6	123	21.00	83.58	0.31
7	108	15.13	61.00	0.23
8	94	13.87	40.30	0.21
9	84	10.00	25.37	0.15
10	74	9.63	11.00	0.14
11	71	2.90	6.67	0.04

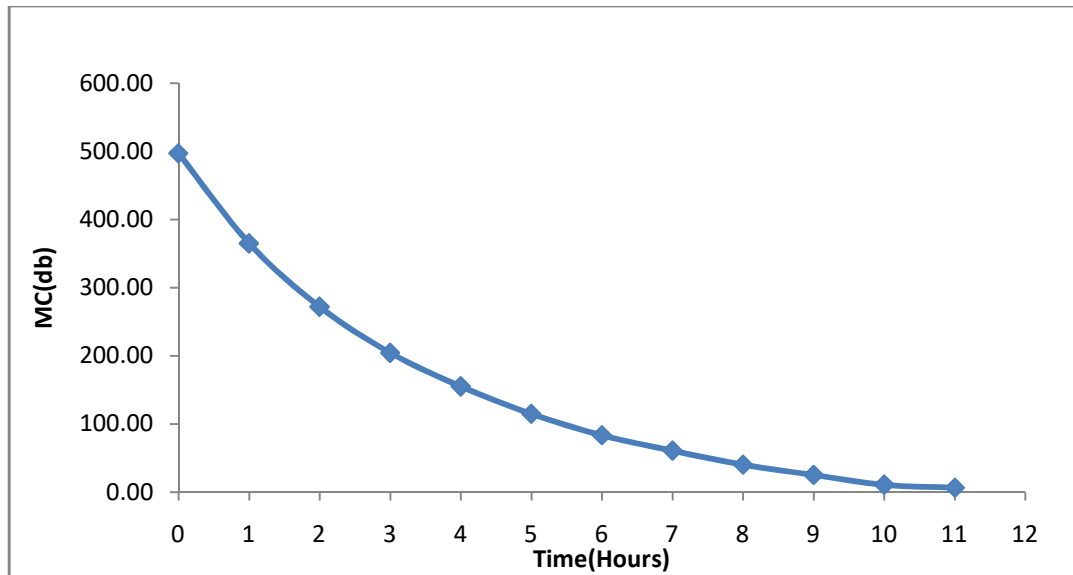


Fig 4.2 (a) Change in moisture content (% db) of samples (T_2) under open sun.

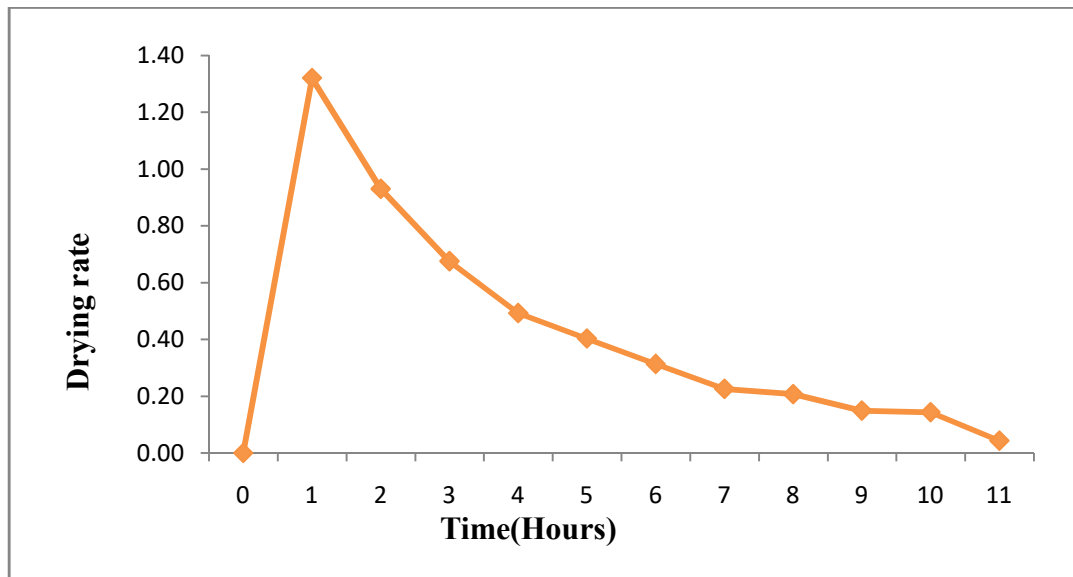


Fig 4.2 (b) Change in drying rate of samples (T_2) under open sun.

4.1.1.3 Drying kinetics of potassium meta-bisulphate treated potato sticks (T_3) under open sun

The experimental data of drying kinetics of potassium meta-bisulphate treated potato sticks under open sun is presented in Table 4.3. The line chart showing the difference in moisture content (db %) during the period of drying is given in Fig. 4.3(a). The line chart

showing the changes in drying rate during the period of drying is given in Fig. 4.3(b). According to data moisture content (db %) was ranged from 497.01 to 6.50 and drying rate was ranged from 1.39 to 0.05. It took about 660 min to completely dry the samples.

4.3: Open Sun of potassium meta-bisulphate treated potato sticks.

Time (h)	Sample weight	Water Removed (g)	M.C.%(db)	Drying Rate (g of water removed/ h / g of dry matter)
0	400.00	0.00	497.01	0.00
1	307.00	93.00	358.21	1.39
2	241.00	66.00	259.70	0.99
3	187.60	53.40	180.00	0.80
4	156.00	31.60	132.84	0.47
5	135.34	20.66	102.00	0.31
6	118.59	16.75	77.00	0.25
7	105.00	13.59	56.72	0.20
8	92.00	13.00	37.31	0.19
9	81.74	10.26	22.00	0.15
10	75.00	6.74	11.94	0.10
11	71.36	3.65	6.50	0.05

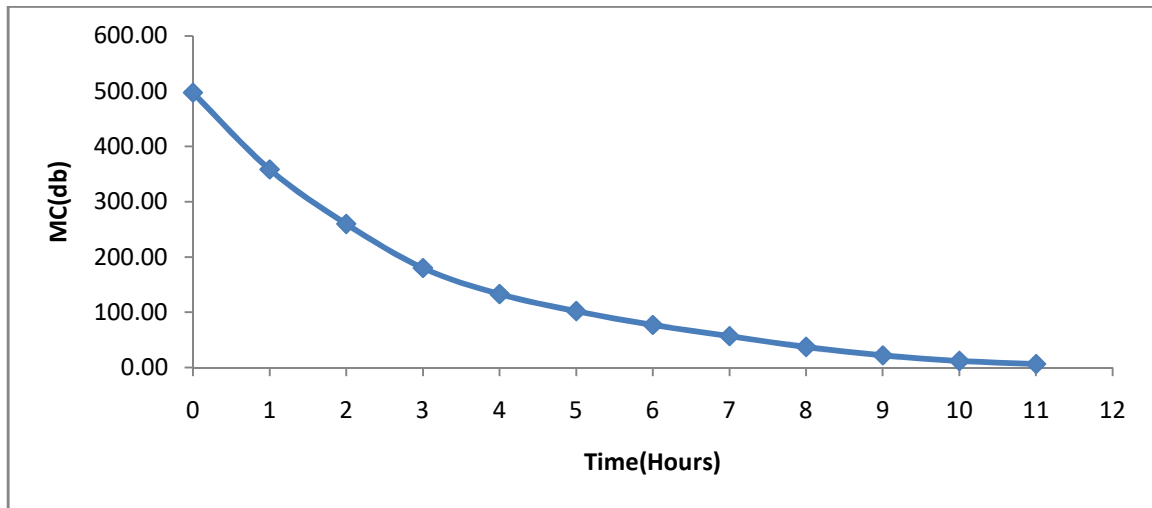


Fig 4.3 (a) Change in moisture content (% db) of samples (T₃) under Open Sun.

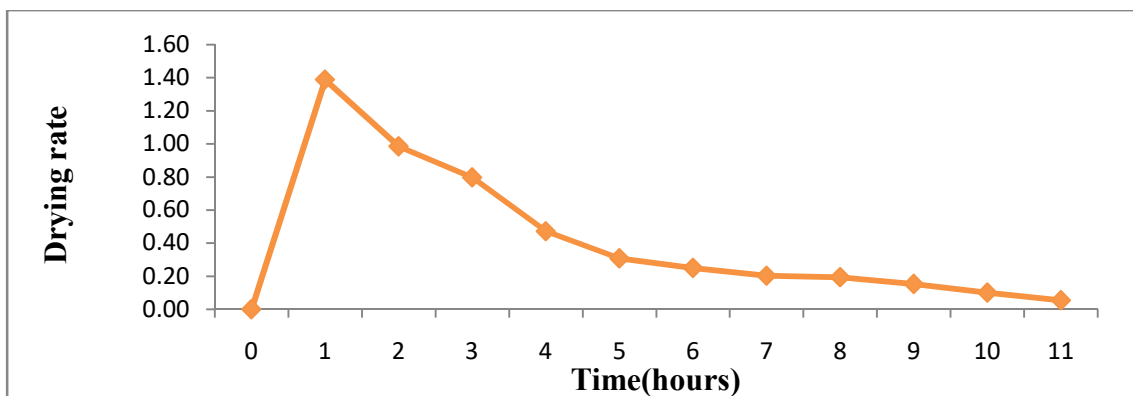


Fig4.3 (b) Change in drying rate of samples (T₃) under Open Sun.

4.1.1.4 Drying kinetics of citric acid + potassium meta-bisulphate treated potato sticks (T₄) under open sun.

The experimental data of drying kinetics of citric acid + potassium meta-bisulphate treated potato sticks under open sun is presented in Table 4.4. The line chart showing the difference in moisture content (db %) during the period of drying is given in Fig. 4.4 (a). The line chart showing the changes in drying rate during the period of drying is given in Fig. 4.4(b).

Table 4.4: Open sun of citric acid + potassium meta-bisulphate of treated potato sticks.

Time (h)	Sample weight	Water Removed (g)	M.C.% (db)	Drying Rate (g of water removed/ h / g of dry matter)
0	400.00	0.00	497.01	0.00
1	314.90	85.10	370.00	1.27
2	256.00	58.90	282.09	0.88
3	212.00	44.00	216.42	0.66
4	177.00	35.00	164.18	0.52
5	150.75	26.25	125.00	0.39
6	128.64	22.11	92.00	0.33
7	112.56	16.08	68.00	0.24
8	98.49	14.07	47.00	0.21
9	85.76	12.73	28.00	0.19
10	77.05	8.71	15.00	0.13
11	73.03	4.02	9.00	0.06

According to table moisture content (db %) was ranged from 497.01 to 9.00 and drying rate was ranged from 1.27 to 0.06. It took about 660 min to completely dry the samples.

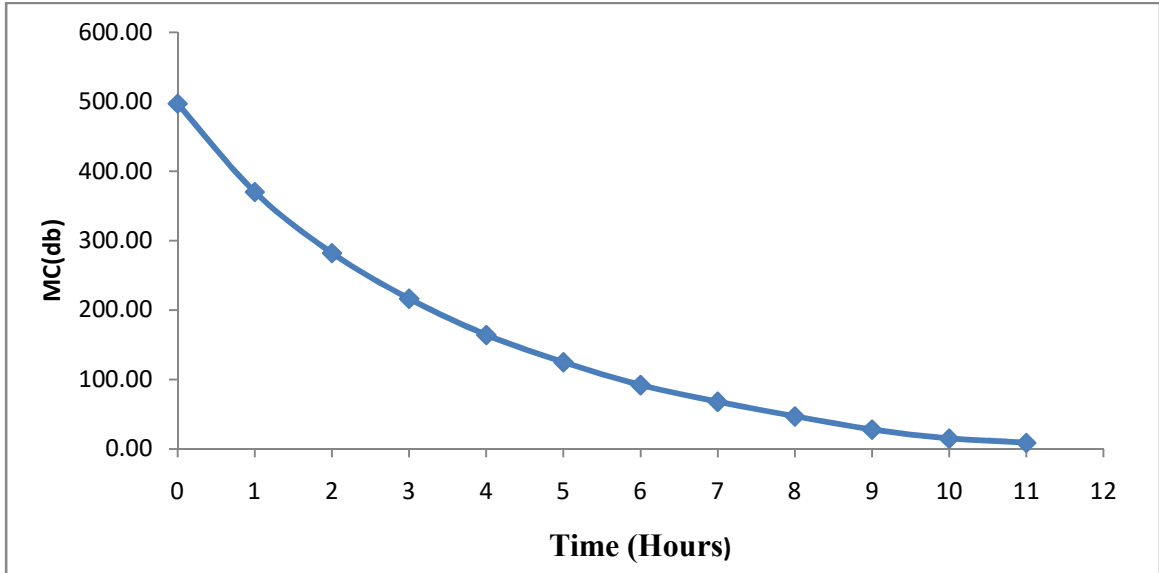


Fig 4.4 (a) Change in moisture content (% db) of samples (T₄) under Open Sun.

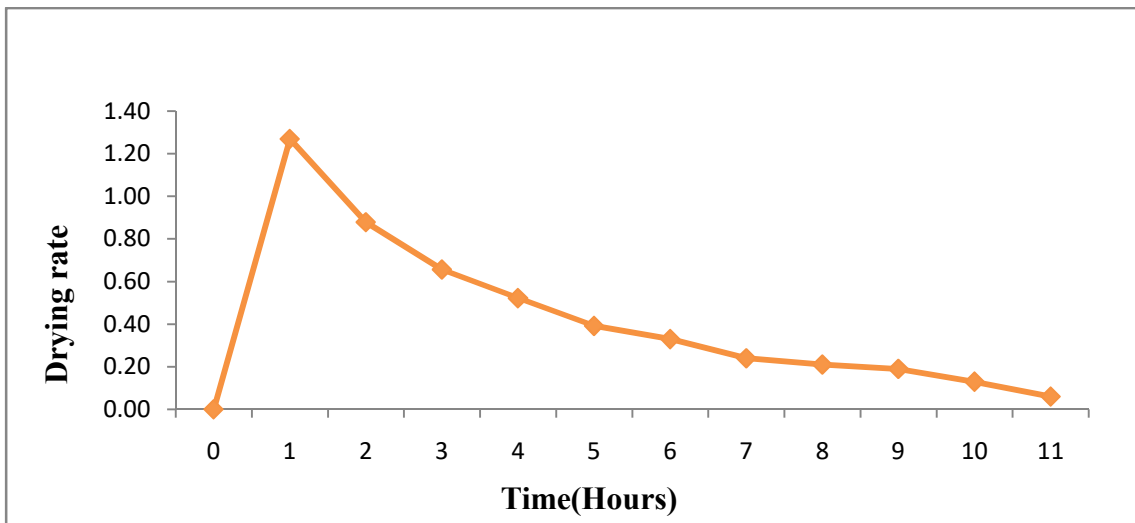


Fig 4.4 (b) Change in drying rate of samples (T₄) under open sun.

4.1.1.5 Drying kinetics of treat blanched of potato sticks (T₅) under open Sun

The experimental data of drying kinetics of blanched potato sticks under open sun is presented in Table 4.5. The line chart showing the difference in moisture content (db %) during the period of drying is given in Fig. 4.5 (a). The line chart showing the changes in drying rate during the period of drying is given in Fig. 4.5(b). According to data moisture content (db %) was ranged from 497.01 to 9.48 and drying rate was ranged from 1.69 to 0.13. It took about 600 min to dry the samples.

Table 4.5 Open Sun of treat blanched at 95 °C of potato sticks.

Time (h)	Sample weight	Water Removed (g)	M.C%(db)	Drying Rate (g of water removed/ h / g of dry matter)
0	400.00	0.00	497.01	0.00
1	287.00	113.00	328.36	1.69
2	229.14	57.86	242.00	0.86
3	192.96	36.18	188.00	0.54
4	165.49	27.47	147.00	0.41
5	144.72	20.77	116.00	0.31
6	126.00	18.72	88.06	0.28
7	109.00	17.00	62.69	0.25
8	95.14	13.86	42.00	0.21
9	81.74	13.40	22.00	0.20
10	73.35	8.39	9.48	0.13

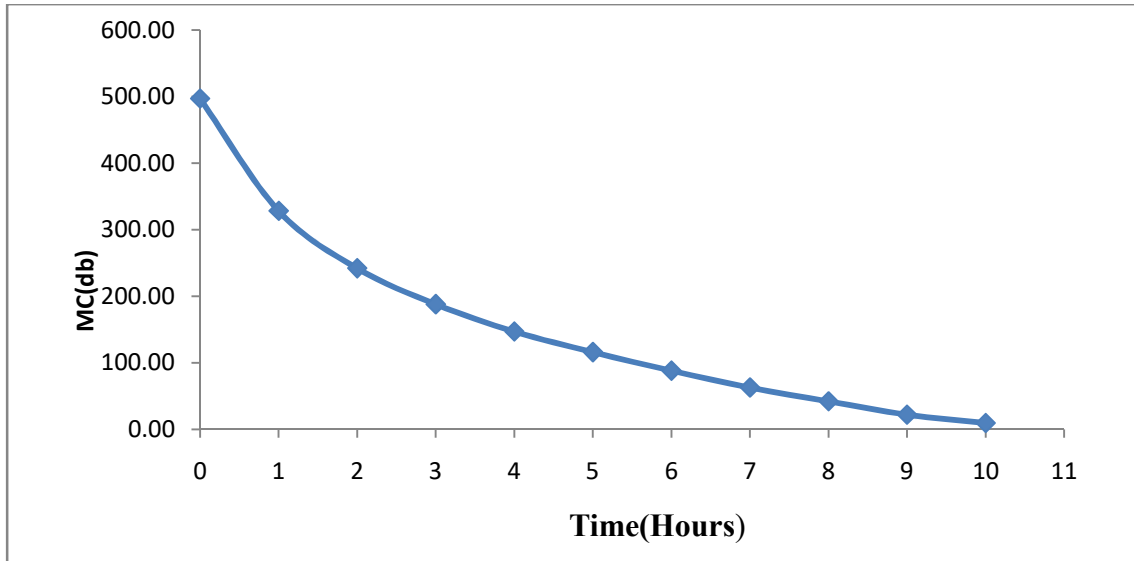


Fig 4.5 (a) Change in moisture content (% db) of samples (T₄) under open sun.

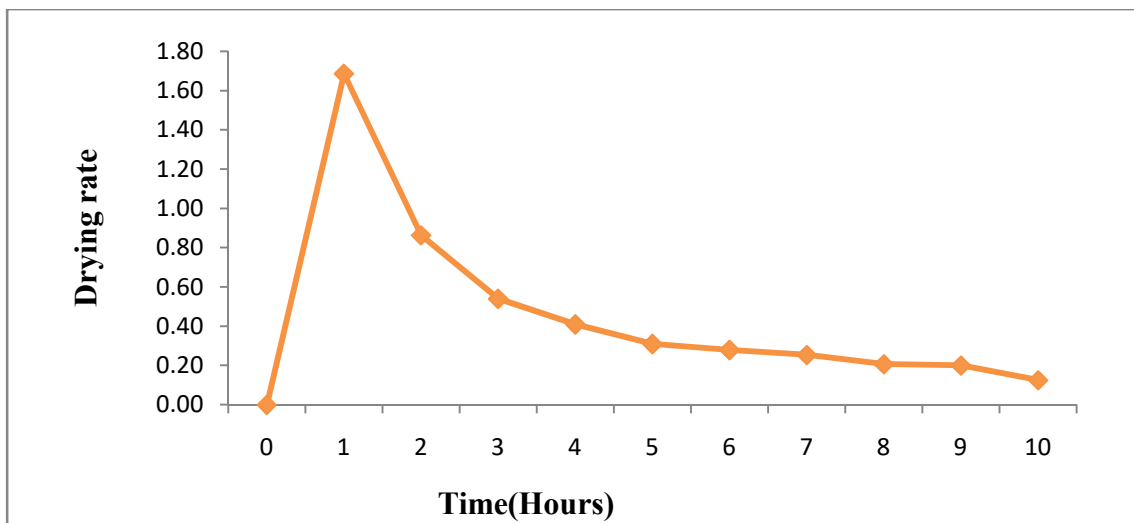


Fig4.5 (b) Change in drying rate of samples (T₅) under Open Sun.

4.1.1.6 Mass reduction in potato sticks under Open Sun.

The experimental data of mass reduction of potato sticks under open sun is presented in Table 4.6. According to data mass reductions (g) were ranged from 329 to 327 and mass reductions (%) were ranged from 81.75 to 82.25. Samples T₁ and T₅ took about 10 hour where as samples T₂, T₃ and T₄ took about 11 hour to dry completely.

Table 4.6 Mass reduction in potato sticks under open sun

Samples	Initial Weight(g)	Final Weight (g)	Mass reduction (g)	%Mass reduction	Total time(hr)
T ₁	400	73	327	81.75	10
T ₂	400	71	329	82.25	11
T ₃	400	71	329	82.25	11
T ₄	400	73	327	81.75	11
T ₅	400	73	327	81.75	10

4.1.1.7 Water loss (%) in potato sticks under Open Sun

The experimental data of water loss of potato sticks under Open Sun is presented in Table 4.7. According to data water loss (g) were ranged from 488.33 to 487.52 and (%) water loss were ranged from 98.09 to 98.69.

Table 4.7 Water loss (%) in potato sticks under Open Sun.

Samples	IMC(db)	FMC(db)	Water loss(g)	% Water loss	Total time(hr)
T ₁	497	8.67	488.33	98.26	10
T ₂	497	6.67	490.33	98.66	11
T ₃	497	6.50	490.50	98.69	11
T ₄	497	9.00	488.00	98.19	11
T ₅	497	9.48	487.52	98.09	10

(IMC=Initial Moisture Content, FMC=Final Moisture Content)

4.1.2 Drying kinetics of treated potato sticks under tray drying

Experiments were conducted to develop the potato sticks using five pretreatment viz. Control (T₁), blanched Citric acid @ 0.5% (T₂), blanched Potassium meta-bisulphate @ 0.5% (T₃), blanched Citric acid 0.5% + Potassium meta-bisulphate @ 0.5% (T₄), Blanched (3-4 min) at 95 °C (T₅) then dried under tray drier at 60 °C temperature.

4.1.2.1 Tray drying of untreated (control) potato sticks

The experimental data of drying kinetics of untreated (control) potato sticks under open sun is presented in Table 4.8. The line chart showing the difference in moisture content (db %) during the period of drying is given in Fig. 4.8(a). The line chart showing the changes in drying rate during the period of drying is given in Fig. 4.8(b). According to data moisture content (db %) was ranged from 497.01 to 7.67 and drying rate was ranged from 1.94 to 0.07. It took about 360 min to dry the samples.

Table 4.8 Tray drying of untreated (control) potato sticks samples

Time (h)	Sample weight (g)	Water Removed (g)	M.C.% (db)	Drying Rate (g of water removed/ h / g of dry matter)
0	400.00	0.00	497.01	0.00
1	270.00	130.00	302.99	1.94
2	164.00	106.00	144.78	1.58
3	110.00	54.00	64.18	0.81
4	83.08	20.00	24.00	0.30
5	76.83	6.25	14.67	0.09
6	72.14	4.69	7.67	0.07

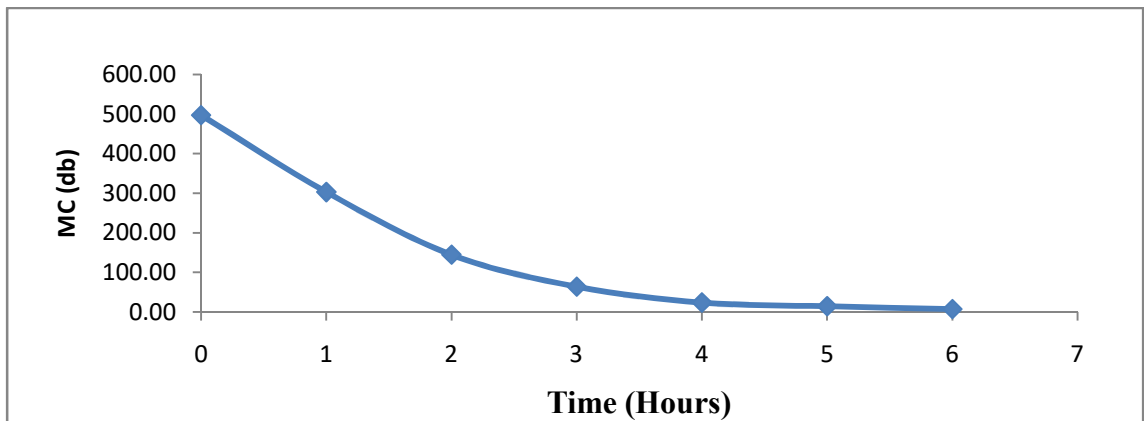


Fig 4.8 (a) Change in moisture content (% db) of sample (T₁) under Tray drying.

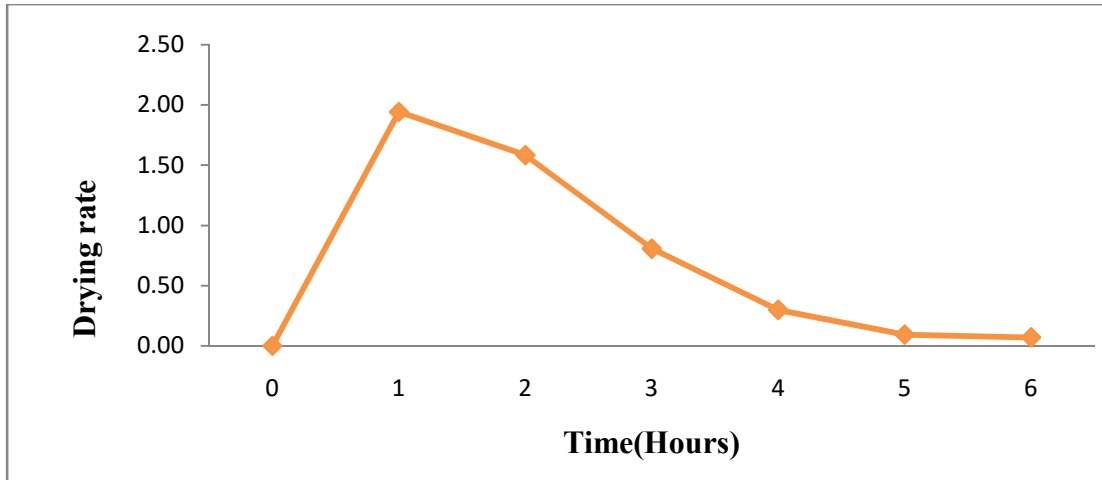


Fig 4.8(b) Change in drying rates of sample (T₁) under Tray drying.

4.1.2.2 Drying kinetics of citric acid treated potato sticks (T₂) under tray drying.

The experimental data of drying kinetics of citric acid treated potato sticks under open sun is presented in Table 4.9. The line chart showing the difference in moisture content (db %) during the period of drying is given in Fig. 4.9(a). The line chart showing the changes in drying rate during the period of drying is given in Fig. 4.7(b). According to data moisture content (db %) was ranged from 497.01 to 5.80 and drying rate was ranged from 1.40 to 0.02. It took about 480 min to dry the samples.

Table 4.9 Tray drying of citric acid treated potato sticks.

Time (h)	Sample weight	Water Removed (g)	M.C.%(db)	Drying Rate (g of water removed/ h / g of dry matter)
0	400.00	0.00	497.01	0.00
1	306.00	94.00	356.72	1.40
2	214.40	91.60	220.00	1.37
3	140.00	74.40	108.96	1.11
4	102.70	37.30	53.28	0.56
5	82.70	20.00	23.43	0.30
6	75.34	7.36	12.45	0.11
7	72.03	3.31	7.51	0.05
8	70.89	1.15	5.80	0.02

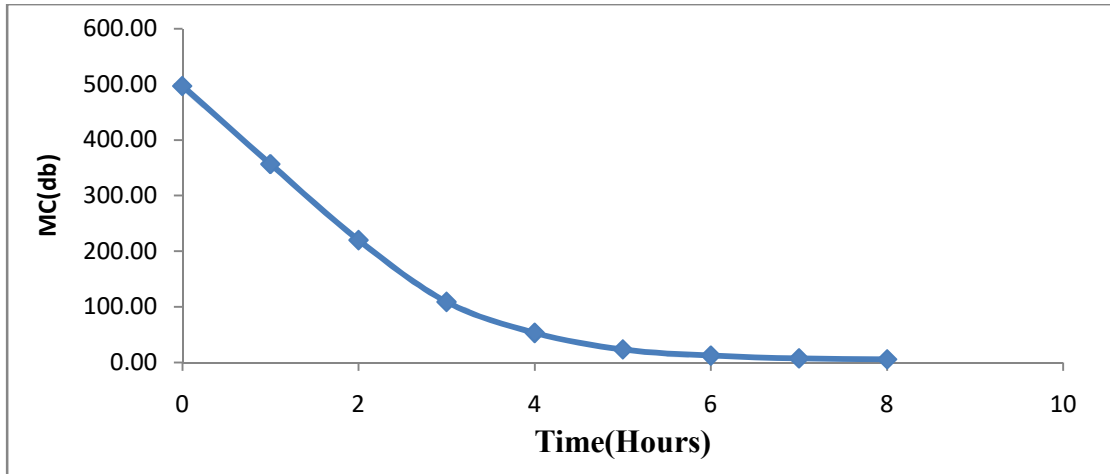


Fig 4.9 (a) Change in moisture content (% db) of samples (T₂) under Tray drying.

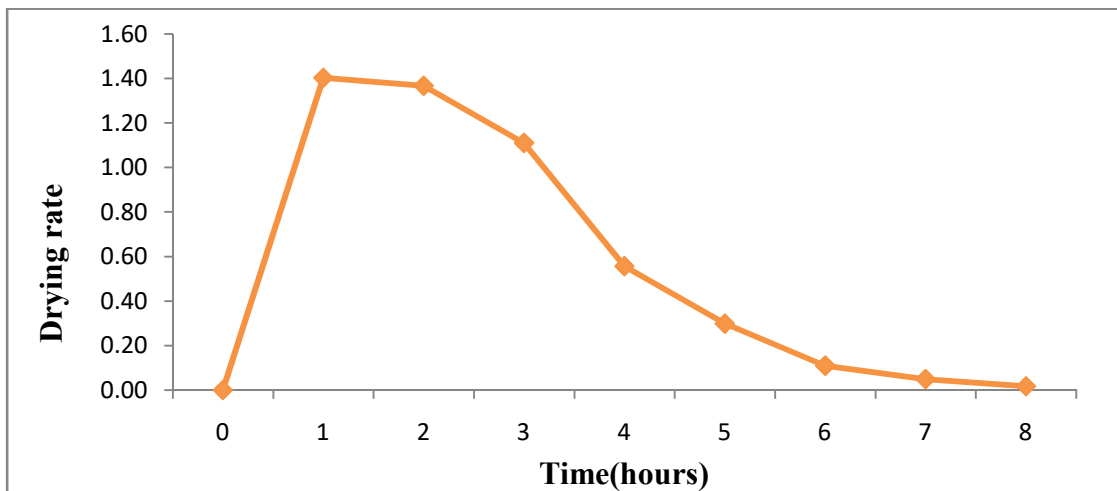


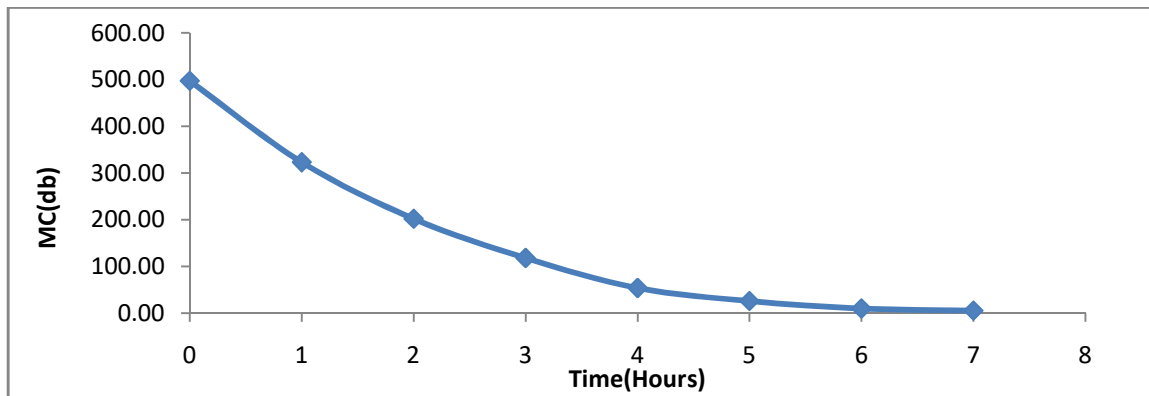
Fig 4.9 (b) Change in drying rate of samples (T₂) under Tray drying.

4.1.2.3 Drying kinetics of potassium meta-bisulphate potato sticks under tray drying

The experimental data of drying kinetics of potassium meta-bisulphate potato sticks under open sun is presented in Table 4.10. The line chart showing the difference in moisture content (db %) during the period of drying is given in Fig. 4.10(a). The line chart showing the changes in drying rate during the period of drying is given in Fig. 4.10(b). According to data moisture content (db %) was ranged from 497.01 to 5.67 and drying rate was ranged from 1.74 to 0.04. It took about 420 min to dry the samples

Table 4.10 Tray drying of potassium meta-bisulphate treated potato sticks.

Time (h)	Sample weight	Water Removed (g)	M.C.%(db)	Drying Rate (g of water removed/ h /g of dry matter)
0	400.00	0.00	497.01	0.00
1	283.41	116.59	323.00	1.74
2	202.34	81.07	202.00	1.21
3	146.06	56.28	118.00	0.84
4	103.18	42.88	54.00	0.64
5	84.42	18.76	26.00	0.28
6	73.70	10.72	10.00	0.16
7	70.80	2.90	5.67	0.04



4.10 (a) Change in moisture content (% db) of samples (T₃) under Tray drying.

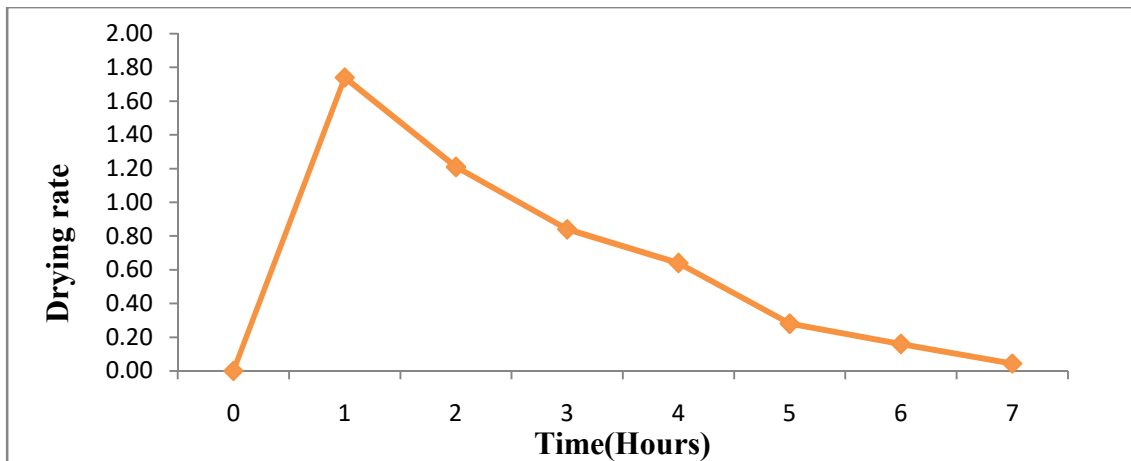


Fig 4.10 (b) Change in drying rate of samples (T₃) under Tray drying.

4.1.2.4 Drying kinetics of citric acid + potassium meta-bisulphate treated potato sticks under Tray drying.

The experimental data of drying kinetics of citric acid + potassium meta-bisulphate potato sticks under open sun is presented in Table 4.11. The line chart showing the difference in moisture content (db %) during the period of drying is given in Fig. 4.11(a). The line chart showing the changes in drying rate during the period of drying is given in Fig. 4.11(b). According to data moisture content (db %) was ranged from 497.01 to 8.00 and drying rate was ranged from 1.61 to 0.03. It took about 420 min to dry the samples

Table 4.11 Tray drying of citric acid + potassium meta-bisulphate treated potato sticks.

Time (h)	Sample weight	Water Removed (g)	M.C.% (db)	Drying Rate (g of water removed/ h / g of dry matter)
0	400.00	0.00	497.01	0.00
1	292.00	108.00	335.82	1.61
2	197.65	94.35	195.00	1.41
3	138.69	58.96	107.00	0.88
4	103.85	34.84	55.00	0.52
5	85.76	18.09	28.00	0.27
6	77.05	8.71	15.00	0.13
7	74.15	2.90	10.67	0.04
8	72.36	1.79	8.00	0.03

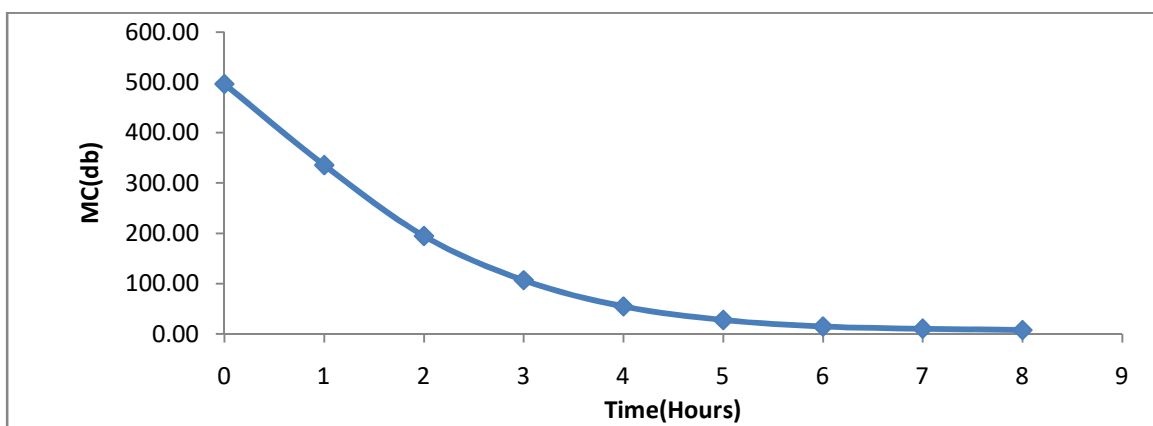


Fig4.11 (a) Change in moisture content (% db) of samples (T₃) under Tray drying

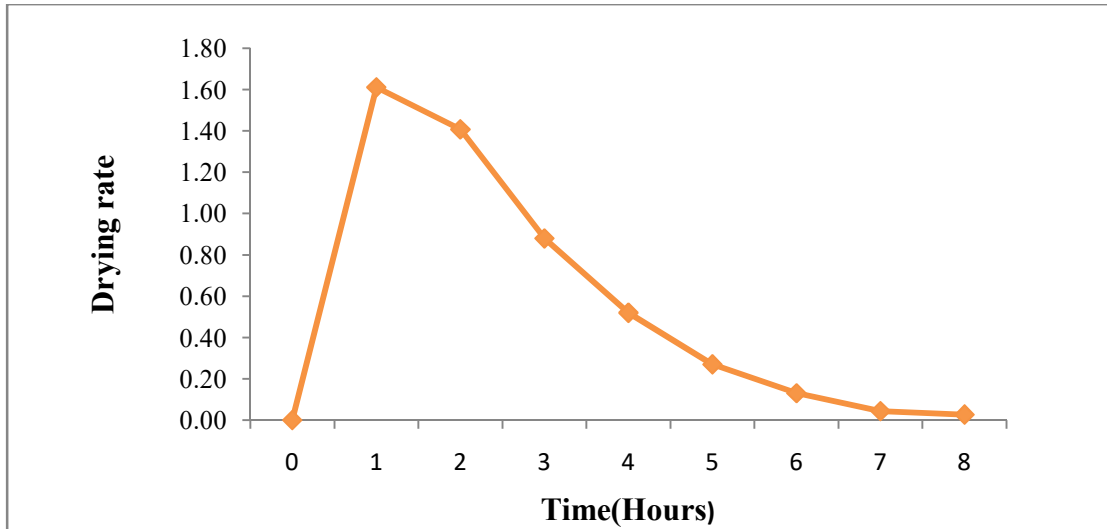


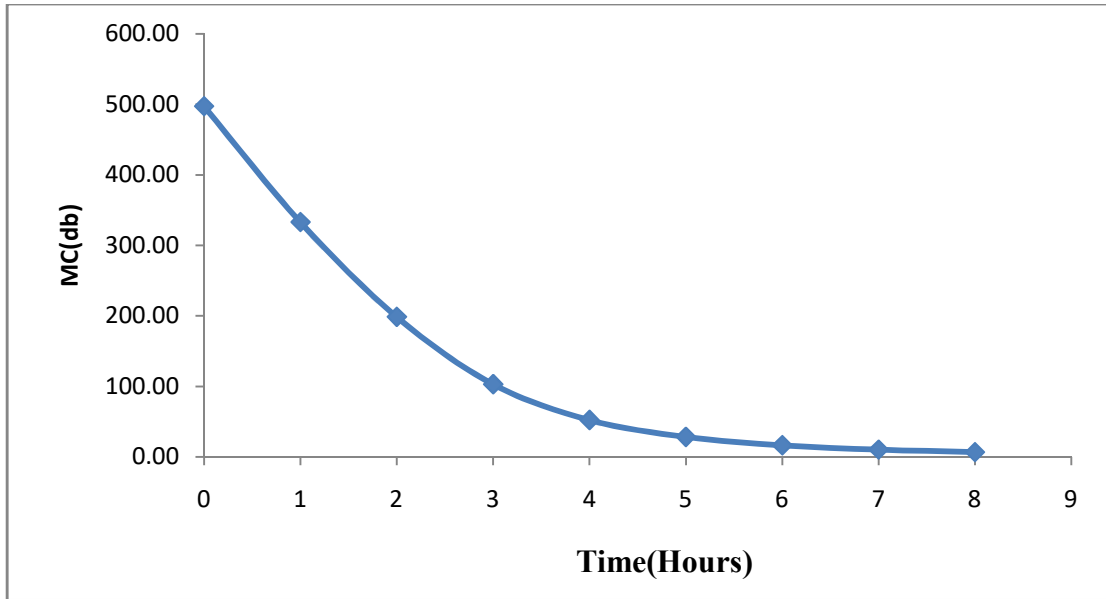
Fig 4.11(b) Change in drying rate of samples (T₄) under Tray drying.

4.1.2.5 Drying kinetics of treat blanched potato sticks under Tray drying

The experimental data of drying kinetics of blanched potato sticks under open sun is presented in Table 4.12. The line chart showing the difference in moisture content (db %) during the period of drying is given in Fig. 4.12 (a). The line chart showing the changes in drying rate during the period of drying is given in Fig. 4.12 (b). According to data moisture content (db %) was ranged from 497.01 to 6.80 and drying rate was ranged from 1.64 to 0.04. It took about 480 min to dry the samples.

4.12 Tray drying of treat blanched with 95°C potato sticks.

Time (h)	Sample weight	Water Removed (g)	M.C.% (db)	Drying Rate (g of water removed/ h / g of dry matter)
0	400.00	0.00	497.01	0.00
1	290.00	110.00	332.84	1.64
2	200.00	90.00	198.51	1.34
3	136.00	64.00	102.99	0.96
4	102.00	34.00	52.24	0.51
5	86.00	16.00	28.36	0.24
6	78.00	8.00	16.42	0.12
7	73.92	4.08	10.33	0.06
8	71.56	2.37	6.80	0.04



4.12 (a) Change in moisture content (% db) of samples (T₅) under Tray drying.

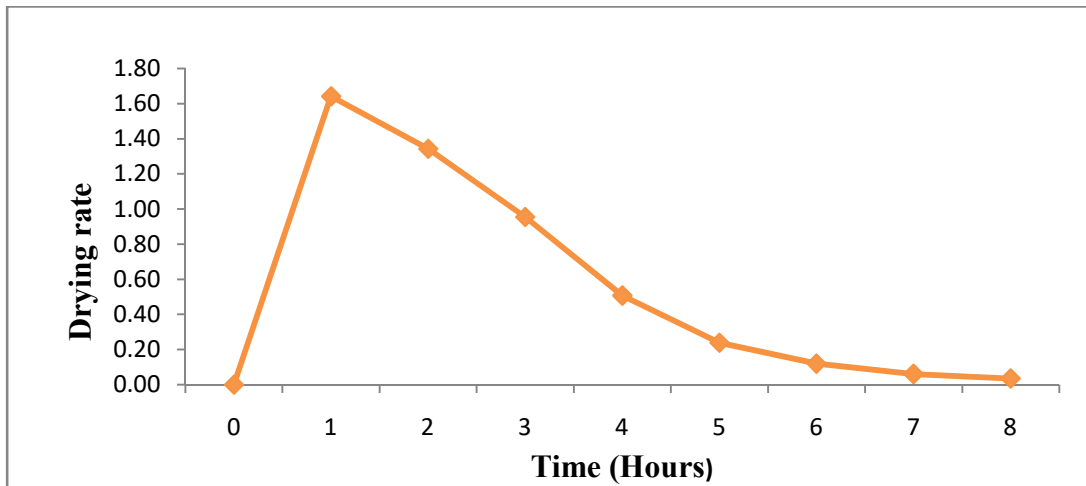


Fig 4.12 (b) Change in drying rate of samples (T₅) under Tray drying.

4.1.2.6 Mass reduction in potato sticks under tray drying

The experimental data of mass reduction of potato sticks under tray drying is presented in Table 4.13. According to data mass reductions (g) were ranged from 328 to 329 and mass reductions (%) were ranged from 82.00 to 82.25. Samples T₁ and T₃ took about 6 to 7 hour whereas samples T₂, T₄ and T₅ took about 8 hour to dry.

4.13 Mass reduction in potato sticks under tray drying.

Samples	Initial Weight(g)	Final Weight (g)	Mass reduction (g)	%Mass reduction	Total time(hr)
T ₁	400	72	328	82.00	6
T ₂	400	71	329	82.25	8
T ₃	400	71	329	82.25	7
T ₄	400	72	328	82.00	8
T ₅	400	72	328	82.00	8

4.1.2.7 Water loss (%) in potato sticks under tray drying.

The experimental data of water loss of potato sticks under open sun is presented in Table 4.14. According to data water loss (g) were ranged from 490.33 to 489.00 and (%) water loss were ranged from 98.39 to 98.86.

Table 4.14 Water loss (%) in potato sticks under tray drying.

Samples	IMC(db)	FMC(db)	Water loss(g)	%Water loss	Total time(hr)
T ₁	497	7.67	489.33	98.46	6
T ₂	497	5.80	491.20	98.83	8
T ₃	497	5.67	491.33	98.86	7
T ₄	497	8.00	489.00	98.39	8
T ₅	497	6.80	490.20	98.63	8

(IMC=Initial Moisture Content, FMC=Final Moisture Content)

4.2 Frying kinetics of potato sticks

Frying kinetics results of potato sticks dried in tray dryer and open sun with five different treatments are presented in following heads. Samples were fried in mustard oil for about 50 to 60 sec. Weight gain (g), % weight gain and oil content % (db) were measured.

4.1.3 Frying kinetics of potato sticks dried under open sun.

Frying kinetics data of potato sticks dried under open sun is presented in Table 4.15. Weight gain (g) ranged from 10 to 11 and % weight gain ranged from 13.70 to 15.49. Maximum weight gain % was observed in sample T₃.

Table 4.15: Frying kinetics of potato sticks dried under open Sun.

Samples	Initial Weight(g)	Final Weight (g)	Weight gain(g)	%Weight gain
T1	73	84	11	15.07
T2	71	81	10	14.08
T3	71	82	11	15.49
T4	73	83	10	13.70
T5	73	83	10	13.70

4.1.4 Frying kinetics of potato sticks dried under tray drying

Frying kinetics data of potato sticks dried under tray drying is presented in Table 4.16. Weight gain (g) ranged from 11 to 12 and % weight gain ranged from 15.28 to 16.90. Maximum weight gain % was observed in sample T₂.

Table 4.16: Frying kinetics of potato sticks dried under tray drying.

Samples	Initial Weight (g)	Final Weight (g)	Weight gain(g)	%Weight gain
T ₁	72	84	12	16.67
T ₂	71	83	12	16.90
T ₃	71	82	11	15.49
T ₄	72	84	12	16.67
T ₅	72	83	11	15.28

4.1.5 Oil content % (db) of potato sticks dried under different drying conditions

Oil content % data of potato sticks dried under open sun and tray drying is presented in Table 4.17. Oil content ranged from 25.37 to 20.90% in sun dried samples and 25.37 to 22.39 % in tray dried samples. In sun dried samples maximum oil content was observed in T₁ where as in tray dried samples maximum oil content was observed in T₁ and T₄. Similar pattern was observed (Miraei *et al.*, 2015)

Table 4.17: Oil content % (db) of potato sticks dried under different drying conditions.

Samples	Sun dried	Tray dried
T ₁	25.37	25.37
T ₂	20.90	23.88
T ₃	22.39	22.39
T ₄	23.88	25.37
T ₅	23.88	23.88

4.1.6 Physico-chemical analysis of fried potato sticks

The Physico-chemical analysis includes the study of ascorbic acid content and ash content of fried potato sticks. These were carried out in the Food Analysis Laboratory, of SVPUAT Meerut.

4.1.6.1 Ascorbic acid content of fried potato sticks

4.1.6.1.1 Ascorbic acid content (mg/100 gm) of sun dried potato sticks samples fried in mustard oil

Ascorbic acid content (mg/100 gm) data of potato sticks dried under open sun and fried in mustard oil is presented in Table 4.18 and bar chart is present in Fig.4.18 Ascorbic acid content ranged from 11.88 to 12.48(mg/100 gm) on 0 day, 11.86 to 12.46 (mg/100 gm) on 15 days, 11.84 to 12.44 (mg/100 gm) on 30 days and 11.82 to 12.42 (mg/100 gm) on 45 days of storage. Maximum ascorbic acid content (mg/100 gm) was

observed in sample T₄ and minimum was observed in sample T₁ during the storage duration.

Table 4.18 Ascorbic acid content (mg/100 gm) of sun dried potato sticks samples fried in mustard oil

Samples	0 days	15 days	30 days	45 days
T1	11.88	11.86	11.84	11.82
T2	12.04	12.02	12.01	12.00
T3	12.10	12.08	12.06	12.04
T4	12.48	12.46	12.44	12.42
T5	12.07	12.05	12.04	12.03

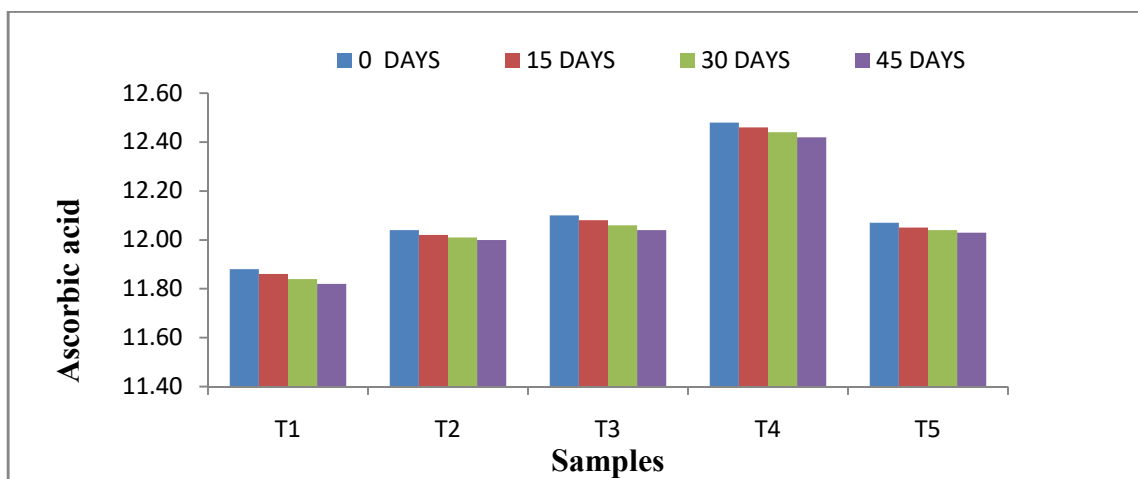


Fig 4.18 Ascorbic acid content (mg/100 gm) of sun dried potato sticks samples fried in mustard oil

4.1.6.1.2 Ascorbic acid content (mg/100 gm) of tray dried potato sticks samples fried in mustard oil

Ascorbic acid content (mg/100 gm) data of potato sticks dried under tray drying and fried in mustard oil is presented in Table 4.19 and bar chart is present in Fig. 4.19 Ascorbic acid content ranged from 11.84 to 12.44 (mg/100 gm) on 0 day, 11.82 to 12.42 (mg/100 gm) on 15 days, 11.80 to 12.40 (mg/100 gm) on 30 days and 11.78 to 12.38 (mg/100 gm) on 45 days of storage. Maximum ascorbic acid content (mg/100 gm) was observed in sample T₄ and minimum was observed in sample T₁ during the storage duration.

Table 4.19 Ascorbic acid content (mg/100 gm) of tray dried potato sticks samples fried in mustard oil.

Samples	0 days	15 days	30 days	45 days
T ₁	11.84	11.82	11.80	11.78
T ₂	12.00	11.98	11.96	11.94
T ₃	12.07	12.05	12.03	12.01
T ₄	12.44	12.42	12.40	12.38
T ₅	12.04	12.02	11.98	11.96

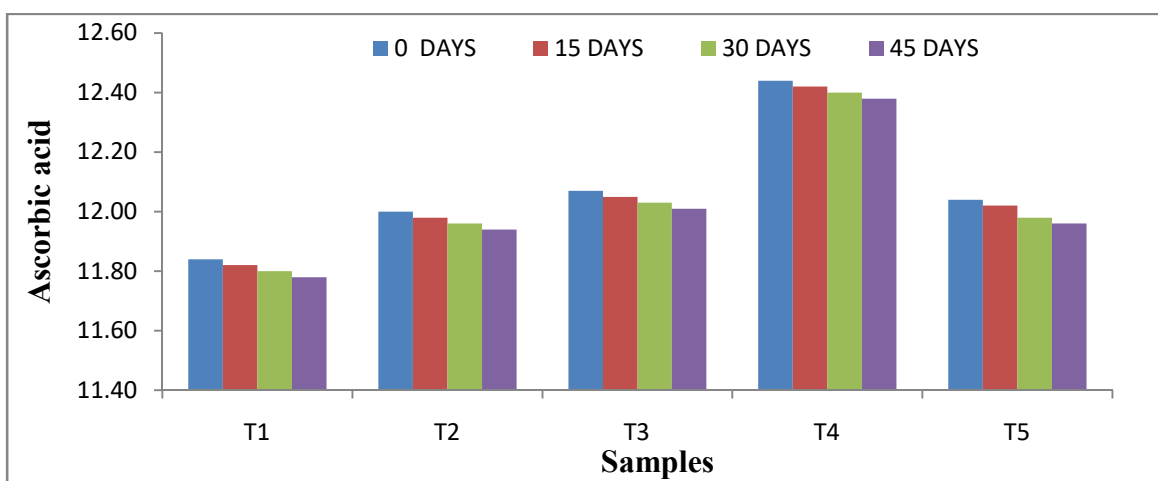


Fig. 4.19 Ascorbic acid content (mg/100 gm) of tray dried potato sticks samples fried in mustard oil

4.1.6.2 Ash content (%) determination of fried potato sticks

4.1.6.2.1 Ash content (%) of sun dried potato sticks samples fried in mustard oil

Ash content (%) data of potato sticks dried under open sun and fried in mustard oil is presented in Table 4.20 and bar chart is present in Fig. 4.20 Ash content ranged from 2.15 to 2.03 (%) on 0 day, 2.14 to 2.02 (%) on 15 days, 2.13 to 2.01 (%) on 30 days and 2.11 to 1.98 (%) on 45 days of storage. Maximum ash content (%) was observed in sample T₁ and minimum was observed in sample T₄ during the storage duration.

Table 4.20 Ash content (%) of sun dried potato sticks samples fried in mustard oil

Samples	0 days	15 days	30 days	45 days
T ₁	2.15	2.14	2.13	2.11
T ₂	2.10	2.08	2.07	2.06
T ₃	2.04	2.03	2.02	2.01
T ₄	2.03	2.02	2.01	1.98
T ₅	2.11	2.10	2.09	2.07

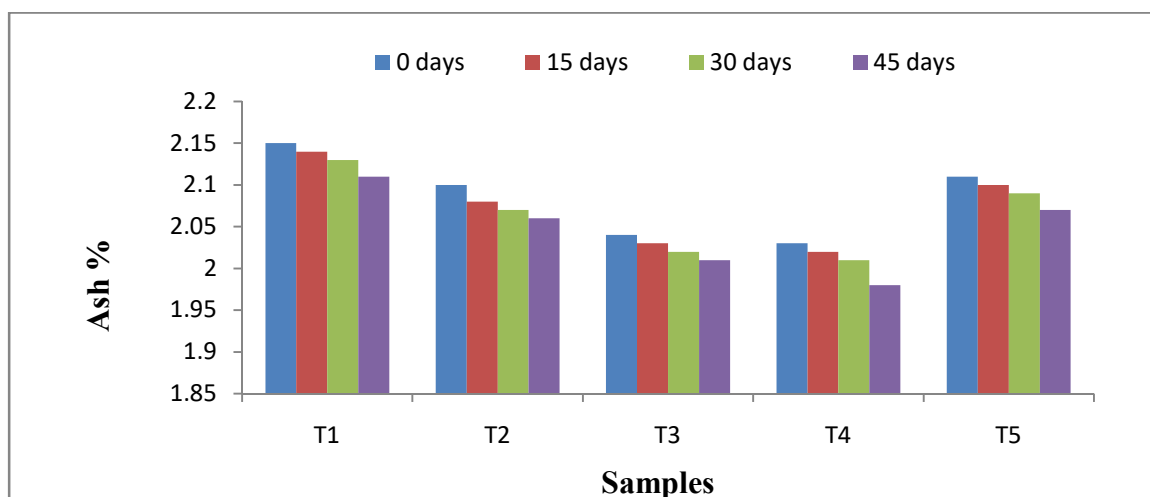


Fig. 4.20 Ash content (%) of sun dried potato sticks samples fried in mustard oil

4.1.6.2.2 Ash content (%) of tray dried potato sticks samples fried in mustard oil Ash content (%) data of potato sticks dried under tray drying and fried in mustard oil is presented in Table 4.21 and bar chart is present in Fig. 4.21 (Ash content ranged from 2.13 to 2.06 (%) on 0 day, 2.12 to 2.05 (%) on 15 days, 2.11 to 2.04 (%) on 30 days and 2.10 to 2.03(%) on 45 days of storage. Maximum ash content (%) was observed in sample T₁ and minimum was observed in sample T₄ during the storage duration.

Table 4.21 Ash content (%) of tray dried potato sticks samples fried in mustard oil

Samples	0 days	15 days	30 days	45 days
T ₁	2.13	2.12	2.11	2.10
T ₂	2.09	2.08	2.07	2.05
T ₃	2.07	2.06	2.04	2.03
T ₄	2.02	2.01	2.00	1.99
T ₅	2.06	2.05	2.04	2.03

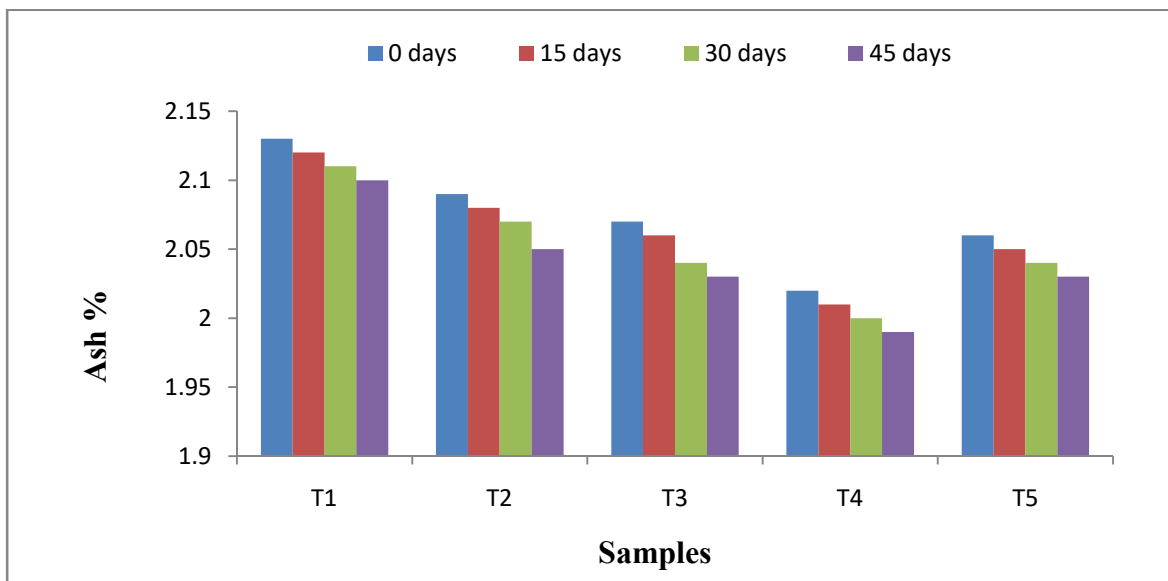


Fig. 4.21 Ash content (%) of tray dried potato sticks samples fried in mustard oil

4.1.7 Sensory attribute of potato sticks samples fried in mustard oil

4.1.7.1 Sensory attribute of sun dried potato sticks samples fried in mustard oil

4.1.7.1.1 Colour attribute of sun dried potato sticks samples fried in mustard oil Colour data of potato sticks dried under open sun and fried in mustard oil is presented in Table 4.22 and bar chart is present in Fig. 4.22 Colour ranged from 6.50 to 8.00 on 0 day, 6.40 to 7.90 on 15 days ,6.30 to 7.80 on 30 days and 6.20 to 7.60on 45 days of storage. Maximum value for colour was observed in sample T₄ and minimum was observed in sample T₁ during the storage duration. ANOVA for the color data is given in appendix-1.

Table 4.22 Colour attribute of sun dried potato sticks samples fried in mustard oil

Samples	0 days	15 day	30 day	45 day
T1	6.50	6.40	6.30	6.20
T2	6.90	6.80	6.70	6.60
T3	7.50	7.30	7.00	6.00
T4	8.00	7.90	7.80	7.60
T5	7.60	7.40	7.30	7.10

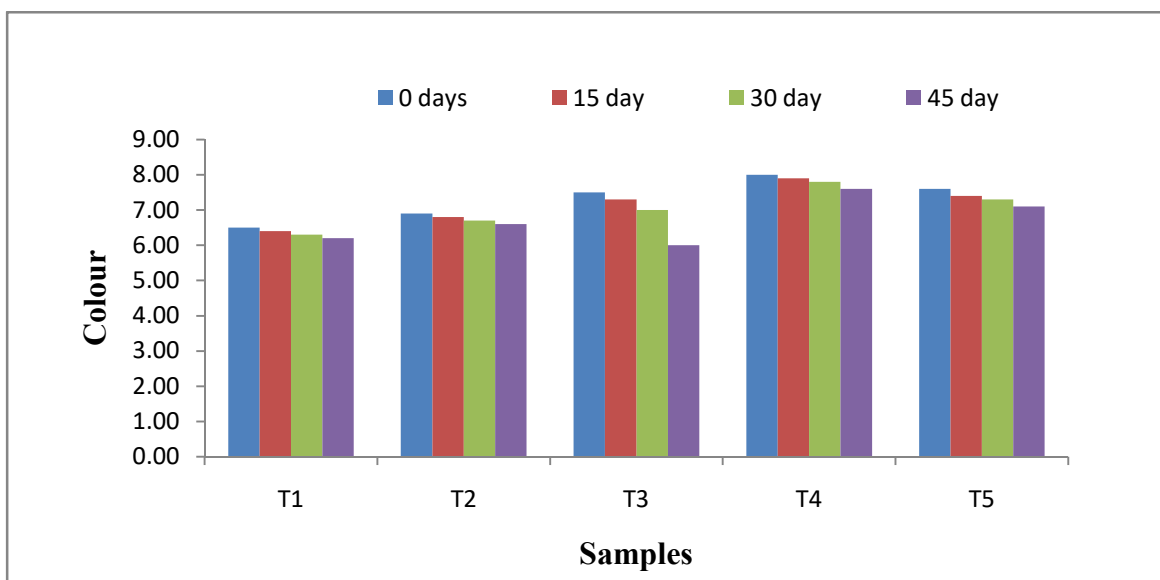


Fig. 4.22 Colour attributes of sun dried potato sticks samples fried in mustard oil

4.1.7.1.2 Texture attributes of sun dried potato sticks samples fried in mustard oil

Texture data of potato sticks dried under open sun and fried in mustard oil is presented in Table 4.23 and bar chart is present in Fig. 4.23 Texture ranged from 6.30 to 8.40 on 0 day, 6.20 to 8.30 on 15 days, 6.20 to 8.20 on 30 days and 6.10 to 8.10 on 45 days of storage. Maximum value for texture was observed in sample T₄ and minimum was observed in sample T₁ during the storage duration. ANOVA for the texture data is given in appendix-2.

Table 4.23: Texture attribute of sun dried potato sticks samples fried in mustard oil

Samples	0 days	15 days	30 days	45 days
T ₁	6.30	6.20	6.20	6.10
T ₂	7.00	6.90	6.80	6.00
T ₃	7.80	7.70	7.60	7.50
T ₄	8.40	8.30	8.20	8.10
T ₅	7.50	7.40	7.40	7.30

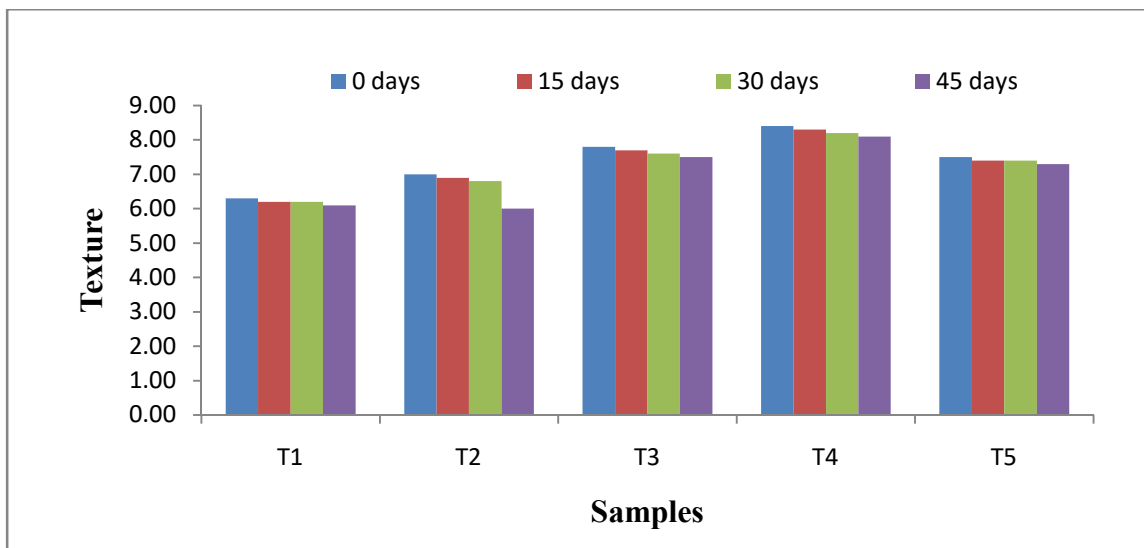


Fig. 4.23 Texture attribute of sun dried potato sticks samples fried in mustard oil

4.1.7.1.3 Flavour attribute of sun dried potato sticks samples fried in mustard oil

Flavour data of potato sticks dried under open sun and fried in mustard oil is presented in Table 4.24 and bar chart is present in Fig. 424 Flavor ranged from 5.50 to 8.90 on 0 day, 5.40 to 8.80 on 15 days, 5.40 to 8.70 on 30 days and 5.30 to 8.60 on 45 days of storage. Maximum value for texture was observed in sample T₄ and minimum was observed in sample T₁ during the storage duration. ANOVA for the flavor data is given in appendix-3.

Table 4.24 Flavour attribute of sun dried potato sticks samples fried in mustard oil.

Samples	0 days	15 days	30 days	45 days
T1	5.50	5.40	5.40	5.30
T2	6.70	6.50	6.50	6.40
T3	7.80	7.80	7.70	7.60
T4	8.90	8.80	8.70	8.60
T5	7.80	7.80	7.70	7.60

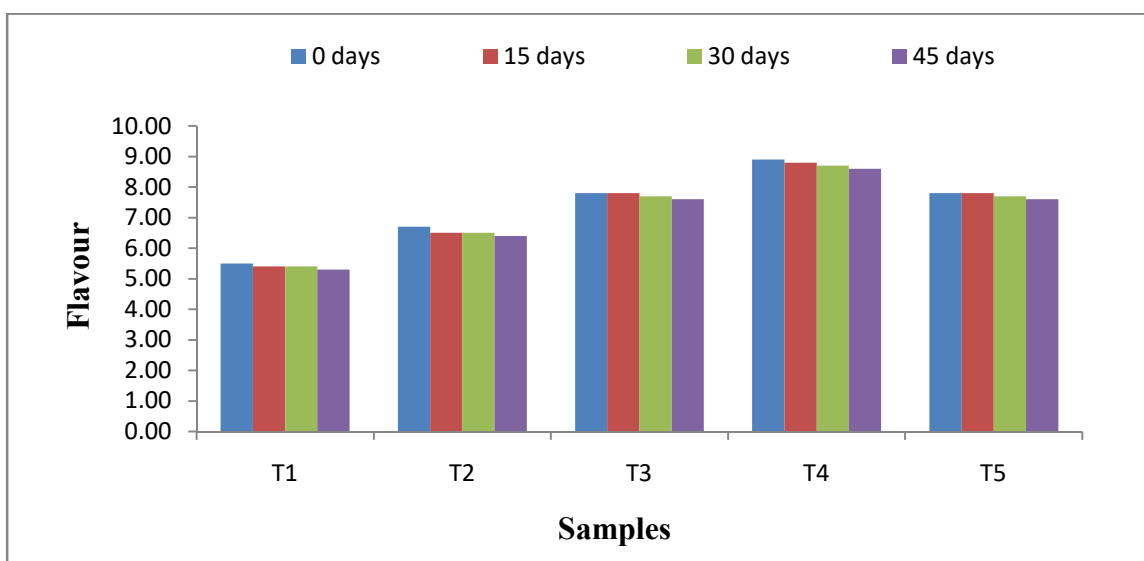


Fig. 4.24 Flavour attributes of sun dried potato sticks samples fried in mustard oil

4.1.7.1.4 Overall acceptability attributes of sun dried potato sticks samples fried in mustard oil

Overall acceptability data of potato sticks dried under open sun and fried in mustard oil is presented in Table 4.25 and bar chart is present in Fig. 4.25 Overall acceptability ranged from 6.10 to 8.46 on 0 day, 6.00 to 8.33 on 15 days, 5.93 to 8.13 on 30 days and 5.86 to 8.10 on 45 days of storage. Maximum value for overall was observed in sample T₄ and minimum was observed in sample T₁ during the storage duration. ANOVA for the overall acceptability data is given in appendix-4.

Table 4.25: Overall acceptability attributes of sun dried potato sticks samples fried in mustard oil

Samples	0 days	15 days	30 days	45 days
T ₁	6.10	6.00	5.93	5.86
T ₂	6.86	6.73	6.66	6.33
T ₃	7.76	7.60	7.50	7.36
T ₄	8.46	8.33	8.13	8.10
T ₅	7.63	6.53	7.46	7.33

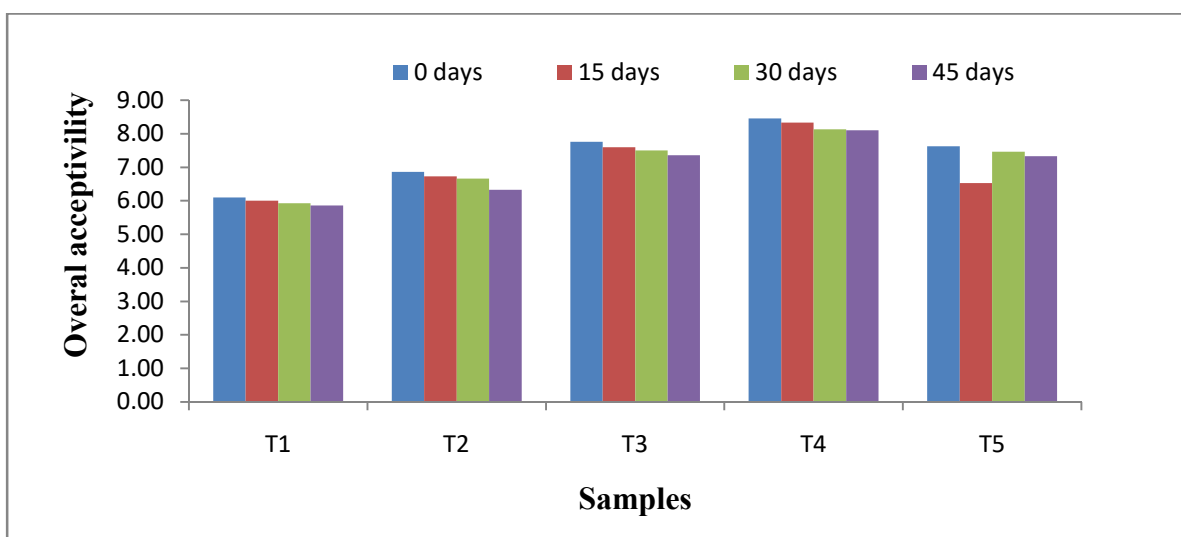


Fig. 4.25 Overall acceptability of sun dried potato sticks samples fried in mustard oil

4.4.2 Sensory attribute of tray dried potato sticks samples fried in mustard oil

4.1.7.2 Colour attribute of tray dried potato sticks samples fried in mustard oil

Colour data of potato sticks dried under tray drying and fried in mustard oil is presented in Table 4.26 and bar chart is present in Fig. 4.26 Colour ranged from 5.60 to 8.50 on 0 day, 5.40 to 8.20 on 15 days, 5.30 to 8.10 on 30 days and 5.20 to 8.30 on 45 days of storage. Maximum value for colour was observed in sample T₄ and minimum was observed in sample T₁ during the storage duration. ANOVA for the colour data is given in appendix-5.

Table 4.26 Colour attributes of tray dried potato sticks samples fried in mustard oil

Samples	0 days	15 days	30 days	45 days
T ₁	5.60	5.40	5.30	5.20
T ₂	6.80	6.70	6.60	6.50
T ₃	6.70	6.50	6.40	6.30
T ₄	8.50	8.20	8.10	8.00
T ₅	7.00	6.80	6.50	6.40

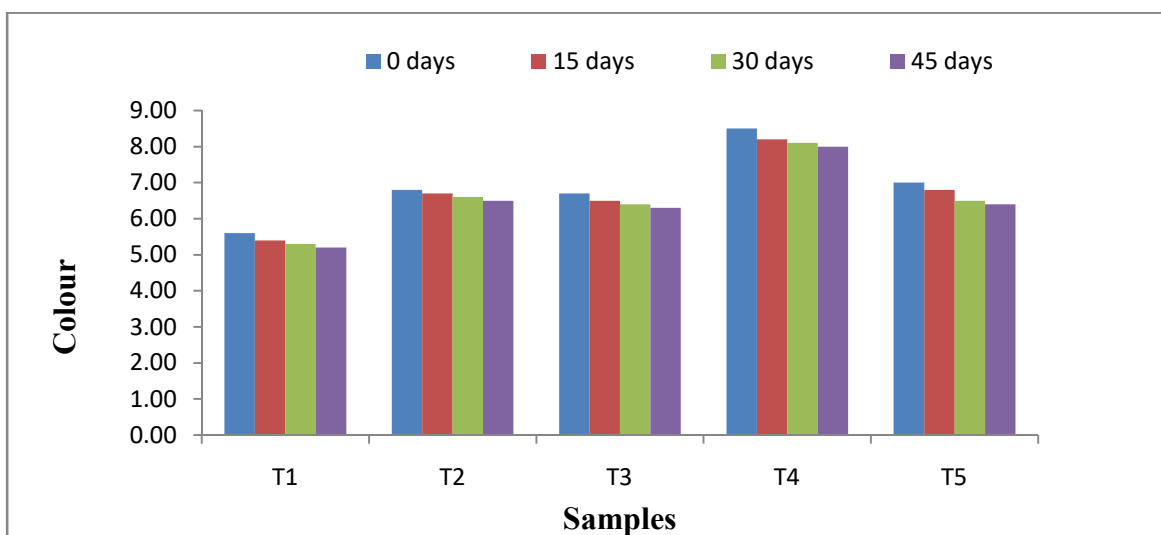


Fig. 4.26 Colour attribute of tray dried potato sticks samples fried in mustard oil

4.1.7.3 Texture attributes of tray dried potato sticks samples fried in mustard oil

Texture data of potato sticks dried under tray drying and fried in mustard oil is presented in Table 4.27 and bar chart is present in Fig. 4.27 Texture ranged from 5.60 to 8.40 on 0 day, 5.50 to 8.20 on 15 days, 5.40 to 8.20 on 30 days and 5.30 to 8.00 on 45 days of storage. Maximum value for texture was observed in sample T₄ and minimum was observed in sample T₁ during the storage duration. ANOVA for the texture data is given in appendix-6.

Table 4.27: Texture attributes of tray dried potato sticks samples fried in mustard oil

Samples	0 days	15 days	30 days	45 days
T ₁	5.60	5.50	5.40	5.30
T ₂	6.70	6.50	6.30	6.20
T ₃	7.50	7.40	7.20	6.80
T ₄	8.40	8.20	8.20	8.00
T ₅	7.50	7.40	7.30	7.20

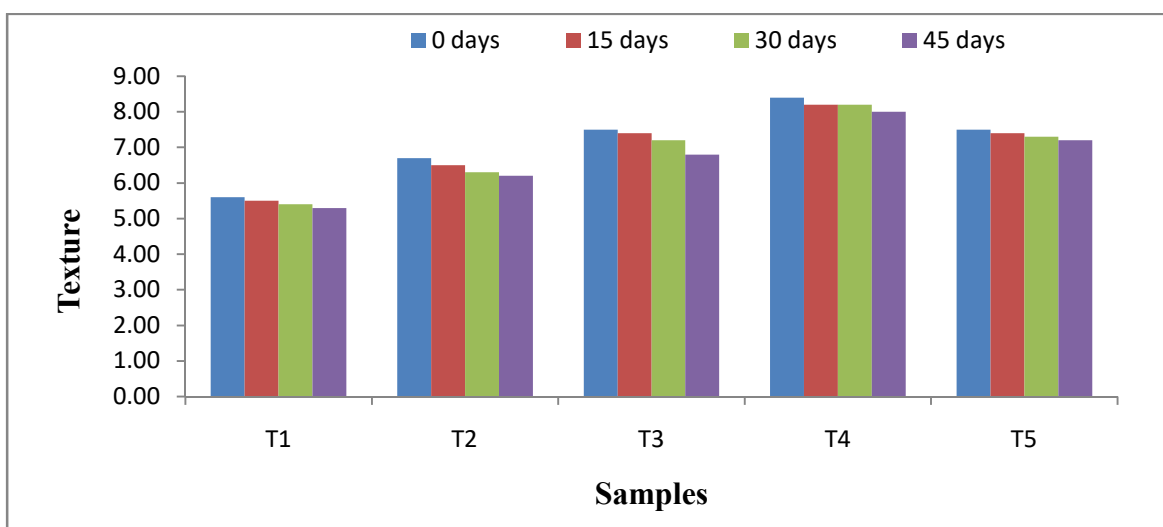


Fig. 4.27 Texture attribute of tray dried potato sticks samples fried in mustard oil

4.1.7.4 Flavour attributes of tray dried potato sticks samples fried in mustard oil

Flavour data of potato sticks dried under tray drying and fried in mustard oil is presented in Table 4.28 and bar chart is present in Fig. 4.28 Flavour ranged from 5.60 to 8.40 on 0 day, 5.50 to 8.20 on 15 days, 5.40 to 8.20 on 30 days and 5.20 to 8.00 on 45 days of storage. Maximum value for was flavor observed in sample T₄ and minimum was observed in sample T₁ during the storage duration. ANOVA for the flavor data is given in appendix-7.

Table 4.28: Flavour attributes of tray dried potato sticks samples fried in mustard oil

Samples	0 days	15 days	30 days	45 days
T ₁	5.50	5.40	5.00	4.50
T ₂	6.50	6.50	6.30	6.20
T ₃	8.00	8.00	7.80	7.60
T ₄	8.50	8.40	8.30	8.10
T ₅	7.80	7.70	7.60	7.50

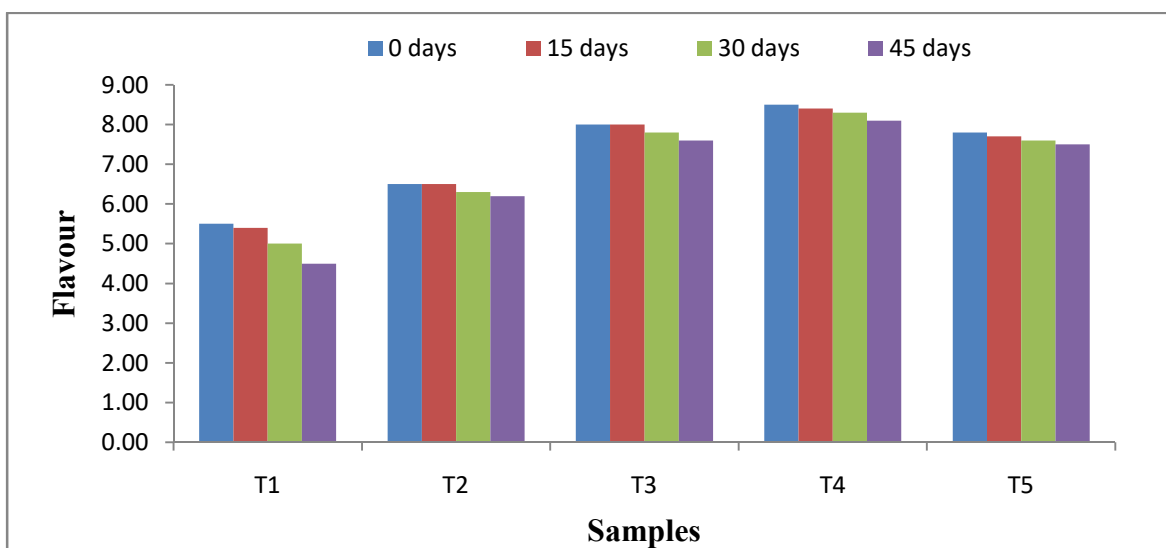


Fig. 4.28 Flavour attribute of tray dried potato sticks samples fried in mustard oil

4.1.7.5 Overall acceptability attributes of tray dried potato sticks samples fried in mustard oil

Texture data of potato sticks dried under tray drying and fried in mustard oil is presented in Table 4.29 and bar chart is present in Fig. 4.29 Texture ranged from 5.50 to 8.46 on 0 day, 5.43 to 8.26 on 15 days, 5.33 to 8.20 on 30 days and 5.26 to 8.03 on 45 days of storage. Maximum value for was flavor observed in sample T₄ and minimum was observed in sample T₁ during the storage duration. ANOVA for the overall acceptability data is given in appendix-8.

Table 4.29 Overall acceptability attributes of tray dried potato sticks samples fried in mustard oil

Samples	0 days	15 days	30 days	45 days
T ₁	5.56	5.43	5.33	5.26
T ₂	6.66	6.56	6.40	6.30
T ₃	7.40	7.30	7.13	6.90
T ₄	8.46	8.26	8.16	8.03
T ₅	7.43	7.30	7.13	7.03

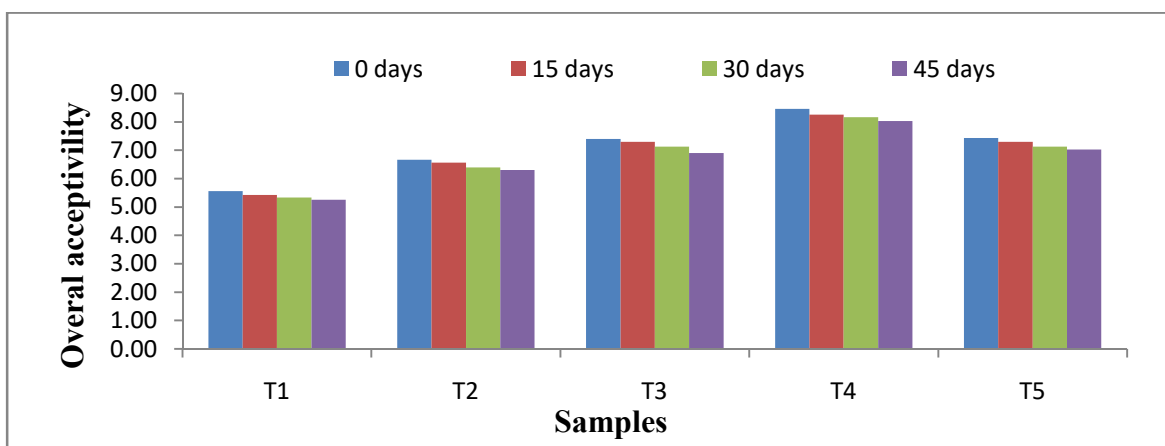


Fig. 4.29: Overall acceptability attributes of tray dried potato sticks samples fried in mustard oil

A decorative border resembling a scroll, with rounded corners and a vertical strip on the left side. The scroll is outlined in black and has a light gray shadow effect on its top and left edges.

***SUMMARY
AND
CONCLUSION***

SUMMARY AND CONCLUSIONS

The present investigation was carried out to study the effect of pre-treatment on drying kinetics and frying of potato finger sticks. Experiments were conducted to develop the potato sticks fries using five treatments and mustard oil for frying. Potatoes were purchased from CPRI and washed into fresh water so as to remove the dust and dirt particle. Peeling was done manually, The washed & potato was sliced and treated with five pre-treatments first is control(T₁), blanching Citric acid @ 0.5% (T₂), blanching Potassium meta-bisulphate @ 0.5% (T₃), blanching Citric acid 0.5% + Potassium meta-bisulphate @ 0.5% (T₄), Blanching (3-4 min) at 95 °C (T₅) and dried under sun drying and tray drying. The frying kinetics was studied of the samples with mustard oil for 45-50 sec. The fried potato sticks packed into LDPE packaging and sensory was done during storage. Sensory quality attributes (colour, flavour, texture, overall acceptability) of fried potato sticks samples were evaluated.

On the basis of findings of present investigation, the following conclusions could be drawn.

1. During sun drying, control treated samples took 10 hour to dry and moisture content (db %) was ranged from 497.01 to 8.67 and drying rate was ranged from 1.33 to 0.14.
2. During sun drying, citric acid treated sample took 11 hour to dry completely and moisture content (db %) was ranged from 497.01 to 6.67 and drying rate was ranged from 1.32 to 0.04.

3. During sun drying, potassium meta- bisulphate treated sample took 11 hour to dry and moisture content (db %) was ranged from 497.01 to 6.50 and drying rate was ranged from 1.39 to 0.05.
4. During sun drying, citric acid+ potassium meta- bisulphate treated sample took 11 hour to dry and moisture content (db %) was ranged from 497.01 to 9.00 and drying rate was ranged from 1.27 to 0.06.
5. During sun drying, blanching with 95 °C treated sample took 10 hour to dry and moisture content (db %) was ranged from 497.01 to 9.48 and drying rate was ranged from 1.69 to 0.13.
6. During sun drying, maximum % mass reductions (82.25) was observed in Sample T₂ and T₃.
7. During sun drying, maximum % water loss (98.69) was observed in Sample T₃.
8. During tray drying, treated control sample took 6 hour to dry and moisture content (db %) was ranged from 497.01 to 7.67 and drying rate was ranged from 1.94 to 0.07.
9. During tray drying, citric acid treated sample took 8 hour to dry and moisture content (db %) was ranged from 497.01 to 5.80 and drying rate was ranged from 1.40 to 0.02.
10. During tray drying, potassium meta- bisulphate treated sample took 7 hour to dry and moisture content (db %) was ranged from 497.01 to 5.67 and drying rate was ranged from 1.74 to 0.04.
11. During tray drying, citric acid+ potassium meta- bisulphate treated sample took 7 hour to dry and moisture content (db %) was ranged from 497.01 to 8.00 and drying rate was ranged from 1.61 to 0.03.

12. During tray drying, blanching with 95 °C treated samples took 10 hour to dry and moisture content (db %) was ranged from 497.01 to 6.80 and drying rate was ranged from 1.64 to 0.04.
13. During tray drying, maximum % mass reductions (82.25) was observed in Sample T₂ and T₃ same as sun drying.
14. During tray drying, maximum % water loss (98.86) was observed in Sample T₃.
15. During frying of sun dried samples maximum weight gain % (15.49) was observed in sample T₃.
16. During frying of tray dried samples, maximum weight gain % (16.90) was observed in sample T₂.
17. During frying of samples, maximum oil content (25.37 %) was observed in T₁ in case of sun drying; where as in tray dried samples it was observed in T₁ and T₄.
18. During the physico-chemical evaluation of sun dried potato sticks, samples fried in mustard oil, maximum ascorbic acid content (12.48) (mg/100 gm) was found in T₄ at 0 days.
19. During the physico-chemical evaluation of tray dried potato sticks samples fried in mustard oil, maximum ascorbic acid content (12.44) (mg/100 gm) was found in T₄ at 0 days.
20. During the physico-chemical evaluation of sun dried potato sticks samples fried in mustard oil, maximum (2.15) ash content (%) was observed in sample T₁ at 0 days.
21. During the physico-chemical evaluation of tray dried potato sticks, samples fried in mustard oil, maximum ash content (2.13) observed in sample T₁ at 0 days.

22. During the sensory evaluation; all the parameters like colour, texture, flavor and overall acceptability of fried samples dried under sun drying was found maximum for T₄ at 0 days. Same pattern was seen for tray dried samples.



BIBLIOGRAPHY

REFERENCES

- Abbas, G., Hafiz, I.A., Abbasi, N.A. and Hussain, A. (2017).** Determination of processing and nutritional quality attributes of potato genotypes in Pakistan, *Pakistan Journal of Botany*. **44**(1):201-208.
- Adeyemi, P.O. A. and Salaam, A. R. B. (2015).** Effect of processing conditions on the quality of fried sweet potato chips. *The international journal of science & technoledg* issn 2321 – 919x).
- Ahmad, T.A.H. and Ismail, I. (2008).** Comparison of the frying stability of standard palmolein and special quality palmolein. *Journal of American of Oil Chemists' Society*, **85**(3):245-251.
- Akhtar, J., Kumar, J. and Malik, S. (2015).** Optimization of Quality Parameters of Dehydrated Potato under Combined Microwave-Fluidized Bed Drying *journal of Food Research and technology* 2015 Vol (3)
- Aktas, T., Fujii, S., Kawano, Y. and Yamamoto, S. (2007).** Effects of pretreatments of sliced vegetables with trehalose on drying characteristics and quality of dried products, *Food and Bio products processing*, **85** (C3): 178- 183.
- Ali, S.H., Razek, Abdel. G.A. and Kamil, M.M. (2012).** Effect Of Pre-Frying Treatments Of french fried Potatoes To Achieve Better Oil Uptake Reduction For Health And Technological
- Alruz, A.K. (2013).** Effect of pre drying and using hydrocolloid system on frying characteristics of fried potato *American Journal of Agricultural and Biological Sciences***8** (4): 282-286, 2013 ISSN: 1557-4989.
- Amjad, A., Randhawa, A.M., Butt, S.M. and Asghar, M. (2016).** Assessing the processing quality of different potato cultivars during storage at various Temperatures *Journal Chem.Soc.Pak.*, 38, No. 05, 1005.

- Andersson, A., Gekas, V., Lind, I., Oliveira, F. and Oste, R. (1994).** Effect of preheating Potato texture. *Critical Reviews in Food Science and Nutrition* **34**(3), 229–251
- Arya, A.M., Chandra, S., Kalnar, B.Y. and Singh, S. (2015).** Effect of pre-treatments (blanching and soaking) on potato (*Solanum tuberosum* L.) french fries. *Green Farming*, (6): 1376-1379.
- Arya, A.M., Chandra, S., Samsher, Chauhan, N., Singh, J. and Kumar, T. (2017).** Moisture loss and oil uptake kinetics in French fries (var. Kufribahar) during frying in different oils and treatments. *International Journal of Chemical Studies*, **5**(5): 594-596.
- Arya, A.M., Chandra, S., Samsher, Chauhan, N., Singh, J. and Kumar, T. (2017).** Effect of different blanching and soaking pretreatments on potato (var. Kufri Pukhraj) french fries. *International Journal of Chemical Studies*, **5**(4): 984-988.
- Baumann, B., Escher, E. (1995).** Mass and heat transfer during deep fat frying of potato slices: *Aspects Journal of Applied Sciences Research*, **8**(10): 5018-5024, 2012 ISSN 1819-544X.
- Blumenthal, M.M. (1991).** A new look at the chemistry and physics of deep-fat frying. *Food Technology*, **45**(2): 68–71, 94.
- Blumenthal, M.M. and Stier, R.F. (1991).** Optimization of deep-fat frying operations Trends in *Food Science and Technology*, 144–148.
- Bouchon, P., Aguilera, J. M., and Pyle, D. L. (2003).** Structure oil absorption relationships during deep-fat frying. *Journal of Food Science*, **68**, 2711–2716.
- Bunger, A., Moyano, P. and Rioseco, V. (2003).** NaCl soaking treatment for improving the quality of french-fried potatoes. *Food Research International*, No. 36, p. 161–166.

- Chavhan, S., Bhong, M. and Chirade, S. (2018).** Effect of various process parameters on drying behavior of Potato- Review. *International Journal on Theoretical and Applied Research*.**63**, 2710–2720
- Chayjan, A.R. (2012).** Modeling Some Drying Characteristics of High Moisture Potato Slices in Fixed, Semi Fluidized and Fluidized Bed Conditions. *Journal of Agriculture Science Technology* Vol. 14: 1229-1241.
- Choe, E. and D.B. Min. (2007).** Chemistry of Deep-Fat Frying Oils.*Journal of Food Science*.**72**:: R7786.
- Choe, E., Kang, W.S. and Chang, Y.S. (1993).** Kinds and changes in the amount of flavor compounds formed during storage of the ramyon Korean.*Journal Food Science and Technology*. **25**:52–6.
- Costa, R.M., Oliveira, F.A.R., Delaney, O and Gekas, V. (1997).** Application of image analysis to the study of water losses from potato slices during frying. In R. Jowitt, Engineering & food at ICEF 7, Part I.*Sheffield: Sheffield Academic Press*.(pp. A157-A160).
- Doymaz, I. (2004).** Convective air drying characteristics of thin layer carrots. *Journal of Food Engineering*, **61**: 359-364.
- Erdogdu, F. andDejmek, P., (2010).** Determination of heat transfer coefficient during high pressure frying of potatoes. *Journal of Food Engineering* **96** (4) 528–532.
- Faisal, S., Tabassum, R. and Kumar, V. (2013).** Performance Evaluation and Process Optimization of Potato Drying using Hot Air *Journal of Food Process Technology*.vol (4)
- FAO, (1981).** Food loss prevention in perishable crop. Food and Agriculture Organization of the United Nations.

- Farkas, B.E. (1994).** Modeling immersion frying as a moving boundary problem. Ph.D, Dissertation, University of California, Davis, USA.
- Farkas, B.E., Singh, R.P., and Rumsey, T.R. (1996).** Modeling heat and mass transfer immersion frying. Part I: model development. *Journal of Food Engineering*, **29**, 211–226.
- Fellows, P.J. (1996).** Food processing technology Principles and practice (2nd ed., pp.331-332). Cambridge: *Wood head Publishing Limited*.
- Gamble, M.H.and Rice, P. (1987).** Effect of pre-fry drying of oil uptake and distribution Potato crisp manufacture. *International Journal of Food Science and Technology*, **22**, 535±548.
- Gamble, M.H., and Rice, P. (1987).** Effect of pre-fry drying of oil uptake, and distribution in potato crisp manufacture. *International Journal of Food Science and Technology*, **22**, 535–548.
- Gamble, M.H., Rice, P. and Selman, J.D. (1987a).** Relationship between oil uptake and moisture loss during frying of potato slices from C.V. Record U.K. Tubers. *International Journal of Food Science of Technology*, **22**, 233–241.
- Garayo, J. and Moreira, R. (2002).** Vacuum frying of potato chips. *Journal of Food Engineering*, **55**: 181-191.
- Hafezi, N., Sheikhdavoodi, J.M., Sajadiye, M. S. and Ferdavani, K.E.M. (2014).** Evaluation of Energy Consumption of Potato Slices Drying Using Vacuum-Infrared Method. *International Journal of Advanced Biological and Biomedical Research* **2** (10), 2651-2658.
- Hatamipour, M.S., Kazemi, H.H., Nooralivand, A. and Nozarpoor, A. (2007).** Drying characteristics of six varieties of sweet potatoes in different dryers. *Food Bioprocess* **85**: 171-177.

- Hindra, F. and Baik, O.D. (2006).** Kinetics of quality changes during food frying. *Critical Reviews in Food Science and Nutrition*, **46**, 239-258.
- Huang, P.Y. and Chung, F.Y. (2014)** .Modelling the Kinetics of Water Loss during Deep-Fat Frying of Potato Particulates *Czech Journal Food Sci. Vol. 32, 2014, No. 6: 585–594*
- Hubbard, L.J. and Farkas, B.E. (2000).** Influence of oil temperature on heat transfer during immersion frying. *Journal of Food Processing and Preservation*, **24**,143–162.
- Kampuse, S., Jefimovs, A. and Rakcejeva, T. (2014).** The influence of pre-treatment method on the fat content decrease in french fries foodbalt (2014).
- Kita, A., Brathen, E., Knutsen, H.S. and Wicklund, T. (2004).** Effective Ways of decreasing acrylamide aontent in potato crisps during processing *Journal Agricultral Food Chemistry*,**52** (23), pp 7011–7016
- Kocabiyik, H. and Tezer, D. (2009).** Drying of carrot slices using infrared radiation. *International Journal Food Sciences Technology*, **44**: 953.959
- Kroikida, M.K., Oreopoulou, V., Maroulis, Z.B. and Kouris, M.D. (2001).** Colour changes during deep-fat frying. *Journal of Food Engineering*, **48**,219-225.
- Krokida, M.K, Oreopoulou, V., Maroulis, Z.B. and Marinos, K.D.(2001).** Effects of osmotic dehydration pretreatment on quality of French fries.*Journal of Food Engineering*. **49**:339-345.
- Krokida, M.K.,Oreopolou, V. and Maroulis, Z.B. (2000).** Water loss and oil uptake as a function of frying time. *Journal of Food Engineering* **44**: 39–46.
- Liu, F., Shahnazari, A., Andersen, N.M., Jacobsen, E.S. And Jensen,R.C.(2006).** Physiological responses of potato (*Solanum tuberosum* L.) to partial root-zone

- drying: abscisic acid Concentration signalling, leaf gas exchange, and water use efficiency. *Journal of Experimental Botany*, (57), No. 14, pp. 3727–3735.
- Mellema, M., (2003).** Mechanism and reduction of fat uptake in deep-fat fried foods. *Trends in Food Science and Technology*, 14: 364-373.
- Mestdagh, F., Dewilde, T., Fraselle, S., Govaert, Y., Ooghe, W., Degroodt, J. M., Verhe, R., Van Peteghem, C. and De Meulenaar, B. (2008).** Optimization of the blanching process to reduce acrylamide potatoes *LWT-Food Science and Technology* 41(9): 1648-1654
- MirBel, J., Oria, R. and Salvador, M.L. (2009).** Influence of the vacuum break conditions on oil uptake during potato post-frying cooling. *Journal of Food Engineering*. 95 (3):416-422.
- Mirzaei, O.H, Garoumi, H., Salehi, F. and Farhadpour, F. (2015).** Effect of Frying Temperature on Amount of Oil Uptake of potato French fries Food process technology,1(1):00006
- Moreira, R.G. (2001).** Impingement drying of food using hot air and superheated steam. *Journal of food sciences* 34: 453_457
- Moreira, R.G. and Barrufet, M.A. (1998).** A new approach to describe oil absorption in fried Food a simulation study *Journal Food Engg*, 31: 485–498.
- Moreira, R.G., Castell-Perez, M.E. and Barrufet, M.A. (1999).** Fried product processing and characteristics. In: Deep-fat frying: fundamentals and applications. Gaithersburg, Md.: *Chapman & Hall Food Science Book*. 11–31.
- Moreira, R.G., Castell-Perez, M.E., Barrufet, M.A. (1999).** Deep-fat frying: fundamentals and applications. Aspen Publishers, Gaithersburg, MA, 6, 98, 179, 202.
- Moreira, R.G., Sun, X. and Chen, Y. (1997).** Factors affecting oil uptake in tortilla chips in deep-fat frying. *Journal of Food Engineering* 31:485–498.

- Moyano, P.C. and Pedreschi, F. (2006).** Kinetics of oil uptake during of potato slices: effect of pre-treatments. *LWT Food Science and Technology*, **39**: 285–291.
- Mujundar, A.S. (1987).** Handbook of Industrial Drying, Marcel Dekker Inc., New York, NY.
- Ngadi, M.O., Watts, K.C., and Correia, L.R. (1997).** Finite element method modelling of moisture transfer in chicken drum during deep-fat frying. *Journal of Food Engineering*, **32**, 11±20.
- Nicanuru, C., Laswai, S.H. and Sila, N.D. (2015).** Effect of sun-drying on nutrient content of orange fleshed sweet potato tubers in tanzania sky *Journal of Food Science* , 4(7), November, 2015 of Food Engineering, **49**: 291.295.
- Oroszvari, B.K., Bayod, E., Sjöholm I. and Tornberg, E. (2005).** The mechanisms controlling heat and mass transfer on frying of beef burgers. Part 2: The influence of the pan temperature and patty diameter. *Journal of Food Engineering*, **71**: 18–27.
- Pedreschi, F., Moyano, P., Kaack, K. and Granby, K. (2005).** Colour changes and acrylamide formation in fried potato slices. *Food Research International*, **38**: 1-9.
- Pedreschi, F., Zuniga, N.R. (2009).** Acrylamide and oil reduction in French fried potatoes: A Review. *Food 3 (special issue 2)*, 83-92.
- Pinthus, E. J., Weinberg, P. and Saguy, S. (1993).** Criterion for oil uptake in deep-fat frying. *Journal Food Sci.* **58**: 204-205, 222. SAS Users' Guide: Statistics, Edn. Cary, NC: SASInst, Inc.
- Pinthus, E.J. and Saguy, I.S. (1994).** Initial interfacial tension and oil uptake by deep-fat fried foods. *Journal Food Sciences.* **59**: 804-807, and 823.
- Pinthus, E.J. Weinberg, P., and Saguy, I. S. (1995).** Deep-fat fried potato product oil uptake as affected by crust physical properties. *Journal Food Sci.* **60**: 770-772.

- Pravisani, C.I. and Calvelo, A. (1986).** Minimum cooking time for Spotato strip frying. *Journal of Food Science*, **51**, 614±617.
- Purwar, A. and Pawar, P.A. (2015).** Optimization of Hydrocolloids Concentration on Fat Reduction in French Fries *American Journal of Engineering Research (AJER)* e-ISSN : 2320-0847 p-ISSN : 2320-0936 Volume-(04).
- Ranganna, S. (1986).** Handbook of analysis and quality control for fruits and vegetable products. 2nd ed, Tata McGraw Hill Publishing Company Limited, New Delhi, India.
- Ranganna, S. (2010).** Handbook of analysis and quality control for fruits and vegetable products 2nd ed, tata mcgraw hill publishing company limited, new delhi, India.
- Reeve, R.M. and Neel, E.M. (1960).** Microscopy structure of potato chips. *An Potato Journal* 37:4552.
- Reshi, M., Mehraj, M., Slathia, D. and Shafi, F. (2017).** Storage studies on potato products of Jammu region influenced by packaging and chemical treatments *International Journal of Chemical Studies* **5(6)**: 253-255
- Sandhu, K.S. and Parhawak, B., (2002).** Studies on the preparation of dehydrated potato. *Lebensmittel-Wissenschaft and-Technologie* **28(4)**, 395–403.
- Santis, N., Mendoza, F., Moyano, P., Pedreschi, F. Sand Dejmek, P.(2007).** Soaking in a NaCl solution produce paler potato chips. *Food Science and Technology*, **40(2)**:307-312.
- Shaker, M.A. (2015).** comparison between traditional deep-fat frying and air-frying for production of healthy fried potato strips. *international food research journal* **22(4)**: 1557-1563.

- Shallal, P., Rajaei, P. and Asadollahi, S. (2014).** The effect of kind and temperature of oil used in deep frying on the amount of oil uptake *International Journal of Biosciences* Vol. 5, No. 12, p. 331-341.
- Smith, O. (1977).** Potatoes: production, storing, processing. westport, connecticut. *the avi publishing company*.
- Sobol, Z., Hebda, T. and Kordon, L.B. (2017).** The impact of pretreatment semi-product on the texture of fried potato *Technical Sciences*, 2017, 20(2), 161–169.
- Supardan, D.M. and Satriana. (2007).** prediction of water loss during potato vacuum frying process *Journal Rekayasa Kimia dan Lingkungan*. 6, No. 2, hal. 82-86.
- Toma, R.B., Leung, H.K., Augustin, J. and Iritani, W.M. (1986).** Quality of French fried potatoes as affected by surface freezing and specific gravity of raw potatoes. *Journal Food Sci.* **51**:1213-1214.
- Truong, D.V. and Avula, Y.R. (2010).** Sweet potato purees and powders for functional food ingredients post harvest aspects in food ISBN 978-1-60876-343 117-161- 2010 Nova Science Publishers, Inc. New York.
- Ufheil, G. and Escher, F. (1996).** Dynamics of oil uptake during deep fat frying of potato slices. *Lebensm.-Wiss. Technol.* **29**, 640±644.
- Velescu, I., Țenu, I., Carlescu, P. and Dobre, V. (2013).** Experiment study of drying behavior of potato **56** (1).
- Vitrac, O., Dufour, D., Trystram, G., Wack, R.A. (2002).** Characterizations of heat and mass transfer during deep-fat frying and its effect on cassava chip quality. *Journal of Food Engineering*, **53**(2) 161-176.
- Williams, R. and Mittal, S.G. (1999).** Low fat fried foods with edible coatings modeling and simulation, *Journal of Food Science*, **64**: 317-322.

Ziaifar, A. M., Achir, N., Courtois, F., Trezzan, I. and Trystram, G. (2008). Review of Mechanisms conditions, and factors involved in the oil uptake phenomenon during the deep-fat frying process *International Journal of Food Science and Technology*, **43**, 1410–1423.

Ziaifar, A.M., Achir, N., Courtois, F., Trezzani, I. and Trystram, G. (2008). Review of mechanisms, conditions, and factors involved in the oil uptake phenomenon during the deep-fat frying process. *International Journal of Food Science & Technology*, **43**:1410–1423.

Mai Tran T.T., Dong C. X., and Southern, C. (2006). Reducing oil content of fried potato crisps considerably using a ‘sweet’ pre-treatment technique. *Elsevier Ltd.* All rights reserved. *journal of food eng* 2006.06.031.

Midilli, A., Kucuk, H. and Yapar, Z. (2002). A new model for layer during. *Drying technology*, **20 (9)** :1503-1573.

Appendix

APPENDICES

Appendix-1: ANOVA for colour of sun dried samples fried in mustard oil.

Source of Variation	D.F	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.989			
Treatment	4	5.122	1.280	23.348	0.00001
Error	12	0.658	0.055		
Total	19	6.769			
C.D	0.365				
C.V	0.324				

Appendix-2: ANOVA for texture of sun dried samples fried in mustard oil.

Source of Variation	D.F	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.434			
Treatment	4	10.458	2.615	93.951	0.00000
Error	12	0.334	0.028		
Total	19	11.226			
C.D	0.260				
C.V	0.231				

Appendix-3: ANOVA for flavour of sun dried samples fried in mustard oil.

Source of Variation	D.F	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.178			
Treatment	4	26.892	6.723	2,507.547	0.00000
Error	12	0.032	0.003		
Total	19	27.102			
C.D	0.081				
C.V	0.716				

Appendix-4: ANOVA for overall acceptability of sun dried samples fried in mustard oil.

Source of Variation	D.F	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.401			
Treatment	4	12.131	3.033	54.469	0.00000
Error	12	0.668	0.056		
Total	19	13.201			
C.D	0.368				
C.V	0.308				

Appendix-5: ANOVA for colour of tray dried samples fried in mustard oil.

Source of Variation	D.F	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.545			
Treatment	4	16.225	4.056	1,036.770	0.00000
Error	12	0.047	0.004		
Total	19	16.818			
C.D	0.097				
C.V	0.937				

Appendix-6: ANOVA for texture of tray dried samples fried in mustard oil.

Source of Variation	D.F	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.522			
Treatment	4	17.287	4.322	558.208	0.00000
Error	12	0.093	0.008		
Total	19	17.902			
C.D	0.137				
C.V	1.27				

Appendix-7: ANOVA for flavor of tray dried samples fried in mustard oil.

Source of Variation	D.F	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.708			
Treatment	4	27.533	6.883	363.678	0.00000
Error	12	0.227	0.019		
Total	19	28.468			
C.D	0.214				
C.V	1.949				

Appendix-8: ANOVA for overall acceptability of tray dried samples fried in mustard oil.

Source of Variation	D.F	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.445			
Treatment	4	17.550	4.387	2,578.961	0.00000
Error	12	0.020	0.002		
Total	19	18.015			
C.D	0.064				
C.V	0.598				

Appendix-9: ANOVA for ascorbic acid on sun drying samples fried in mustard oil.

Source of Variation	D.F	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.008			
Treatment	4	0.779	0.195	8,129.462	0.00000
Error	12	0.000	0.000		
Total	19	0.786			
C.D	0.068				
C.V	0.040				

Appendix-10: ANOVA for ascorbic acid on tray dried samples fried in mustard oil.

Source of Variation	D.F	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.021			
Treatment	4	0.774	0.194	103.169	0.00000
Error	12	0.023	0.002		
Total	19	0.818			
C.D	0.067				
C.V	0.359				

Appendix-11: ANOVA for ash content on sun dried samples fried in mustard oil.

Source of Variation	D.F	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.004			
Treatment	4	0.040	0.010	533.932	0.00000
Error	12	0.000	0.000		
Total	19	0.045			
C.D	0.007				
C.V	0.210				

Appendix-12: ANOVA for ash content on tray dried samples fried in mustard oil.

Source of Variation	D.F	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.003			
Treatment	4	0.026	0.006	535.709	0.00000
Error	12	0.000	0.000		
Total	19	0.029			
C.D	0.005				
C.V	0.169				

Abstract

ABSTRACT

Name : Rahul Kumar **I.D. No** : PG -3695
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Thesis Title: Effect of pretreatment drying method cooking medium on yield, quality and storability of potato sticks.

Potato (*Solanum tuberosum* L.) is one of the unique and most potential crops have high productivity, supplementing major food requirement in the world. It is rich in carbohydrates, proteins, phosphorus, calcium, vitamin C, β -carotene and has high protein calorie ratio. Drying is a process of removing water from food and agricultural products constitutes a significant portion of the processing activity for persons working in the food and agricultural processing industries. The frying is a process, in which physical, chemical and organoleptic properties of food changed, the main goal of deep fat frying is to maintain tenderized and crispy shapes. Oil content is one of the important quality attributes in fried products. In the present investigation drying and frying characteristics of potato sticks treated with Control (T₁), blanching Citric acid @ 0.5% (T₂), blanching Potassium meta-bisulfite @ 0.5% (T₃), blanching Citric acid 0.5% + Potassium meta-bisulfite @ 0.5% (T₄), Blanching (3-4 min) at 95 °C (T₅) and dried under sun drying and tray drying and to study the frying kinetics and sensory during storage was done. Moisture content (% db) of potato sticks were found 497.01 before drying operation which last up to 6.50 % for sun drying and 5.67 % in case of tray drying. During sun drying it took about 10 to 11 hours to dry the different pretreated samples completely while in tray drying it took about 6 to 8 hours. During sun drying maximum % mass reductions (82.25) was observed in Sample T₂ and T₃, same things was observed in tray drying; while maximum % water loss (98.69) was observed in Sample T₃ during sun drying and in tray drying it was observed in Sample T₃ but value was increased to 98.86. During frying of dried samples in mustard oil, maximum weight gain % for sun dried samples was found 15.49 in sample T₃ and for tray dried samples it was 16.90 in sample T₂. During the physico-chemical evaluation of fried samples maximum ascorbic acid content for sun dried samples was found 12.48 mg/100 gm and 12.44 mg/100 gm for tray dried samples in T₄. Maximum ash content (%) for sun dried samples was found 2.15 % and for tray dried sample it was 2.13 observed in sample T₁ at 0 day of storage. All the sensory parameters like colour, texture, flavor and overall acceptability attributes of fried samples dried under sun drying was found maximum for T₄ at 0 days. Same pattern was seen for tray dried samples.

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