FOOD FORTIFICATION WITH TOMATO POWDER AND SUBSEQUENT ANALYSIS OF PHYSICOCHEMICAL, NUTRITIONAL AND SENSORY PROPERTIES

Thesis submitted for partial fulfillment of the requirement for the degree of

MASTER OF TECHNOLOGY
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BY

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Declaration of originality and compliance of academics ethics

I hereby declare that thesis contains literature survey and original research work by the undersigned candidate, as part of Master of Technology in Food Technology and Biochemical Engineering Department.

All information in this document have been obtained and presented in accordance with academic rules and ethical conduct.

I also declare that, as required by these rules and conduct, I have fully cited and referenced all materials and results that are not original to this work.

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Certificate of Recommendation

We hereby recommend the thesis entitled **"Food fortification with tomato powder and subsequent analysis of physicochemical, nutritional and sensory properties"** prepared under supervision of Prof. Mr. Utpal Ray Chaudhuri

By Rumki Saha (Class roll no-00141092006, Registration No- 129083 of 2014-2015), student of second year has been evaluated by us and found satisfactory. It is therefore, being accepted in partial fulfillment for the requirement for awarding of degree of Master of Technology in Food Technology and Biochemical Engineering.

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This is to certify that Rumki Saha has carried out the research work entitled **"Food fortification with tomato powder and subsequent analysis of physicochemical, nutritional and sensory properties"** under our supervision, at the Department of Food Technology and Biochemical Engineering, Jadavpur University, Kolkata. We are satisfied that she has carried out her work independently with proper care and confidence. We here by recommended that this dissertation be accepted in partial fulfillment of the requirement for awarding the degree of **Master of Technology in Food Technology and Biochemical Engineering.**

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ABSTRACT

Tomato *(Solanum lycopersicum)* is an economically important vegetable crop grown in tropical and sub-tropical parts of the world. Tomato and tomato products are very beneficial to our health as they decrease the risk of many diseases, such as cancer, asthma, heart disease etc. The whole fruit of tomato i.e pomace, seed and tomato solids have many nutraceutical benefits and is extensively used in food processing industry either as raw or in powder form. Many bioactive components are present in tomato, such as lycopene, oleoresin, carotenoids etc Tomato is very popular for high content of antioxidant compounds and antioxidant activity. It is preserved mainly by drying (tray drying, freeze drying) and encapsulation process. We have tried to focus on to get the answer, which one is better in food application, lycopene supplementation or direct tomato powder fortification in food products.

Drying is particularly important for handling and distribution of agricultural products with high moisture content and limited shelf life such as fruits and vegetables. Effect of different temperatures (40ºC, 50ºC and 60ºC) on tomato was studied by two thin-layer drying models: Page model and Lewis model. Equilibrium moisture content had a significant role on the normalized drying curve and was determined for tomato at each temperature (40ºC, 50ºC and 60ºC). The models were compared based on their coefficients of determination (R^2) and model fit was analyzed by root mean square error (RMSE) value. Color profile analysis and antioxidant content (phenol, flavonoid), antioxidant activity by DPPH were studied for different drying temperatures and subsequent results were observed. It was observed that increase in drying temperature, a* value was decreased and b* was increased for tomato powder. Phenol, flavonoid and antioxidant activity of tomato powder was 9.34 mg/g, 0.945 mg/g and 62.670%

Dhokla is easy to cook and highly demandable snacks in market. Tomato is a very good fortification ingredient in food product development not only for its nutritional and high antioxidant property, but also its good sensory value. In this study, dhokla was prepared with 0, 1, 4 and 7% of tomato powder fortification and subsequent analysis was studied in the initial day as well as in storage. Acidity was increased from 0.09 to 0.45 for incorporation of tomato powder. Corelation coefficient (R^2) suggests that there is a good relation antioxidant content with antioxidant activity. Rheological characteristics suggested that dhokla batter has viscoelastic property. Moisture content was decreased from 16.928 to 15.10, 18.05 to 17.45 and 20.10 to 18.03 after storage in tomato incorporated dhokla. Nutritional values were highest when dhokla was incorporated with 7% tomato powder. In respect of sensory analysis 4% tomato powder incorporated dhokla shows best overall acceptability.

Instant tomato dhokla mix is very helpful in our busy daily life. Instant tomato dhokla mix was prepared and comparative study of dhokla mix (without tomato powder) and commercial dhokla mix (MTR) were analyzed. Powder property was evaluated by bulk density, reconstitution and rehydration index, oil absorption capacity, antioxidant compound analysis and color properties. The result of powder property analysis reveals that instant tomato dhokla mix was better in antioxidant property and color content than controlled dhokla mix and commercial dhokla mix powder. Optimization of instant dhokla was studied by varying water content and baking powder content by response surface model and quality characteristics was observed by moisture content, L value and pH analysis. Optimized dhokla sample was stored with varying temperature, varying time and varying storage type and a and b value were analyzed by factorial experimental method.

Keywords:

Dhokla, tomato powder, antioxidant content, Color, Sensory, Storage.

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pH meter (Thermo Orion Basic pH Meter, Model 420A pH/mV/ORP/temperature meter)

Sonicator (TRANS-O-SONIC/D150-IM, Mumbai)

Centrifuge Machine (Hanil, Supra 22K, Koria)

Rheometer (Anton Paar, Physica MCR 51, India)

Weighing Machine (Sartorius, India)

Hunter Lab Colorimeter (DP-9000 D25A Huntet associates laboratory, Restron, USA).

Scanning electron microscope (JEOL JSM 6360 LV)

Spectrophotometer (U 2800, Hitachi, Japan)

CHAPTER 1

1. INTRODUCTION:

Together with drying and salting, fermentation is one of the oldest methods of food preservation, and embedded in traditional cultures and village life. Over the years, fermentation processes are believed to have been developed by women, in order to preserve food for times of scarcity, to impart desirable flavor to foods, and to reduce toxicity (Rolle and Satin, 2002). Today, in many countries, as a household or village-level fermentation technology is still widely been practiced but comparatively very few operations are carried out at an industrial level (Holzapfel, 2002). Fermented foods are treasured as major dietary constituents in many developing countries because of their keeping quality under ambient conditions - thereby contributing to food security - and because they add value, enhance nutritional quality and digestibility, improve food safety, and are traditionally acceptable and accessible (Holzapfel, 2002, Rolle and Satin, 2002).The principal objectives of fermentation, is to preserve and safeguard the foods and beverages that remain with wholesomeness, acceptability and overall quality, by increasing the valued features to consumers, especially in rural areas where old traditions and cultural particularities in food fermentations are generally well maintained (Marshall and Mejia, 2011).

Food fortification (FF) is defined as the addition of one or more essential nutrients to a food, whether or not it is normally contained in the food, for the purpose of preventing or correcting a demonstrated deficiency of one or more nutrients in the population or specific population groups (Codex Alimentarius, 1991). It has been in practiced since 1930s to target specific health conditions such as iodine deficiency through the iodisation of salt, anaemia through the fortification of cereals with iron and vitamins, and neural tube defects through the fortification of wheat flour with folic acid that is to the population lack in micronutrients concentration. Food fortification includes biofortification, microbial fortification and synthetic biology; commercial and industrial fortification, and home fortification. The several types of FF are distinct because different techniques and procedures are used to fortify the target foods. Using biotechnology (genetic engineering) to biofortify staple crops is more modern and has gained much attention in recent years. The most popular example of this approach is the transgenic 'Golden Rice' containing twice the normal levels of iron and significant amounts of beta-carotene (Holzapfel, 2002).

Tomatoes *(Solanum lycopersicum)* are one of the most widely used and versatile vegetable crops. They are consumed fresh and are also used to manufacture a wide range of processed products

(Madhavi and Salunkhe, 1998). In a rank of 10 vitamins and minerals, tomato is the first in terms of contribution in diet. After potato tomato is the 2nd largest production and consumed vegetable in the whole world (Unison, 1998). Tomatoes and tomato products are rich in health-related food components. United States, Turkey, Italy, and Spain are the leading tomato growing countries (Jumah et al. 2004).There is a need to develop stable, high quality tomato-based food products. The advantages of using tomato by-products as food ingredients are noticeable both to reduce environmental pollution and to provide an extra-income for producers (Lavelli and Scarafoni, 2012). Tomato can be consumed as raw or as an ingredient in many dishes, sauces, salads, and drinks. Factors influencing the considerable increase in tomato consumption include consumer awareness of benefits such as preventing cancer and chronic diseases (Lana and Tijskens, 2006). This beneficial effect is due to the action of antioxidant compounds, which reduce oxidative damage in the body (Beecher, 1998). Tomatoes are rich in lycopene (87%) and other carotenoids such as carotene, phytoene, phytofluene, lutein and L-ascorbic acid (Soma, 2013). Lycopene is a carotenoid that can be incorporated into foods with the purposes of conferring both color and functional characteristics (Itaciara and Adriana, 2007). Lycopene has attracted attention due to its biological and physicochemical properties, especially related to its effects as a natural antioxidant. Lycopene does exhibit a physical quenching rate constant with singlet oxygen almost twice as high as that of beta-carotene (Shi and Le Maguer, 2000). Several food technology studies have been carried out to optimize the processing and storage of the tomato products by preventing the heat and oxidative damage on the antioxidants (Shi et al. 1999). Tomatoes are not as sweet due to its lower sugar content then other edible fruits. Tomatoes are low in calories and a good source of vitamins A and C, the flavor, texture, and cooking characteristics of tomatoes depend on the variety, growing method, local environment, and handling techniques used during and after harvest (Parnell et al. 2004). Most of the tomatoes are processed for its juice, ketchup, sauce, paste, puree and powder. Flavor characteristics of tomatoes are an important purchasing criterion (Krumbein et al. 2004). Researchers have reported that lack of flavor of tomato is associated with various storage treatments, e.g., modified atmosphere (Ho, 1996; Hobson, 1988; Maul et al. 2000). Dried tomato products (i.e., tomato halves, slices and powders) are in high consumption as compared to other tomato products due to their excellent properties. Tomato solids in powder form have many advantages, including ease of packing, transportation and mixing, and no drum-clinging loss (Giovanelli et al. 2000).

1.1 Nutritional benefits of tomato derivatives

1.1.1) Skin:

The by-products of tomato processing (skin) contain a very high amount of lycopene. In particular, tomato skin has 2.5 times higher lycopene level than the pulp (Shi et al. 1999). Tomato skin contains more than 20 ppm lycopene, protected within the chromoplasts in the cells. Besides serving as a micronutrient with important health benefits, lycopene is an excellent natural food colourant (Lavelli and Torresani, 2011). Tomato skin contains more than 70% (w/w, db) of dietary fibre. Tomato skin fibre is mainly insoluble (Zeinab et al. 2010). The use of dried tomato skin in powder form are proposed as an addition to refined oils for carotenoid solubilization in view of upgrading low quality oils, in the formulation of ketchup, in dry fermented sausages, and in beef hamburgers (Benakmoum et al. 2008; Calvo et al. 2008; Farahnaky et al. 2008; García et al. 2009). The skin powder also provides proteins, cellulose and pectins, thus representing a good candidate to be used to modulate water sorption and rheological properties of food. Indeed the use of skin powders in the formulation of ketchup, improves its textural properties (Farahnaky et al. 2008). Approximately one-third of the total weight of tomatoes in the form of skin and seeds is discarded during processing of tomatoes into paste (Toor and Savage, 2005).

1.1.2) Seed:

Seeds are the major part of the pomace, and they are, 34% protein and 30% lipid. Seed proteins have been extracted to produce protein concentrate (Savadkoohi and Farahnaky, 2012). Studies on nutritive value of tomato seed proteins *in vivo* could not be found, however, reports involving the use of microorganism and enzymes are available. Canella and Castriotta (1980) reported that the tomato-seed protein is a mixture of globulin, albumin, prolamine and glutelin components. Tomato-seed protein components are adsorbed at oil–water (o/w) interfaces and reduce the interfacial tension considerably. Furthermore, compared to isolated soy protein, tomato proteins produce emulsions with greater globule size (Savadkoohi and Farahnaky, 2012). Tomato seed protein is rich in lysine (approximately 13% more lysine than soya protein) and can supplement feed that is deficient in lysine (Lavelli and Torresani, 2011).

1.1.3) Pomace:

Tomato pomace is an inexpensive byproduct of tomato manufacturing, contains almost 75% water and the cost of shipping tends to be very high (due to its weight). The conventional procedure for tomato processing generates heat-treated tomato pomace (skins and seeds); in contrast, a new plant operates the pulping/finishing steps on raw fruits at room temperature, thus producing an unheated pomace (Savadkoohi and Farahnaky, 2012). Dehydrated tomato pomace as a by-product of tomato production can be used for animal feed or human food. Tomato pomace contains high levels of polysaccharides, such as fiber and pectin (Yuanglang et al. 2010). It increasingly has been used as valuable feed stuff in ruminants and poultry nutrition in developing countries. Tomato pomace is the mixture of tomato peels, crushed seeds and small amounts of pulp that remains after the processing of tomato for juice, paste and ketchup (Aghajanzadeh et al. 2010; Ventura et al. 2009; King and Zeidler, 2004). It contains 5.1% moisture, 11.9% fat, 26.8% protein and 26.3% crude fiber. Moreover, it contains 13% more lysine than soybean protein, a good source of vitamin B, fair source of vitamin A and 2130 kcal/kg metabolizable energy (Melkamu et al. 2013). Tomatoes contain a solanine-like alkaloid (Saponin) called tomatine which have medicinal properties such as antibiotic, anticancer, anti cholesterol, anti inflammatory and anti pyretic affects (Calvo et al. 2008).

1.1.4) Tomato solids:

Tomato powder is much in demand by dehydrated soup manufacturers, and it also can be used as an ingredient in many food products, mainly soups, sauces and ketchup. The skin powder also provides proteins, cellulose and pectins, thus representing good characteristics to be used to modulate water sorption and rheological properties of food (Papadakis et al. 1998). The solubility of the powder is associated with the moisture content and operational conditions of the dryer, increasing with decrease in the moisture content (Goula and Adamopoulos, 2005; Paiva and Russell, 1999)**.**

1.2. Bioactive components of tomato:

1.2.1) Lycopene :

Lycopene, a member of carotenoid family; is a lipid soluble antioxidant synthesized by many plants and microorganisms but not by animals and humans. It serves as an accessory light-gathering pigment and protects the plant against the toxic effects of oxygen and light. Tomato (lycopene, 8.8-42 µg/g W/W and its derivative mainly represent main dietary sources of lycopene , but also watermelon, papaya, guava and pink grapes are rich sources. it is the naturally occurring compound that gives the characteristic red color to the tomato, watermelon, pink grapefruit, orange, and apricot (Rao and Agarwal, 2000). Lycopene has polynutrient, in many fruits and vegetables it consist of the potent antioxidant. Tomatoes and processed tomato products constitute the major source of dietary lycopene accounting for up to 85% of the daily intake (Chauhan et al. 2011). Lycopene content of various fruits and vegetables were represented in table 1.1. (Nguyen and Schwartz 1998).

Table 1.1: Lycopene content of various fruits and vegetables.

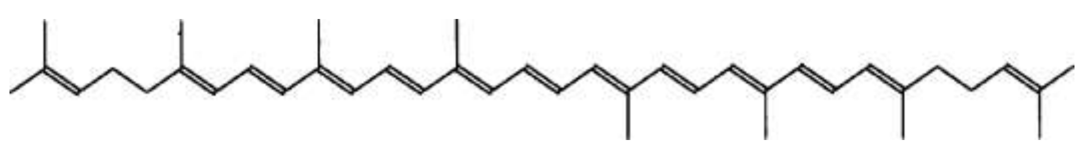
FOODS	Lycopene content (mg/100 g)
Tomato foods	
Tomatoes, raw	0.9–4.2
Tomatoes, cooked	3.7–4.4
Tomato sauce	7.3–18.0
Tomato paste	5.4–55.5
Tomato soup (condensed)	8.0–10.9
Tomato juice	5.0–11.6
Ketchup	9.9–13.4
Other fruits and vegetables	
Apricots, fresh	0.005
Watermelon, fresh	2.3–7.2
Papaya, fresh	2.0–5.3
Grapefruit, pink/red	0.2–3.4
Guava, raw	5.3–5.5
Vegetable juice	7.3–9.7

It was reported that the concentration of lycopene is two folds higher in pericarp than in locular cavity and β-carotene is four folds higher in locular cavity (Chauhan et al. 2011). Lycopene is a highly unsaturated straight chain hydrocarbon with a total of 13 double bonds, 11 of which are conjugated. *In vitro* studies have shown lycopene to be twice as potent as β-carotene and ten times that of α-tocopherol in terms of its singlet oxygen quenching ability (Ali et al. 2010). Lycopene in raw tomatoes is generally present as the all-*trans* geometric isomer, the most thermodynamically stable form. Indeed, heat, light or several chemical reactions can induce isomerization from the *trans*-isomer to various mono- or poly-*cis* forms in Figure 1. Lycopene, either as a pure agent or as part of tomato components, can be incorporated into semi-purified diets for studies of carcinogenesis or tumorigenesis (Nguyen and Schwartz, 1998). Moreover, several studies suggested that lycopene is a more potent scavenger of oxygen radicals than other major dietary carotenoids (Gajic et al. 2006). Lycopene in tomatoes are found in association with protein complex or membrane structure, which prevent lycopene digestion and absorption. Harsh treatments during food processing, such as mechanical texture disruption and steam, may denature the lycopene-protein complex and release lycopene from the cellular matrix (Shi et al. 2004).

1.2.2) Lycopene metabolism:

The enzymatic metabolism of lycopene and other carotenoids is only beginning to be understood. Lycopene, like β-carotene, when metabolized by carotenoid monooxygenase 2 will generate apo lycopenals (Khachik et al. 1995). The major metabolite of lycopene identified in human plasma is 5, 6-dihydroxy-5,6-dihydrolycopene, probably due to the oxidation of lycopene via conversion from intermediate lycopene epoxides (Erdman et al. 1993).

Figure 1.1: Molecular structure of lycopene



1.2.3) Relationship between bioavailability and bioaccessibility with lycopene:

Accessibility of lycopene is mainly influenced by crystalline formation called bioavailability. The bioavailability of cis-isomers in food is higher than that of all-trans isomers. Lycopene bioavailability in processed tomato products is higher than in unprocessed fresh tomatoes (Shi et al. 2000). Lycopene absorption was found to be apparently more efficient at low dosages than at higher dosages, possibly due to the low potential to form crystals at low dosages (Stahl and Sies, 1992). Ultrasound processing can cause decrease in lycopene bioaccessibility, due to lycopene entrapment in the stronger network of pectin, making it less accessible for digestion. The effects of lipids on lycopene bioaccessibilty are the use of lycopene as food supplement dissolved in a lipophilic carrier, which can improve the lycopene bioavailability (Beeby and Potter, 1992). Some other bioactive components in tomato are represented in table 1.2.

Table 1.2. Some other bioactive components in tomato

OLEORESIN	CAROTENOID	PHENOL AND FLAVONOID	ASCORBIC ACID
(i)Tomato oleoresin is a semisolid mixture of a resin and essential oil.	Tomato carotenoids include compounds called carotenes and xanthophylls.	Phenolics include flavonoids, phenolic acids. Phenol such as- hydroxybenzoic and hydroxycinnamic acids, and tannins. And flavonoid such as quercetin and kaempferol, flavanols catechins, Naringerin,anthocyanidins.	L-ascorbic acid and dehydroascorbic acid are the main dietary forms of vitamin C, a labile molecule with reducing property. It is a water-soluble compound easily absorbed but it is not stored in the body.
(ii) Oleoresins have medicinal properties, used mainly as a flavoring agent in the food processing industry because it is more economical to use and it gives a consistent quality to the food products.	The carotenoids in tomatoes are yellow, orange and red pigments that act as antioxidants to help protect cells.	Supports maintenance of heart health neutralizes free radicals.	Ascorbic acid content in fresh tomatoes depends on genotype, climatic conditions, fruit development, maturation, senescence, and time of storage. Ascorbic acid content in tomato fruit increases reaching a maximum and then began to decline with ripening.
(iii)Food colorant in	Carotenoid present in	Polyphenolic compounds	Vitamin C in tomato is

dairy products, non alcoholic flavored drinks, cereal and cereal products, bread and baked goods and spreads, to provide color shades from yellow to red. It enhances the nutritional value, functionality, color, and flavor.	red tomatoes having antioxidant capacity is a natural cancer-fighting agent.	are associated with therapeutic tools in inflammatory diseases including cardiovascular diseases, obesity and type II diabetes, neurodegenerative diseases, cancer, and aging.	highly bioavailable, so a regular intake of small amounts of tomato products can increase cell protection from DNA damage induced by oxidant species.

1.3.) Preservation methods for tomato:

1.3.1) Drying:

Drying is a complex process of removal of moisture from wet material by means of thermal energy where both heat and mass transfer take place. Many physical, chemical, and nutritional changes occur in foods during the dehydration process (Roberts et al. 2008). Though food drying indicates the loss of volatiles and flavors, changes in color and texture, and minimally decrease in nutritional value, drying is the useful means to increase the shelf life of perishable food for further use (Mars and Scher, 1990). During processing and storage a number of changes occur in dried tomato products. It is reported that the moisture content, bulk density and solubility of tomato powder, three most commonly quoted specifications of a powder product, were all dependent on the spray drying conditions, i.e. air inlet temperature, drying air flow rate, and compressed air flow rate (Chauhan et al. 2011). Drying methods of tomato are represented in table 1.3.

Table 1.3: Different drying methods of tomato

Tomato drying process	Observation	References
Tray drying	To incorporate tomato powder in place of artificial coloring and flavoring agent in the fudge and to evaluate its sensory and microbial parameters and antioxidant	Soma S[6]

	activity.	
Spray drying	The effects of the spray dryer operational conditions on the moisture content, solubility, consistency, wettability and color index of tomato powder were analyzed.	Sousa et al 2008[46]
Freeze drying	Physico chemical property of extruded snack with tomato peel powder was analysed.	Zeinab *et al* 2010 [17]
Solar drying	Color retention and rehydration ratio of tomato powder were analyzed.	Rajkumar *et al* 2007 [47]
Tray drying	Antioxidant content, color and rehydration ratio were analysed.	Sanchez *et al* 2012 [48]
Cabinet air oven drying	To investigate the effect of temperature and osmotic dehydration on air drying kinetics and quality of tomato pomace and to asses moisture removal	Al Muhtaseb *et al* 2010 [49]
Hot air oven drying	To study drying kinetics and quality attributes of tomato slices.	Abano *et al* 2011 [50]
Laboratory solar drying	Effect of different drying thickness and drying kinetics of tomato slices.	Bagheri *et al* 2013 [51]

1.3.2) Encapsulation:

Microencapsulation is a technique by which solid, liquid or gaseous active ingredients are packed within a second material from the surrounding environment for the purpose of shielding the active ingredient (Dubey et al. 2009). Microencapsulation allows the creation of a physical barrier between the core and the wall materials (Favaro-Trindade et al. 2008). A convenient and simple procedure for the formation of microcapsules is the method known as complex coacervation (Gouin 2004; Gülay and Seda, 2014). Encapsulated natural colors such as carotenoids, anthocyanins, and chlorophylls are easier to handle and offer improved stability to oxidation and solubility (Dubey et al. 2009). Lycopene was encapsulated in powder form by spray drying and inclusion freeze drying process (Itaciara and Adriana, 2007). Carotenoid rich extract was obtained from tomato paste and it was encapsulated by inulin in a prebiotics matrix system. Encapsulated carotenoid was used for formulation of functional foods (Duarte et al. 2011).

1.4.) Application:

Tomato, either as a whole or as powder form has several uses in different food industries to prepare cookies, snacks, jelly, sauce, ketch up etc.

1.4.1) Tomato powder vs lycopene supplement:

Many researchers have suggested that tomato can be used in powder form as well as as lycopene supplement. The points below are discussion on the application of both the tomato powder and lycopene supplement in food industry.

1.4.2) Tomato powder:

Tomato powder has good potential as substitute of tomato paste and other tomato products; the final quality of dehydrated products is affected by the drying conditions. Among several processing methods spray drying is the efficient mode of preservation of tomato powder. The temperatures and drying conditions experienced by a droplet during the drying have an important influence on the powder properties (Benakmoum et al. 2008). Tomato powder is readily marketable due to ease in packaging, transportation and utilization in different ready to eat food preparations with extended storage life. The quality of dehydrated tomato depends on many parameters such as tomato variety, total soluble solid content (^{o}Brix) of the fresh product, the air humidity, the size of the tomato segments, the air temperature and velocity and the efficiency of the drying system. The dehydrated powder was packed in polythene bags and kept in glass bottles at room temperature; here the peroxide value increases with storage period, indicating deterioration (Reihaneh and Mehdi, 2010). "Lycopene was a little better than the control group but not as good as the tomato powder group." (Stahl and Sies, 1992)

1.4.2.1) Uses:

- The tomato powder used in soups, instant sauce premixes, ketchups, sambar and rasam mix, puddings, bakery products, health foods, sweets, biscuits, baby foods, confectioneries, snacks etc.

- They are also used in the preparation of recipes viz., tomato dosa, soup, rice and burfi and compared with fresh tomato recipes. As the powder is in the concentrated form, it gave attractive appearance, color and taste to the recipes.
- Tomato skin powder was incorporated into refined oils for carotenoid solubilisation in view of upgrading low quality oils.

The use of skin powders in the formulation of ketchup, improves its textural properties. (SHU et al. 2006)

1.4.3) Lycopene supplement:

Researchers observed that the stability of microencapsulated lycopene was significantly higher when compared to the free material such as lycopene obtained by spray drying using gelatin, sucrose and modified starch. Human populations consume lycopene from both food and supplements (Rocha et al. 2012). Lycopene is an important issue in nutrition due to the bioavailability of a bioactive substance. The lycopene taken as a supplement is easy to the body as a food substitute. Recent studies have suggested a protective role for lycopene, an antioxidant carotenoid, in the prevention of oxidative stress (Gajic et al. 2006).

1.4.3.1) Uses:

- Lycopene was used for preventing heart disease, (atherosclerosis) and cancer of the prostate, breast, lung, bladder, ovaries, colon, and pancreas.
- Lycopene is also used for treating human papilloma virus (HPV) infection, which is a major cause of uterine cancer.
- Some people also use lycopene for cataracts and asthma.

The application of tomato in food products is represented in table 1.4.

Table 1.4: Application of tomato in food products

Tomato by products	Use in type of food	Observation	References
Tomato powder	Cookies	Physico chemical, color, texture and sensory parameters.	Chung H.J[60]
Tomato powder	Fudge (confectionary)	Tomato powder used as coloring and flavoring agent. Sensory, microbial parameters and antioxidant activity	Soma S[6]

		evaluated.	
Freeze dried tomato paste and skin powder	Rice, corn and wheat based extruded snacks	Lycopene content, expansion, product density, hardness, percentage of moisture loss and color parameters of the snacks evaluated.	Zeinab *et al* [17]
Tomato peels	Ice cream	Carotenoid content, antioxidant content and sensory parameter analysed.	Rizk *et al* [61]
Tomato seed meal	Bread	Physico chemical property analysed	Sogi *et al* [62]
Tomato peel, tomato powder and lycopene	Beef patties, sausages, minced meat and frankfurters	The presence of lycopene from different tomato matrices leads to a better color in the meat products, improved nutritional quality, reduced lipid oxidation and increased stability during the shelf life period and retaining overall acceptability.	Candogan[63] Calvo *et al* 2008[19] Østerlie & Lerfall [64] Deda *et al* [65]
Tomato skin powder	Refined oil	For carotenoid solubilisation in view of upgrading low quality oils	Benakmoum *et al* 2008[18]

1.5) Conclusion:

Tomatoes are most valuable and are most commonly used crops in many food dishes. They are very much beneficial to our health due to their antioxidant properties. Tomato contains high concentration of L-ascorbic acid, lycopene and carotenoid. Dietary intake of tomatoes and tomato products decreases the chronic diseases, cardiovascular diseases and also reduces certain risk of cancer. Tomato has various nutritional benefits from their skin, seed and pomace. Various tomato products are made from tomato skin, seed, pomace and are very much useful in our diet. Now -a-days tomato powders are mainly used due to their excellent properties. Tomato powders are used in the formulations of ketchup, soups, sauces and they can also be act as a natural colorant. Tomatoes have bioactive components mainly the lycopene which has poly nutrient property and is contain potent antioxidants. Tomato powder can easily be handled, preserved and stored, have low transportation cost. The storage time of tomato powder is much more than raw tomatoes. Hence, the use of tomato is very useful for our body due to its great antioxidant properties, health effects, and enzymatic metabolism due to bioactive substances.

CHAPTER 2

2. REVIEW OF LITERATURE

1. Liu et al. (2010) observed that changes of tomato powder qualities at different storage temperatures (0, 25, and 37 °C) for 5 months. There were insignificant changes for these indicators at 0 °C during storage ($P<0.05$). Sucrose, fructose and total sugar (TS) exhibited significant reduction ($P<0.05$) only at 37 °C. And it gives the good result of TS, L-ascorbic acid, bulk density, L*, a*, b* when stored at 25 and 37 °C.

2. Effat et al. (2014) studied that characterization of carotenoids (lyco-red) extracted from tomato peels and its uses as natural colorants and antioxidants of ice cream. The nine carotenoid pigment compounds of tomato peels were identified by HPLC. The antioxidant activity of carotenoids (lyco-red) extracted from tomato peel was also studied by the Rancimat test at 110°C on sunflower oil by adding 50–200 ppm of carotenoids (lyco-red) extracted from tomato peels. Analysis of variance was done for sensory evaluation of prepared ice cream indicated that, ice cream containing 3% and 2% of carotenoids (lyco-red) extracted from tomato peels had the highest scores for flavor, body and texture, melting and color and the best mix compared with that prepared with 1%, 4% and 5% which recorded the lowest scores in all tested quality attributes.

3. Soma S. (2013) found that the development and evaluation of antioxidant activity of tomato based confectionary. The fudge prepared by using 1-3 g of tomato powder were having higher sensory scores while antioxidant activity was found highest in fudge having 5 g of tomato powder. The sensory characteristics of fudge prepared by using 1 g of tomato powder were preferred by most of adults and children. The confectionery products are highly popular among the children throughout the world due to their taste and flavor.

4. Lana and Tijskens (2006) studied that the effects of cutting and maturity on antioxidant activity of fresh-cut tomatoes. The changes in total antioxidant activity of fresh-cut tomato during storage, tomato fruits harvested at three different stages of maturity were cut into 7-mm thick slices and stored at 5°C. There was a decrease in the hydrophilic (HAA) compared to the control fruits and it did not influence the lipophilic (LAA) after cutting of tomato. The HAA also decreased exponentially in the beginning of the storage time but increased again afterwards. For both hydrophilic and lipophilic the riper the fruit the higher was the antioxidant activity. There was decrease in the value of cut tomatoes as a source of hydrophilic antioxidants in the diet as

compared with the stored fruit. Antioxidant activity was measured in methanol extracts and aqueous extracts measured the pro-oxidant activity.

5. Kohajdová et al. (2013) studied that rheological and qualitative characteristics of pea flour incorporated cracker biscuits. The suitability of pea flour for cracker biscuits production was investigated. From the sensory evaluation revealed that higher levels of pea flour in the products adversely affected the odour, taste, firmness, color and overall acceptance of final products and no effect of cutting or storage time was observed.

6. Raiola et al. (2014) studied that enhancing the health-promoting effects of tomato for bio fortified food product. The recent progress was on mechanisms of action of tomato on different phytochemicals against inflammation processes and prevention of chronic non-communicable diseases (e.g., obesity, diabetes, coronary heart disease, and hypertension). It also summarizes the significant progress made to improve the nutritional quality of tomato through metabolic engineering and/or breeding.

7. Zeinab et al (2010) found that the physico-chemical characteristics of extruded snacks enriched with tomato lycopene. The crisp low density extruded snacks were manufactured from corn, wheat and rice, with or without dried tomato skin or paste powder extruded at temperatures of 140, 160 or 180 ºC. Lycopene content and the physico-chemical properties (expansion, density, hardness, color parameters and percentage of moisture loss) of the extruded products were measured. The results show that increases in the processing temperature improved the physicochemical characteristics of the snacks but had no significant effect on lycopene retention ($P > 0.05$).

8. Barreiro et al. (1997) studied that kinetics of color change of double concentrated tomato paste during thermal treatment. The kinetics of the color change of double concentrated tomato paste observed during heating. The Hunter 'L ', 'a', 'b' values were measured to characterize the color, color difference (AE), saturation index (SI) and 'a/b' ratio. All the color parameters followed apparent first order kinetics, with the exception of activation energy, which follows the zero order.

9. Fazaeli et al (2012) found that characterization of food texture by the application of microscopic technology. The latest and more recent applications of microscopy in the morphological changes that food components or microorganisms undergo during processing. Microscopic studies of food structure are presented as the potential technique to reveal detailed

and specific information and understanding the relation between processing conditions and food structure, by the use of microscopy, it can be helpful to retain the quality of the product.

10. Ghavidel and Davoodi (2006) studied those physiochemical properties of tomato powder as affected by different dehydration methods and pretreatments. Pre-treatment with $CaCl_2$ and NaCl increased water removal and moisture mobility in tomato slices during drying of tomatoes, where $CaCl_2$ used along with potassium metabisulphate (KMS) was recorded and was compared to other treatments and the best results were obtained while using the two chemicals in combination form. The effect of different pre treatments on physicochemical characteristics of tomatoes, the influence of different types of driers and dehydration conditions on physicochemical properties of tomato slices, the lycopene retention and browning reaction are affected by different packaging materials, pre drying treatments and dehydration methods after storage.

11. Nagamani (2014) reviewed that processing technology developed for preparation of tomato powder using dehydration method and to incorporate powder in popular recipes as tomato is one of the most popular and widely grown vegetable crops. Tomato and tomato products are the major sources of lycopene and are considered to be important contributors of carotenoids in human diet. Among the drying methods, oven drying had a significantly higher mean score for all organoleptic parameters at one per cent level.

12. Sousa et al. (2008) found that reconstitution properties and color characteristics on spray dried tomato powder. Moisture content, solubility, wet ability and consistency were observed also but the factors only significantly affected the color parameter. All the tomato powder samples became significantly darker and less red with an increase of the storage.

13. Bhowmik et al. (2012) reviewed that tomato as a natural medicine and its health benefits. Lycopene and the newly discovered bioflavonoid in tomatoes are responsible as cancer fighting agents and can reduce high blood pressure. Tomato has detoxification effect in the body and it is due to the presence of chlorine and sulfur in tomatoes. 51 mg of chlorine and 11 mg of sulfur in 100 g size of tomato have a vital role in detoxification process. Tomato juice can be used for healing sunburn because of its unique vitamin C.

14. Elbadrawy and Sello (2011) studied that evaluation of nutritional value and antioxidant activity of tomato peel extracts. Preliminary chemical composition, minerals content, amino acids, fatty acids and phenolic compounds, nutritional composition and the antioxidant activity of some tomato peel extracts were determined by using different solvents such as petroleum

ether. Due to many nutrients and its antioxidant activities tomato peel or its extracts can be used as a food supplement.

15. Rani and Punia (2014) found that nutrient content and sensory evaluation of dhokla prepared by incorporating green beans powder. The beans were dried, made into fine powder and supplemented at 5 and 10 % level in the preparation of dhokla. The nutritional properties revealed that the protein content of control dhokla was 15.60% which increased significantly up to 17.21 percent with incorporation of fresh beans powder. The organoleptic evaluation of dhokla prepared incorporating 5% beans powder was more acceptable as compared to the one containing 10% beans powder.

16. Kalaiyarasi and Kalaimathi (2014) observed that the food products were prepared and evaluated for their nutritional and sensory properties the proximate analysis of carbohydrate, protein, fat, moisture and ash contents of dhokla had 19.48%, 31.04%, 14.54%, 8.04% and 1.67%. In sensory evaluation, dhokla had good smell and taste. The antimicrobial activity of products were found using bio autography against *Pseudomonas aeruginosa, Bacillus cereus, Escherichia coli and Mucor circinelloides* such that the consumption of these fermented food products might increase the immunity of the consumers.

17. Usha et al. (2010) studied that development of a cereal-pulse complementary of food fortified with different concentrations of pumpkin powder (*Cucurbita moschata*), its sensory and physico-chemical parameters. Pumpkin powder was added to this mixture at 10%, 20% and 30% variations. The complementary weaning food mix was analysed for its moisture, energy, protein, fat, carbohydrates, fibre, beta-carotene and anti-oxidant content. Nutritional analysis of the weaning mix has significant increase in the protein, fibre, carbohydrate and antioxidant levels with an increase in concentration of pumpkin powder. The sensory revealed that the complementary food mix with 20% pumpkin powder fortification had good sensory qualities.

18 Gumusay et al (2015) found that the effects of four different drying processes, sun drying (SD), oven drying (OD), vacuum oven drying (VOD) and freeze drying (FD) for tomatoes (*Solanum lycopersicum*) and ginger (*Zingiber officinale*) in terms of thiolic and phenolic contents. Significant losses in the contents of total phenolic content, ascorbic acid, glutathione and cysteine and cupric ion reducing antioxidant capacity (CUPRAC) values in all samples that were dried using the thermal method. Between the use of thermal drying and freeze drying (except cysteine in tomatoes) methods there is a significant difference in the losses of the total

phenolic content, ascorbic acid, and thiol contents. Freeze dried tomato and ginger samples have been found to have better antioxidant properties.

19. Khaled and Sayed (2014) found that the effects of different drying methods (hot-air drying, microwave drying and freeze-drying) on the color, phytochemicals content and antioxidant capacity of purslane leaves. The fresh purslane leaves had high contents of total phenolics (1447.59 mg GAE/ 100 g) and flavonoids (5011.87 mg catechin/ 100 g) on dry weight basis. They exhibited high antioxidant capacity (53.23% and 147.78 μmol trolox/ 100 g) measured by 1,1-diphenyl-2-picrylhydrazyl (DPPH). Drying by hot-air at 50ºC and freeze drying had the lowest adverse effects on antioxidant capacities of purslane leaves while microwave drying cannot be a competitive process for preserving antioxidants and antioxidant capacity. Drying methods caused a significant decrease in total phenolics, total flavonoids and antioxidant capacity of purslane leaves.

20. Upadhyaya et al. (2012)studied that drying characteristic curve of spinach in universal hot air oven drying were conducted using drying air temperature of 55, 65, and75^{o}C. The drying rate increased with increased in temperature and decrease with increase in time. The observed result of spinach applied to four moisture ratio models and the nonlinear regression analysis performed to relate the parameters of the model with the drying conditions. The drying behavior of spinach leaves the standard error of estimation was least (0.004-0.031) as well as coefficient of determination (R^2) was highest (0.991-1).

21. Navneet Kumar and Kshitij Kumar (2011) observed that development of carrot pomace and wheat flour based cookies. The carrot pomace was dried in hot air oven at 65°C and then grinded to pass through 2 mm sieve. The formulation was baked at 175 °C for 12 min. in the gas oven with air circulation. The moisture content of cookies was measured using hot air oven method. The hardness was measured using a texture analyzer (TA-XT2) with the cutting probe in compression mode. The color of both the sides of cookies was measured using a Hunter’s lab color analyzer. The moisture content varied from 4.03 to 4.79%. The hardness was ranged from 41.047 to 116.1N. The moisture content, hardness and L*, a* values were increased with the increase in proportion of carrot pomace in cookies.

22. Baixauli et al (2008) studied that the effect on baked muffins of progressively replacing wheat flour with resistant starch (RS) Rheological properties of the raw batters, the mechanical spectra of batters, the evolution of the dynamic moduli with rising temperatures (from 25 to 85

°C) and the mechanical spectra were obtained from oscillatory rheological tests. There was a decrease in the viscosity and in the elastic properties of the muffin batter as the flour was increasingly replaced by RS and was related to the baking performance of the final baked products.

23. Choy et al (2013) found that the feasibility of incorporating common buckwheat (*Fagopyrum esculentum Moench*) into instant noodle formulations. Australian Soft (AS) and Baker's flours were used in varying buckwheat contents (0 - 40%) on noodle quality. The color L* value was decreased with increased in addition of buckwheat for both flours. Fat uptake for noodle samples made from AS flour was only marginally affected, but increased for Baker's flour, when higher levels of buckwheat flour were added. The antioxidant rutin was detected in noodles made from both wheat flours, increased with % buckwheat flour added. The incorporation of 20% buckwheat into the formulation can be used to enhance the quality of instant noodles.

24. Chegini and Taheri (2013) studied that process technology (spray drying) and physical properties of whey powder spray-drying process of whey and the effect of spray-dryer operating parameters, feed flow rate, atomizer type and inlet/outlet air temperature on food powder physical properties such as bulk density, particle size, moisture content, insoluble solids, wet ability and morphology of powder particles. The spray-drying condition was the best way for the change in quality factors of powders products. Spray-dried whey is easier to storage, handling and transport and the quality of spray-dried whey is quite dependent on the spray-dryer operating parameter.

25. Rao et al (2011) observed that the preparation of instant tomato pickle mix (ITPM) by blending optimized levels of tomato powder (TP) and other spice ingredients. The TP and ITPM were stored to evaluate the shelf- stability. Titrable acidity and protein content in ITPM was found to be 4.8 and 12%. Total polyphenol content increased (1026 to 1608 mg/100g) and lycopene content decreased (14.01 to 5.2 mg/100g) in samples packed in pouches during storage for six months. Sensory analysis of reconstituted instant tomato pickle mix packed in pouches with cooked rice scored very good (8.1) after six months of storage.

26. Khan et al. (2012) studied that virgin coconut meal (VCM) was used for the development of instant wheat sooji (semolina) halwa mix with better nutritional attributes. VCM incorporated instant halwa mix was prepared using optimized levels of ingredients that contained moisture 0.95%; fat 26.2%; protein 7.65%; total ash 0.86%; fibre 1.02% and received overall acceptability

score of 8.5 on a 9 point hedonic scale. Instant halwa mix remained stable and acceptable for one year in both the packaging materials under ambient temperature conditions (15°C - 34°C). Fatty acid composition of VCM incorporated instant halwa mix remained practically unchanged during storage. Oleic acid was the major fatty acid present in fat extracted from halwa mix followed by palmitic and lauric acids.

27. Boonkasem et al. (2015) found that ascorbic acid and total phenolics related to the antioxidant activity of some local tomato (*Solanum lycopersicum*) varieties. Fresh tomato fruits were homogenized and kept as a freeze-dry powder prior to be extracted with methanol, ethanol and deionized water using ultrasonicator as a green extraction method. The methanol extracts of these samples gave rather higher antioxidant activities (171.6-197.1 mg Butylated hydroxyl toluene/100 g dry weight) and total phenolics (302.3-349.7 mg Gallic acid equivalent/100 g dry weight) than those of both ethanol and aqueous extracts such as ascorbic acid contents of the aqueous extract (37.6-62.9 mg/100 g dry weight). Phenolic compounds have antioxidant activity which has been linked to slow down the ageing process and lowered risks of many prevalent chronic diseases such as cancer and coronary heart disease.

28. Adenike (2012) studied that the effect of pretreatment and drying on some vitamin contents with the initial ascorbic acid, thiamin, riboflavin, niacin and beta carotene contents of freshly harvested tomatoes. Some of them are sun and oven dried and other of them were dipped in 1% metasulphite for 5 minutes. Drying increases the ascorbic acid, thiamin, niacin and beta-carotene content of tomato powder significantly ($p<0.05$) compared to the fresh ones. Drying and pretreatment has no significant effects ($p<0.05$) on the riboflavin content of tomatoes. The use of metasulphite as pretreatment resulted in a lower increase in the vitamin content as compared to the untreated samples. Sun dried samples had higher vitamin content than the oven dried samples. Sun drying method is the most suitable for tomato drying the terms of increased vitamin content compared to oven drying method.

29 Boye et al (2010) observed that the characteristics of pulse proteins, current and emerging techniques for their fractionation, major functional properties and opportunities for use in various applications. Pulses (pea, chickpea, lentil and bean) are an important source of food proteins. The protein content of most pulse legumes fall within the range of 17–30% (dry weight basis). Apart from their nutritional properties, pulse proteins also possess functional properties that play an important role in food formulation and processing. The functional properties of pulse proteins

have been exploited in the preparation and development of products such as bakery products, soups, extruded products and ready to eat snacks. Consumption of pulses associated with the increased in health benefits and it also overcome with the protein malnutrition, a problem in many countries around the world. Pulses when blended with cereal proteins, may offer a promising alternative source for nutritional and functional proteins.

30. Akdeniz et al (2012) studied that the effects storage time, storage temperature and packaging type on color stability of sun-dried tomatoes by using factorial experimental design. The 2^3 factorial design was used to represent mathematical relationship between the storage conditions and color values (L and a/b). The main effect was found to be the time having the highest coefficient (-3.3 for L and -0.12 for a/b) in design models and storage temperature was found to be the least effective factor. Design model and response surface plots revealed that storage temperature could be kept around 20°C for 9 months and storing under vacuum packaging should be selected to reduce color losses for the safe storage conditions.

CHAPTER 3

AIMS AND OBJECTIVES

1. To study drying characteristics of tomato and determine physicochemical, antioxidant and morphological analysis.
2. Preparation of innovative dhokla fortified with tomato powder and analysis of nutritional, antioxidant and sensory properties.
3. Analysis of storage study of dhokla on the basis of color profile, moisture content and sensory analysis.
4. To prepare instant dhokla mix and analysis of powder properties in storage.
5. To prepare instant dhokla and optimization of the ingredients using RSM (CCRD) and storage study using 2 factorial design.

CHAPTER 4

4. Effect of temperatures on drying kinetics of tomato (*Solanum lycopersicuml*) and analysis of color and their antioxidant properties

4.1 INTRODUCTION

Drying is defined as a process of moisture removal due to simultaneous heat and mass transfer (Ertekin and Yaldiz, 2004). Purposely it is carried out to reduce water to the level at which microbial spoilage, deterioration reactions are greatly minimized and a large amount of nutrients are preserved (Akpinar and Bicer, 2004). Drying is one of the basic ways of preserving food. The demand for high quality dried products is increasing all over the world. Drying of agricultural products is one of the oldest and most important methods of food preservation which allows for market surplus management. Drying improves the product shelf life without addition of any chemical preservative and reduces both the size of package and the transport cost (Al-Harahsheh *et al*., 2009; Figiel, 2010; Singh *et al*., 2010). To achieve consistent quality dried product industrial dryers should be used and the choice of dryers depends on the fruits and vegetable characteristics. Drying behavior is basically influenced by a number of internal (e.g., density, permeability, porosity, sorption-desorption characteristics, and thermo physical properties) and external parameters (e.g., temperature, velocity, and relative humidity of the drying medium) (Kaya et al. 2007). Hot air drying is one of most widely used methods for food preservation. This procedure not only reduces the weight and volume of the fruit and depreciates storage and transport costs (Vega-Gálvez et al. 2009) but also facilitates the use of the products in non-harvest seasons (Miranda et al 2009). In last year's, the interest in dried tomato products is increasing since their use as ingredients for pizza and various vegetable and spicy dishes became popular (Marfil et al. 2008). The use of mathematical equations is necessary for the simulation of the kinetics of matter transfer (water) that occurs during this unit operation (Vega et al. 2007). There are several empirical equations used to simulate the drying process that are exceptionally practical for the study, the modeling of kinetics and the process optimization, as well as for dryer design (Senadeera et al. 2003). A good mathematical model of each drying process can be an important tool for improving processes and minimizing problems such as damage to the product, excessive consumption of energy, excessive wire on the drying equipment and decrease in yields (Aghbashlo et al. 2008). Compared to light microscopy, SEM has been very attractive for food scientists because both surface and internal features can be studied, a wide range of magnification is possible and the SEM can achieve a depth of field roughly 500 times greater than that of light microscopy (Bogner et al. 2010).

Tomato (*Solanum lycopersicum* L.) is one of the vegetables most consumed in the world. It is a source of vitamins A and C and mineral salts, such as K and Mg. Tomato is a climacteric fruit with a short maturation and color change period, firmness, aroma, and flavor throughout shelf-life (Oliveira, 2010). Dried tomato products (i.e., tomato halves, slices and powders) are in high consumption as compared to other tomato products due to their excellent properties. Tomato solids in powder form have many advantages, including ease of packing, transportation and mixing, and no drum-clinging loss (Giovanelli et al. 2002).

The objective of the research study is

- To observe the characteristics of drying curve on tomato using Lewis and Page model and justify curve fitting by RMSE value.
- To determine color profile analysis for different temperatures (40, 50 and 60ºC) on tomato powder.
- To determine antioxidant content (phenol, flavonoids), other bioactive components (Lycopene, chlorophyll and beta carotene) and antioxidant activity of tomato powder.
- To observe color, morphology, protein characteristics of tomato powder.

4.2 MATERIAL AND METHOD

4.2.1 Blanching and Sulphiting

To improve the color and shelf life, tomatoes are subjective by blanching by steeping in boiling water for 10-15 seconds. Then, it was immersing in 0.2% potassium meta-bi-sulfite (KMS) solution for 5 minutes at room temperature.

Blanching is a popular pretreatment used usually to denature or inactive enzymes, reduces off flavor and color changes in vegetables and fruits. (Barrett and Theerakulkait, 1995)

Blanched samples give shorter drying time and higher water diffusivity than unblanched vegetables (Doymaz and Goi, 2011).

4.2.2 Drying process

At first fresh tomato was properly cleaned with cold water. Then it was sliced in thin pieces, after that thin pieces of the samples were dried in hot air oven (Mac Pharma Tech, India) at 40, 50 and 60 ºC for 5 hours and moisture content was reported for every 30 times intervals until constant weight was obtained. After drying the samples were grinded in a kitchen mixer

(Prestige Stylo Mixer Grinder, Prestige, Bangalore, India) to obtain smooth powder whose mesh size was 80µm. Then the samples were stored in refrigerator in air tight polythene packets for analysis purpose.

Initial moisture contents of all samples were determined by the oven drying method at 70 ºC in hot air oven for 24 hours (AOAC, 1990).

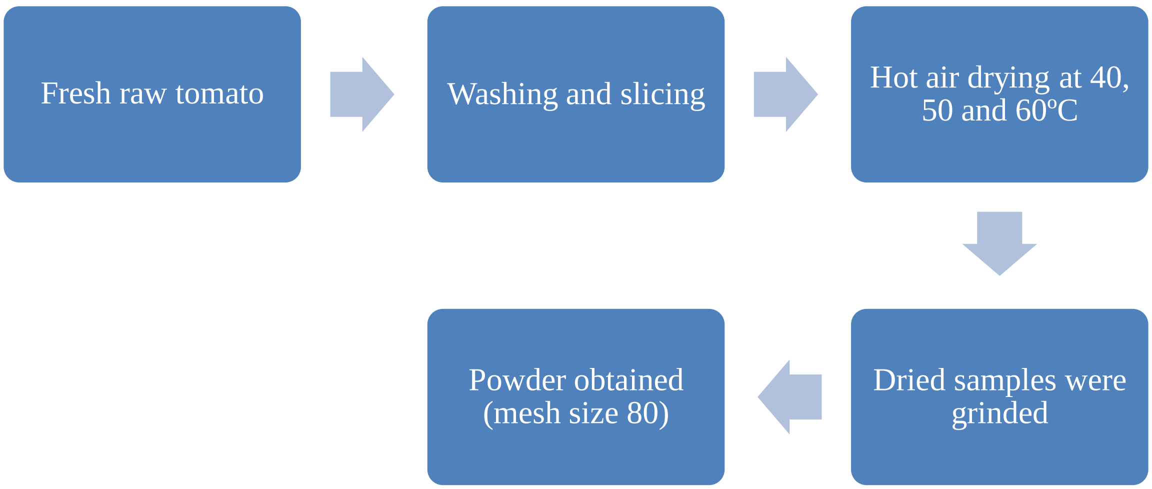


Figure 4.1. Flow diagram process used to dry tomato

4.2.3 Drying models

Simplified drying models have been used to quantify drying kinetics of various grains and some seeds (Sogi et al., 2003; Parti, 1993; Bruce, 1985). Two common models are the Page model

$MR = (M-Me)/(M_i-M_e) = \exp(-kt^N)$

Lewis Model

$MR = (M-Me)/(M_i-M_e) = \exp(-kt)$

where MR represents the unaccomplished moisture content or moisture ratio, M is the moisture at any time t during drying, M_i is the initial moisture content, M_e is the equilibrium moisture content, k is the drying rate constant, and N is the constant.

The empirical constants for the thin-layer drying models were determined experimentally from normalized drying curves at different temperatures, which were evaluated based on coefficient of determination (R^2). The form of the normalized Page equation is

$$\ln[-\ln (MR)]= \ln (k)+N \ln (t)$$

where the drying constants, k and N, are determined from the interceptand slope of the ln(-ln(MR)) vs ln(t) curve, respectively.

The form of the normalized Lewis equation is

$$\ln (MR)=-kt+1$$

For the Lewis equation, the intercept is set equal to 1.

The equilibrium moisture content (M_e) was obtained by extending the drying time until no measurable weight loss was observed.

The goodness of fit for each model was evaluated based on root mean square error (RMSE). The predicted moisture ratio was compared to the experimental moisture ratio using root mean square error by the equation (McMinn, 2006).

4.2.4 SEM

The dried samples were taken and their morphological characteristics were observed in different magnification 25X, 500X, 1000X, 3000X in a Scanning Electron Microscopy (JEOL JSM 6360 LV).

4.2.5 Extraction of samples

Extracts of samples were prepared for the determination of antioxidant activity. 1 g sample was weighed and was mixed with 20 ml of 80 % methanol. Then the mixture was sonicated in a sonicator (Trans-o-sonic/D150-IM, Mumbai) to agitate the particles of the sample to make the homogeneous mixture. Then it was centrifuged (Hanil, Supra 22 K, Korea) at 8944g for 10 min at 4ºC. Then the extracts was transferred into culture tubes, and kept in the refrigerator at 4ºC for analysis purpose.

4.2.5.1 Total phenolic content

0.2 ml extracted sample was added with 1.8 ml of distilled water. Then, 0.2 ml Folin Ciocalteu reagent was added and was mixed properly by shaking it for 5 minutes. Then, 2 ml of 7% sodium carbonate solution was added. Next 0.8 ml distilled water was added. After incubation for 90 minutes in dark, the absorbance of the mixture was observed at 750 nm in a spectrophotometer [U 2800, Hitachi, Japan]. The results were expressed as mg of gallic acid equivalents (GAE) per g of sample (Sharma et al. 2010).

4.2.5.2 Total Flavonoid Content:

1ml extracted sample, 4 ml distilled water and 0.3 ml $NaNO_2$ were mixed. Then, 0.3 ml $AlCl_3$ and 2 ml (1(M)) NaOH were added. Then, after incubation for 25 minutes in light the absorbance of the mixture was observed at 510 nm in the spectrophotometer. The result was expressed as mg of catechin equivalents (CAE) per g of sample (Xu and Chang 2007).

4.2.5.3 Total antioxidant activity

0.002g of 2, 2-diphenyl-1 picryl hydrazyl radical (DPPH) was taken and was mixed with 50 ml of ethanol in a volumetric flask. Then, the flask was kept in dark and in ice cold condition. 0.1 ml of sample was taken in a test tube and was mixed with 3.9 ml of above prepared DPPH solution. Then, it was placed in a dark place for 45 minutes and the absorbance was measured in a spectrophotometer at 515nm **(**Yu et al. 2003). Ethyl alcohol was used for auto zero condition.

Total antioxidant activity = ((Blank- Sample)/ Blank)*100

4.2.6 Other Bioactive compounds:

4.2.6.1 Lycopene

The lycopene content of the samples was analysed by AOAC method. The lycopene content was obtained from extracted sample by spectrophotometer in various wavelengths i.e; 663nm, 645nm, 505nm and 453nm.

Lycopene content (mg/100ml) = -0.0458(A_{663}) + 0.204 (A_{645}) + 0.372 (A_{505}) – 0.0806 (A_{453}).

4.2.6.2 Beta- carotene

The beta- carotene content of the samples was analyzed by AOAC method. The beta- carotene content was obtained from extracted sample by spectrophotometer in various wavelengths i.e; 663nm, 645nm, 505nm and 453nm.

Beta-carotene (mg/100ml) = 0.216 (A_{663}) – 1.22 (A_{645}) – 0.304 (A_{505}) + 0.452 (A_{453}).

4.2.6.3 Chlorophyll

The Chlorophyll content of the samples was analysed by AOAC method. The Chlorophyll content was obtained from extracted sample by spectrophotometer in various 665nm and 649nm wavelength.

Chlorophyll content (mg/l) = 6.45 (A_{665}) + 17.72 (A_{649})

4.2.6.4 Color

The colorimetric study was done by Hunter Lab color measurement system (Color Flex 45/0, D 65, 10º observer; Hunter Associates Laboratory Inc. Reston, VA, USA). TheCIE L*a*b* system was considered. Samples were put in optical glass cells 3.5 cm in length. The results were expressed in L* lightness (0; black to 100; white), a* redness (-; green to +; red), and b* yellowness (-; blue to +; yellow) values. A 3.5 cm thick layer was covered with the white standard plate (X = 79.22; Y = 84.10; Z = 88.76) for measurement of diffused reflected light from the cell bottom using a1.25 inch diaphragm aperture.

4.2.6.5 Statistical analysis

All the studies were replicated three times (n=3) and the means were reported. All the experimental data were analyzed statistically for analysis of variance (ANOVA) with Microsoft excel 2007. Means were compared by Fisher's least significant difference test at a significance level of $p \leq 0.05$.

4.3 RESULT AND DISCUSSIONS

4.3.1 Drying models and powder morphology

The empirical drying constants for tomato at each temperature (40, 50 and 60ºC) are given in Table 4.1. The coefficients of determination (R^2) for the drying rate constants of all thin-layer drying models for tomato was above 0.85 for Page model and above 0.99 for Lewis model, these high coefficients of determination are due to the highly linear plots of the unaccomplished moisture content, which are perhaps due to accurate equilibrium moisture contents. Drying curve of tomato was represented in Figure 3. From RMSE result, in page model for tomato varies from 0.014-0.032 and for Lewis model it varies from 0.14-0.20. As RMSE approaches zero, the closer the prediction is to experimental data, the model was good fit for the experiment. So it can be concluded from the experiments that at 60ºC page model and Lewis model was significant for tomato drying.

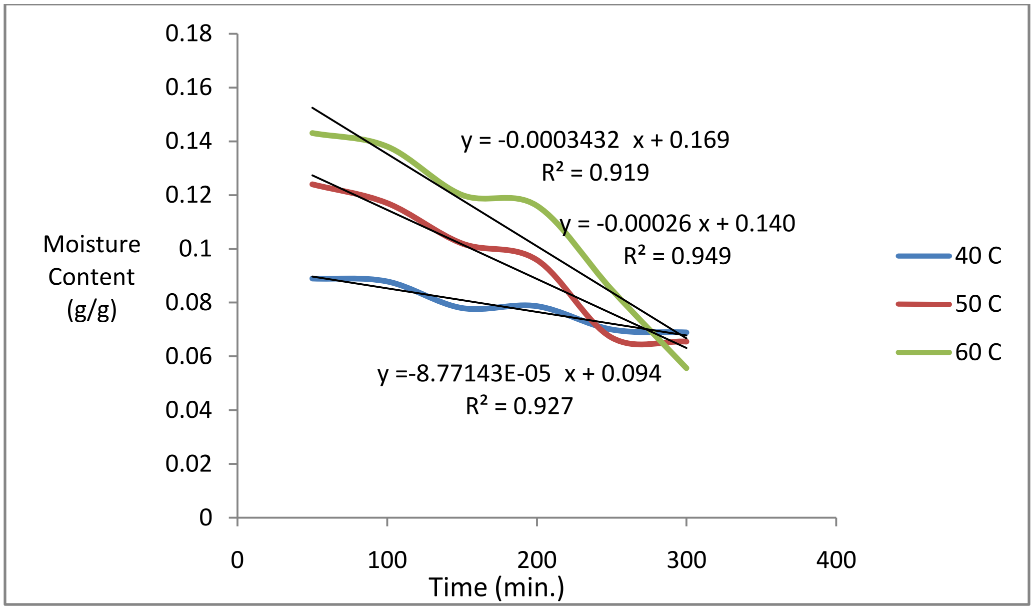


Figure 4.2. Drying curve at 40º, 50º and 60ºC for Tomato

Table 4.1. Empirical constants and RMSE of the Page and Lewis model for tomato

Sample	Temperature (ºC)	Page model				Lewis model		
		K	N	R^2	RMSE	K	R^2	RMSE
Tomato	40	3.425	-0.05937	0.853	0.018	0.768	0.999	0.18
	50	4.335	-0.121	0.9653	0.032	0.774	0.997	0.2035
	60	6.930	-0.2257	0.982	0.014	1.097	0.995	0.1432

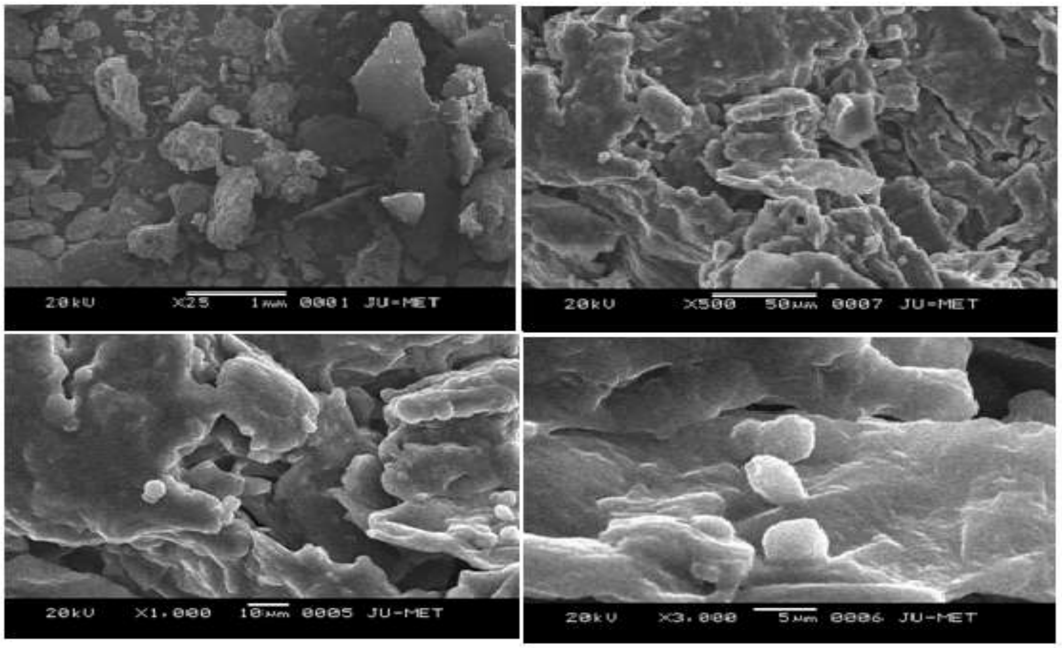


Figure 3 : SEM of tomato powder sample at 60ºC at different resolution

From the figure, it was observed that the powder kept at 3000X magnification shows the better fine particles than the rest 1000X, 500 X and 25 X. Various important characteristics of food change during drying due to loss of moisture from the inner structure to the surrounding environment. Knowledge of microstructure is important in understanding the mechanisms involved during drying of foods. There are studies done in literature investigating the microstructure of dried foods by microscopic techniques. It is well recognized that changes in many physical characteristics of food during drying are due to changes in the product microstructure. Microscopic analyses were performed to visualize the impact of heating and drying methods on food microstructure in many studies (Fazaeli et. al. 2012).

4.3.2 Antioxidant compound and antioxidant activity

The most abundant types of antioxidants contained in fruits and vegetables include vitamin C, carotenoids and phenolic components which result from electron-rich structures in the form of oxidizable double bonds and hydroxyl groups (Kalt 2005). The flavonols of fruits and vegetables are present in glycosylated form, mainly as O-β-glycoside with a sugar moiety at the C_3 position, having a diverse number and type of sugar residues (Amarowicz et al. 2009). Antioxidant compounds (phenol and flavonoid) and antioxidant activity for tomato powder was represented in Table 4.2. Phenol and flavonoid content of tomato powder was 9.34 mg/g and 0.945 mg/g. Tomato is rich in lycopene which is considered a strong antioxidant that has many health-promoting benefits (Kun et al. 2006). Considering to available literature, there are several studies which reported a highly positive relation between total phenolic content and antioxidant activity in many plants and fruits (Sim et al. 2010). Hence, antioxidant activity of tomato powder 58.670% justifies phenolic and flavonoid content.

Results indicate that the phenol and flavonoid content also decreases with increase in temperature. The lycopene content of tomato decreases when the temperature increases. The phenol and flavonoid content at 40 °C was (40.78 and 4.03) mg/g and it decreases to (9.34 and 0.945) mg/g at 60 °C. As lycopene is one of the major antioxidant compounds in tomato like phenol and flavonoid. Lycopene content of air dried tomato at 65 °C was 43.65 mg/100g and that of 75 °C was 24.53 mg/100g showed that, increase in drying temperature had a negative effect on color and retention of lycopene rate decreased by increasing of temperature (Sahin et. al. 2011). Results indicate that hot air drying decreased antioxidant compound retention in tomato slices, but the rate of degradation was significantly different and pre-treatments influenced the rate of reduction during dehydration process (Ghavidel and Davoodi, 2010).

Table 4.2. Antioxidant compound and antioxidant activity for tomato 3
powder

Sample	Temperature	Phenol (mg/g)	Flavonoid (mg/g)	DPPH (%)
Tomato powder	40 °C	40.78 ± 0.38^{c}	4.03 ± 0.06^{c}	72.11 ± 0.95^{c}
	50 °C	24.45 ± 0.52^{b}	2.32 ± 0.09^{b}	66.12 ± 0.35^{b}
	60 °C	9.34 ± 0.467^{a}	0.945 ± 0.0473^{a}	$62.670 \pm .25^{a}$

Means with the same superscript within the same column are not significantly different ($p<0.05$) as determined on Fisher's least significant difference test.

4.3.3 Bioactive Compounds

Bioactive compounds determination is essential for fruits and vegetables to determine its antioxidant activity as well as other characteristics. Bioactive compounds of tomato are represented in table 4.3. It was observed that after drying at 60 °C the lycopene content of tomato was increased from 60.05 to 63.49 mg/g and beta- carotene decreased from 1.6 to 0.72 mg/g. It can be said that the drying processes that are performed higher temperature above 65°C may cause the higher retention loss in lycopene content, but we can also say that the if exposure duration to drying process is longer, the rate of degradation of color is higher. It is known that the carotenoids are highly sensitive in presence of oxygen and lycopene is an also heat sensitive pigment (Sahin, 2011). They found that fresh tomato has 0.88-4.20 mg/100 g while this value was determined as 46.50 mg/100g for sun dried tomato samples. Beta- carotene showed a content decrease in all heated products (D'Evolli, 2013).

Table 4.3. Bioactive compounds for tomato powder

Sample= Tomato powder	Lycopene	Beta- carotene
40°C	60.05 ± 0.21^{a}	1.6 ± 0.09^{a}
50°C	61.87 ± 0.16^{b}	1.1 ± 0.1^{b}
60°C	63.49 ± 0.23^{c}	0.72 ± 0.05^{c}

Means with the same superscript within the same column are not significantly different ($p<0.05$) as determined on Fisher's least significant difference test.

4.3.4 Color

Color has to be considered as a special parameter that seems to be one of the first attributes of quality that a consumer perceives, and that influences the consumer judgment of other attributes such as flavor and appearance too (Chen et al. 2005). The color results are also important quality indicators of heat treatment intensity, which could, therefore, influence its utilization as a food ingredient (Pathare et al. 2013).Color profile analysis for tomato at different temperatures (40, 50 and 60ºC) was represented in Table 4.4. L* value at 40ºC for tomato is 30.63, after increasing temperature at 60ºC it was 42.65; so it becomes whitish in nature so comparatively darkening occur a* value was decreased (27.86 to 21.16) for tomato powder. Yellowness was increased for tomato powder by increasing in temperature due to heat increases bioavailability of carotenoids pigment upto 60ºC but at very high temperature carotenoids contents degrade (Goula and Adampoulus 2005)

Table 4.4. Color profile analysis for dried tomato for different temperatures

Temperature	L*	a*	b*
40° C	30.63 ± 0.07^{a}	27.86 ± 0.04^{a}	18.76 ± 0.13^{a}
50° C	35.24 ± 0.25^{b}	24.35 ± 0.04^{b}	22.74 ± 0.31^{b}
60 °C	42.65 ± 0.06^{c}	21.16 ± 0.03^{c}	27.53 ± 0.21^{c}

Means with the same superscript within the same column are not significantly different ($p<0.05$) as determined on Fisher's least significant difference test.

4.4 CONCLUSION

Drying is one of the preservation methods applied to agricultural products. Drying of agricultural products is the removal of water in the solids up to a certain level, at which microbial spoilage and deterioration chemical reaction are greatly minimized. Hot air oven drying is suitable to reduce moisture content of tomato and increased their shelf life period. At 60ºC Page model was best suited for tomato samples whose RMSE value was 0.014. Co-relation coefficient > 0.99 was suggested that Lewis model was fit for tomato the best. Antioxidant activity (DPPH) (57.670) of tomato samples correlates antioxidant compounds such as phenol and flavonoids. L* value was increased for tomato powder (30.63 to 42.65) in increasing temperature. b* value was increased for tomato powder at (40 to 60º C). Morphological analysis gives the best magnified result when tomato powder at 60 °C was kept at 3000X resolution in scanning electron microscope.

CHAPTER 5

5. Development of tomato powder incorporated dhokla and its physicochemical, nutritional and sensory assessment

5.1 INTRODUCTION

Legumes play an important role in nourishment of world population and have a very specific place from the nutritive point of view. As good sources of plant proteins, carbohydrates, dietary fibre and several water-soluble vitamins especially of the B-complex, and minerals such as calcium and iron and other nutrients legumes make a major contribution to human nutrition (Sreerama et al. 2012; Kaur et al. 2007). Consequently, the combination of grain with legume proteins would provide a better overall balance of essential amino acids (Kadam et al. 2012). Legume proteins are rich in lysine but deficient in sulphur-containing amino acids, whereas cereal proteins are deficient in lysine but have adequate levels of sulphur containing amino acids. The combination of cereal and legume proteins would thus provide a better overall balance of essential amino acids, which is very important in a balanced diet (Hera et al. 2012; Kadam et al. 2012). Bengal gram is a widely used legume in food products all over India. Durum wheat semolina is mostly used for the preparation of pasta and couscous and also used to make bread. It has been reported that bread obtained from durum wheat flours is characterized by relatively slow staling and, consequently, a longer shelf life due to the high water-binding capacity of durum wheat flour (Quaglia et al. 1988; Boyaçioglu and D'Appolonia 1994). The addition of durum wheat flours has been found to be useful for improving the bread-making properties of poor quality common soft wheat and for extending the shelf life of the derived products.

Dhokla, a lactic acid fermented cake, is one such food having its origin in Gujarat, India. Dhokla is prepared from a batter of coarsely ground rice (*Oryza sativa* L.) and Bengal gram dhal (*Cicerarietinum* L.), fermented at low temperature, steamed in a dish, cut and seasoned (Joshi et al. 1989; Roy et al. 2009; Manay and Shadaksharaswam 2001). Dhokla is a fermented steamed pancake with appealing mild sour taste, color, flavor and spongy texture and comprise an interesting group of legume cereal- based traditional fermented foods that are thesource of dietary energy and nutrients (Moktan et al. 2011).Lactic acid bacteria, predominantly *Leuconostoc mesenteroides, Lactobacillus fermentum and Pediococcus pentosaceus,* and yeasts, mainly *Pichia silvicola* and *Saccharomyces cerevisiae*, are involved during the auto-fermentation of dhokla batters (Ramakrishnan et al. 1979; Joshi et al. 1989).

Tomatoes (*Solanum lycopersicum*) are one of the most widely used and versatile vegetable crops. They are consumed fresh and are also used to manufacture a wide range of processed products (Madhavi and Salunke, 1998). Tomatoes are an integral part of the human diet rich in several nutrients including vitamin A, vitamin C, potassium, calcium and lycopene (Chung2007). The main antioxidants in the tomatoes are the carotenoids, ascorbic acid and phenolic compounds (Giovanelli et al. 1999). The consumption of tomato and tomato-based products have been associated with a lower risk of developing certain type of cancers such as digestive tract and prostate cancer, which may be due to the ability of lycopene and other antioxidant components (Tapiero et al. 2004). Lycopene is a powerful antioxidant which has been linked to reduced frequency and severity of several types of cancer and heart disease (Moselhi et al. 2008). Consumer demand for high quality, minimally processed products has increased remarkably in recent years. Several food technology studies have been carried out to optimize the processing and storage of the tomato products by preventing the heat and oxidative damage on the antioxidants (Shi and Le Maguer, 2000). In order to develop new formulation of dhokla incorporated with tomato, challenging strategy could be not only to recover lycopene-rich fractions, but also to generate additional importance in food processing industry.

Against the background of this information, the present investigation was undertaken with clear objectives of:

- Dhokla preparation with semolina and Bengal gram and incorporation of tomato powder,
- To evaluate the antioxidant content and antioxidant properties,
- To evaluate the moisture content of dhokla after storage,
- To distinguish the color and sensory profile characteristics,
- To determine nutritional analysis (carbohydrate, protein and ash) of dhokla.

5.2 MATERIALS AND METHODS

5.2.1 Ingredients

Given below is the list of the raw materials used along with the company from which they were procured within brackets.

Semolina (Ganesh Grains Ltd., Kolkata, India), Sugar (Sakthi sugar, Chennai, India), Bengal gram flour, refined oil (Purti, Kolkata, India), baking powder (Weikfield Foods Pvt Ltd, Nalagarh, India), curd (Amul, Gujrat, India), salt (Tata, Mumbai, India), turmeric powder, lemon, mustard seed, cumin seed, curry leaves were purchased from the local stores of Jadavpur, Kolkata, India, were used.

5.2.2 Chemicals

Given below is the list of the chemicals used with the name of the company from which they were procured in brackets.

Ethanol (Jiangsu Huaxi International Trade Co. Ltd, China), Folin–Ciocalteu reagent, Sodium bi carbonate, Sodium potassium tartrate, Hydrochloric acid (Hcl), Anthrone (Merck Specialties Pvt. Ltd, Mumbai, India), DPPH (Sigma-Aldrich, St. Louis, MO, USA), Sodium Nitrite ($NaNO_2$), Aluminium chloride ($AlCl_3$) (LOBA Chemie), Sodium hydroxide (NaOH), Copper sulfate ($CuSO_4$) (HI Media, Mumbai, India), Phenolphthalein (RFCL Limited, New Delhi, India), Bovine serum albumin (Sd Fine-Chem limited, Mumbai, India).

5.2.3 Dhokla preparation

The rawa-dhokla ingredients include in %: Bengal gram 10, semolina 20, curd 12, sugar 8, salt 2, lemon juice 5, baking powder 3.0 and water 40. The Bengal gram was at first soaked in curd for 1 h and then the above weighed ingredients were mixed properly to make batter. The microwave oven proof container was greased with refined oil, then the batter was poured into the pan and then baking powder was added to fluffing up the product. Then the container was placed in microwave oven (Samsung combi, India) for 8 minutes at 450 W. Then a knife was inserted to check the sponginess of dhokla. Then it was cut into square pieces. Mustard seed, cumin seed, seasame seed, sugar and lemon juice was poured in heat remaining oil. Then it was taken out and was cut. Curry leaves were used for garnishing. Thus dhokla was prepared to serve.

5.2.4 Preparation of tomato powder

Fresh tomatoes were brought from the local market of Jadavpur. They were washed and were sliced into pieces. They were then placed in a hot air oven (Mac Pharma Tech, India) at 60 °C for 12 hours and then ground to powder in a commercial mixer grinder (Prestige Stylo Mixer Grinder, Prestige, Bangalore, India). The obtained powder was stored in the freeze (New Brunswick Scientific) at -20 °C for further analysis. The obtained powder was then sifted to particle size less than 0.250 mm (BS 60).

5.2.5 Preparation of composite mix:

To obtain the mix blends for dhokla preparation, 100 g above mixture was mixed with 0.0, 1.0, 4.0 and 7.0 % of tomato powder.

Dhokla without tomato powder was denoted as A, 1%, 4% and 7% tomato powder incorporated dhokla were denoted as B, C and D respectively.

5.2.6 Evaluation of batter and product

5.2.6.1 Acidity and pH

1 g batter was dissolved in 10 ml distilled water. Then the sample was titrated by 0.1 (N) NaOH using phenolphthalein indicators till the end point (Balasubramanian et al. 2006)

Acidity can be calculated as:

Total acidity (%) = (volume in ml of NaOH * 0.1(N) *0.090 * 100)/ (sample weight)

5.2.6.2 Rheology

The batter of dhokla sample prepared for the dynamic rheological tests. Dynamic oscillatory tests were performed in a controlled stress rheometer, (Physica MCR 51 Anton Paar, Germany). Parallel plates of 49.986 mm and 0 mm gap were used and the measurements monitored with Rheo Plus software package (version 2.65). A temperature of 25ºC was kept during the analyses with a water circulator device (Neslab RTE 7, Refrigerated Bath, Thermo Electron Corporation, USA). Frequency-sweep tests of the batter dhokla were performed at a constant stress of 1% and angular frequency ranging between 0.1 and 100ω. Dynamic module G', G" were obtained as a function of frequency. G' is the dynamic elastic or storage modulus, related to the material response as a solid, while G" is the viscous dynamic or loss modulus, related to the material response as a fluid.

5.2.6.3 Antioxidant analysis

5.2.6.3.1 Extraction of samples Same as 4.2.5

5.2.6.3.2 Total phenolic content Same as 4.2.5.1

5.2.6.3.3 Total flavonoid content Same as 4.2.5.2

5.2.6.3.4 Total antioxidant activity Same as 4.2.5.3

5.2.6.4 Moisture content

The metal dish was weighed properly using digital weighing balance [Sartorius, India], 5 g of the sample was weighed. Then, the sample in metal dish was kept in the hot air oven [Mac Pharma Tech, India] at 105 °C for 3 hours until the constant weight was desired. Then, the sample in dish was placed in the desiccators for 10 minutes to cool down the temperature. The final weight of the sample was measured (AOAC, 1984).

Moisture content = ((initial weight - final weight)/ initial weight) * 100

5.2.6.5 Color analysis Same as 4.2.6.4

5.2.6.6 Color degradation kinetics

The color kinetics of the product was calculated by using equations (1) and (2) for a first-order reaction given below:

Kinetics data was analyzed by using linear regression.

$$- dC/dt = kt$$

$$\ln (C/C_0) = - kt \qquad (1)$$

Where, C is the concentration, t for the time (day), k for the first-order reaction rate constant (day^{-1}).

$$\ln C = \ln C_0 - Kt \qquad (2)$$

where, C_0 the initial value at zero day which was replaced by a_0 and b_0 value.

5.2.6.7 Nutritional analysis

Carbohydrate content of the sample was done by the method of Akindahunsi and Vetayo 2006. 100 mg of the sample was measured; sample was hydrolyzed by keeping it in a boiling water bath for three hours with 5 ml of 2.5 N HCl and cooled to room temperature. To neutralize the acid, sodium carbonate was added until sample was not nutralised as indicated by pH paper. The volume is made up to 100 ml and centrifuged. The supernatant was collected and used for analysis. Glucose was used for the standards by taking 0, 0.2, 0.4, 0.6, 0.8 and 1 ml of the working standard.'0' serves as blank. 4 ml of anthrone reagent was added to the sample and was heated for eight minutes in a boiling water bath. Then cooled rapidly and absorbance was measured at 630 nm.

Amount of Carbohydrate (%) = (mg of glucose/ Volume of sample)* 100

Protein content of the sample was determined by using Folin Lowry method. Bovine serum albumin was used for standard. 1 ml distilled water in a test tube serves as blank. 4.5 ml of Reagent I [48 ml of 2% Na_2CO_3 in 0.1 N NaOH+1 ml 1% NaK Tartarate in H_2O+ 1 ml 0.5% $CuSO_4.5H_2O$] was added and incubated for 10 minutes. After incubation, 0.5 ml of reagent II [1:1 Folin phenol: water] was added and incubated for 30 minutes, absorbance was measured at 660 nm. Thus amount of protein present was calculated in the samples.

5.2.6.8 Ash content

Sample was taken in the crucible and then was placed in hot plate until the mass is well- charred. Then the crucible was placed in muffle furnace at 550°C for 4 hours till the ash was formed. Then, the final weight of the crucible was measured and the process was continued till the constant weight of the ash was found. (AOAC, 1984)

%of ash = (weight of ash/ Weight of the sample) *100

5.2.6.9 Sensory analysis

Dhokla samples were coded and given to 50 panel members for sensory scoring. The panel members are faculties, research scholars and students of Food Technology and Biochemical Engineering Department. Each set contained one control (without fortification) and the other dhokla prepared with the fortifying agent (1%, 4% and 7%) of tomato powder. Water was used for mouth rinsing before and after each sample testing. Dhokla were scored for color, appearance, taste, aroma and overall acceptability by numerical scoring system. The model used in this analysis was an acceptance test on the hedonic scale, with values ranging from 1 (extremely disliked) to 9 (extremely liked).

5.2.6.10 Statistical analysis Same as 4.2.6.5

5.3 RESULTS AND DISCUSSION

5.3.1 Acidity and pH

Acidity is an important parameter for determining product quality. Acidity of the dhokla A, B, C, D was measured and it was observed from figure5.1 that the acidity increases in sample D than sample A due to the fortification of tomato powder. The acidity of sample A was 0.09, in sample D, it was increased 0.45. Citric acid is the most abundant acid in tomatoes and the largest contributor to the total titratable acidity (Stevens et al. 1972; Paulson and Stevens, 1974), malic acid also presents in tomato (Gould, 1983). Khazaei et al. (2008) reported that drying of tomato slices caused an increase in soluble solids and acidity.

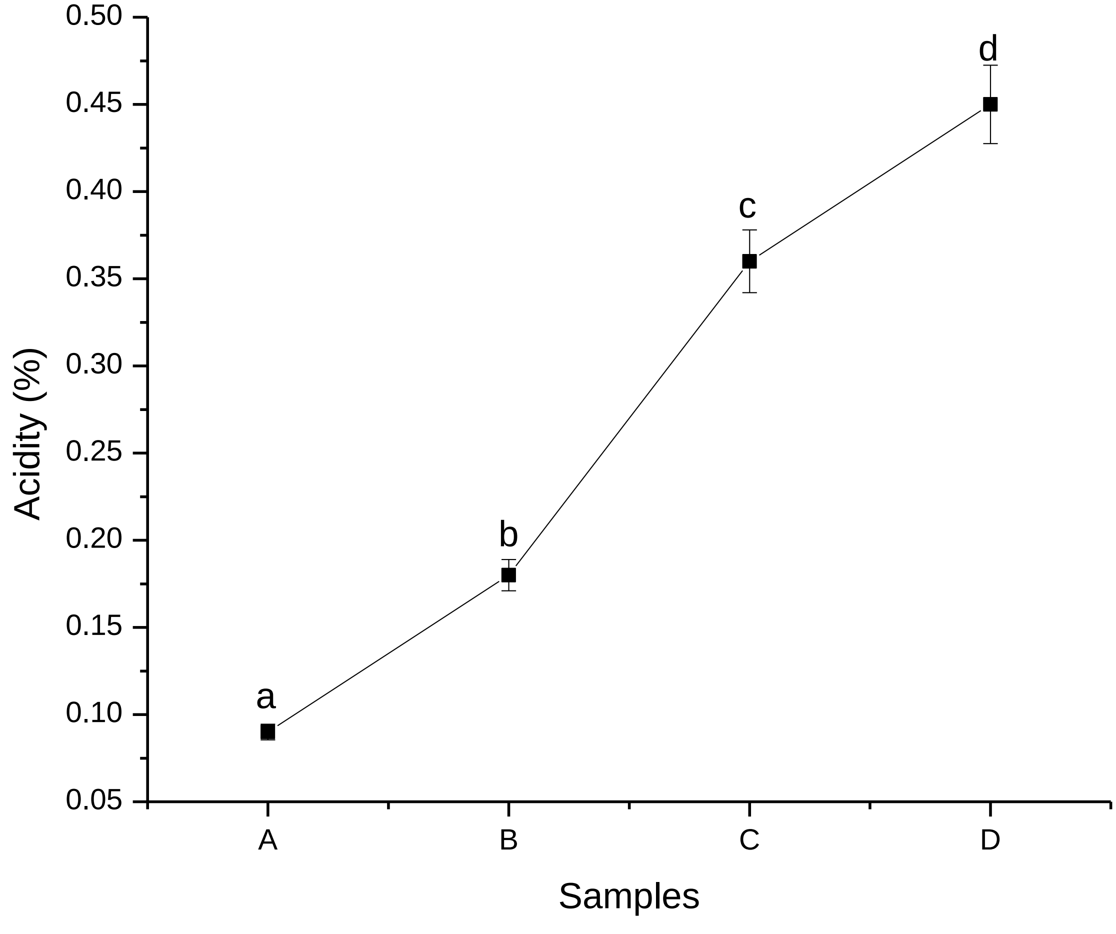


Figure 5.1 Acidity content of dhokla samples

Dhokla without tomato powder was denoted as A, 1%, 4% and 7% tomato powder incorporated dhokla were denoted as B, C and D respectively.

5.3.2 Rheology

Rheological property of batter is useful to determine the potential of the ingredient and also the quality of the product. The dynamic oscillation test curves were concerned about storage modulus and loss modulus with different dhokla batters and it was represented in figure 5.2. It was observed that storage modulus of dhokla batters were increased as the frequency increased at constant temperature 25ºC. Storage modulus was higher than loss modulus exhibited that the dhokla batters have viscoelastic property. Application of tomato powder in dhokla preparation revealed variation of the effect of different percentage (0, 1, 4 and 7) of tomato powder. It was observed that sample D shows highest in storage and loss modulus among all samples and there was no crossing point in storage and loss modulus.

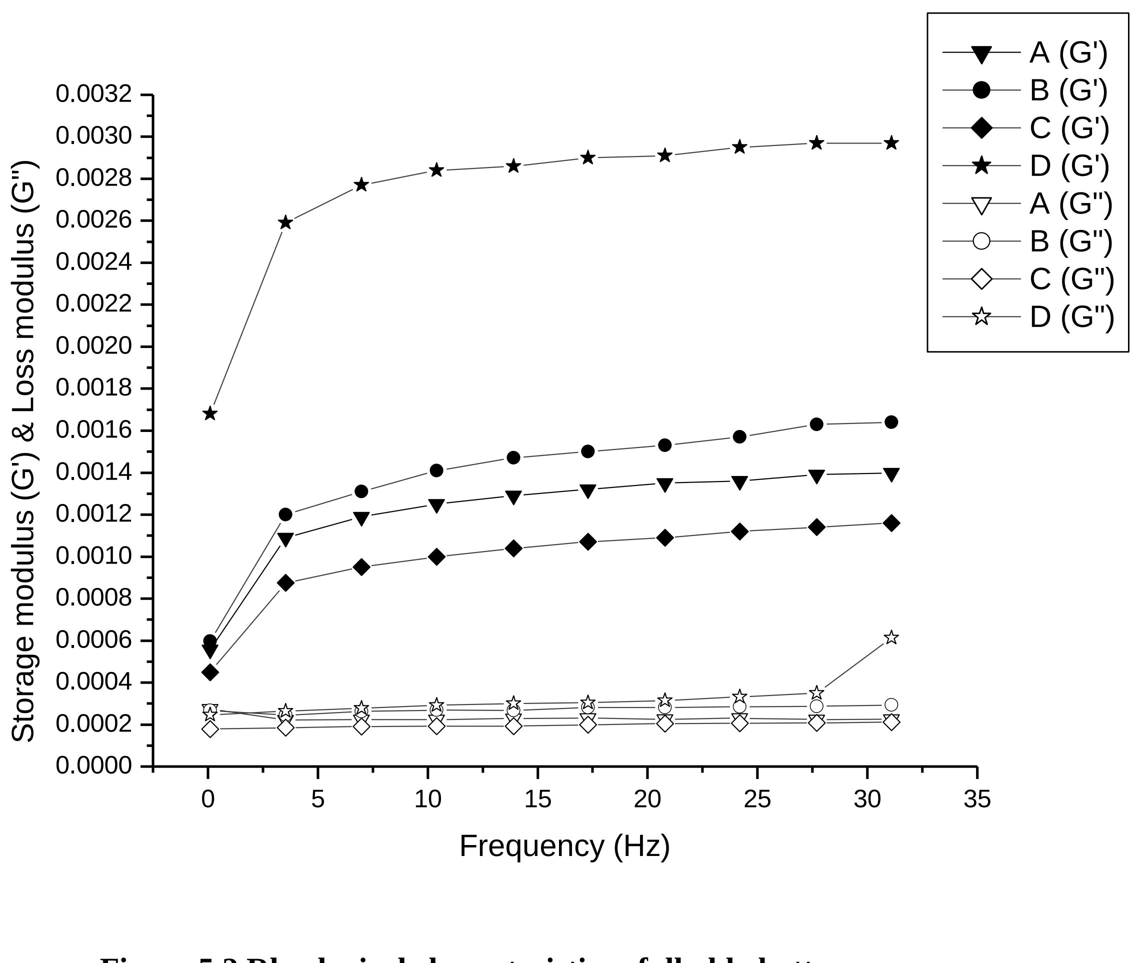


Figure 5.2 Rheological characteristics of dhokla batter

Dhokla without tomato powder was denoted as A, 1%, 4% and 7% tomato powder incorporated dhokla were denoted as B, C and D respectively.

5.3.3 Antioxidant property

Several studies had shown that 80 % methanol was an effective solvent in extracting phenolics, flavonoids and other polar compounds in sample (Przybylski et al. 1998; Zielinski and Kozlowska, 2000). The total phenol, flavonoid and vitamin C content were expressed as mgequivalents of gallic acid, catechins and ascorbic acid per g of sample respectively. The relationship was observed between total phenolic content, flavonoid content and Vitamin C with the antioxidant activity by DPPH scavenging activity in Figure 5.3. Total phenolic content is an important parameter to study as it determines the polyphenolic content of the sample which is interrelated with the antioxidant activity of the sample.

The results showed a significant increase in anti-oxidative compound after fortification (Figure 5.3), it is possibly due to the liberation of phenolic compounds from the matrix during the process. The content of ascorbic acid (Figure 5.3) significantly increases with respect to fresh ones as tomato contents high amount of ascorbic acid. Tomatoes and tomato products are rich inhealth-related food components, as they are good sources of carotenoids (in particular, lycopene), ascorbic acid (vitamin C), vitamin E, folate, flavonoids and potassium (Leonardi et al. 2000). If there was a comparison among dhokla without tomato powder and dhokla with tomato powder the result showed that in product A, phenol, flavonoid and vitamin C were2.34 mg/g, 0.2mg/g and 8.26 mg/g whereas it was increased in product C as 5.97 mg/g, 0.58 mg/g and 24.44 mg/g and was highest in product D as 7.57 mg/g, 0.79 mg/g and 30.22 mg/g respectively. It was observed that the correlation constant (R^2) for phenol, flavonoid and vitamin C is greater than 0.9(0.912, 0.906, 0.907) which were significant thus it follows the 1st order equation.

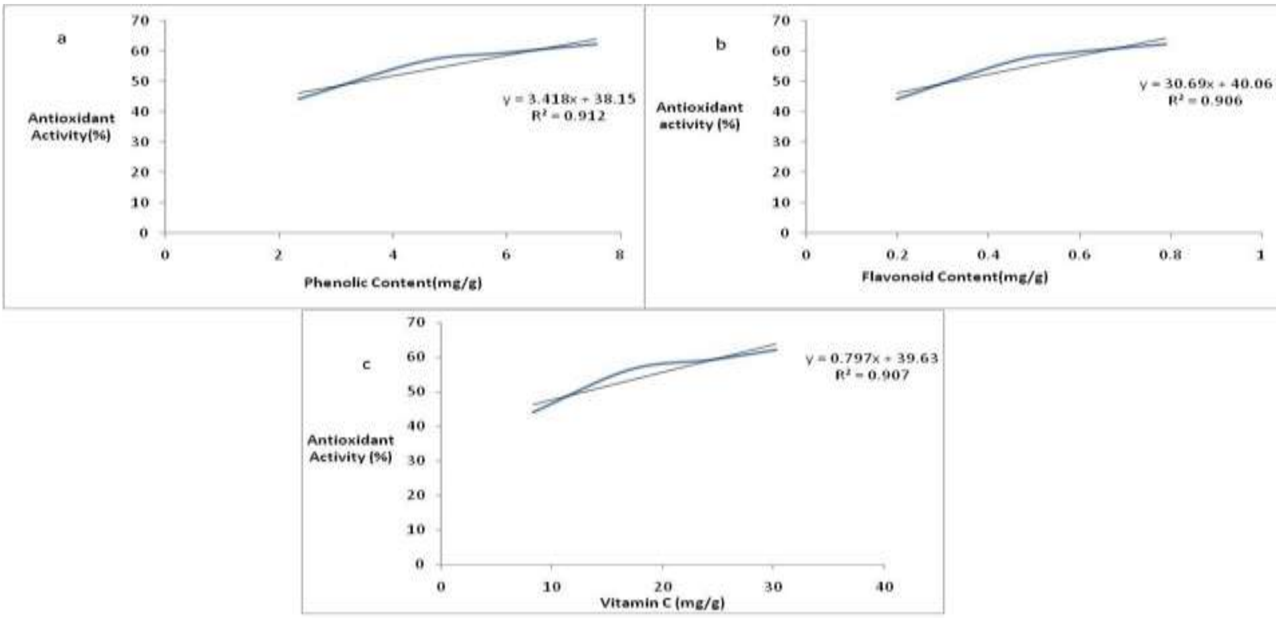


Figure 5.3. Relationship between (a) phenolic content and antioxidant activity (a) flavonoid content and antioxidant activity (c) vitamin C content and antioxidant activity

5.3.4 Moisture Content

Evaluation of moisture content is an important parameter to determine the quality of the food. It mainly determines the amount of water present in the food sample. Moisture content and hardness of the product is usually measured in percentage (%) and Newton (N). Effects of moisture content of sample during storage and hardness-moisture content relationship of dhokla were represented in fig. 5.4 and fig. 5.5.

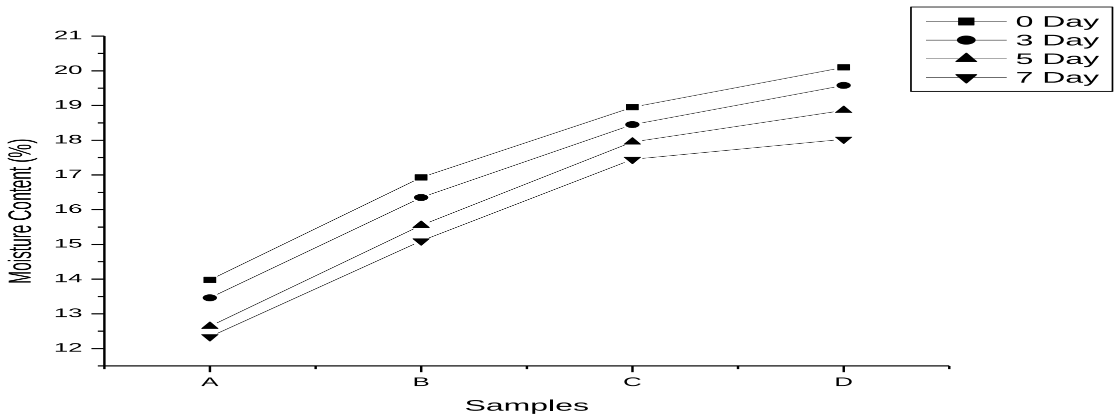


Figure 5.4 Moisture content of dhokla samples during storage

Dhokla without tomato powder was denoted as A, 1%, 4% and 7% tomato powder incorporated dhokla were denoted as B, C and D respectively.

From figure 5.4, it was observed that in sample A moisture content (13.98) was lower than B (16.928), C (18.05) and D (20.10) at 0 day becausetomato itself contains about 94 % moisture (Jayathunge and Kapilarathne, 2012). But during storage, there was decrease in moisture content in sample A than other dhokla. In sample A moisture content was decreased from 13.98 to 12.38 whereas in sample B, C and D moisture content was decreased from 16.928 to 15.10, 18.05 to 17.45 and 20.10 to 18.03 after 7 days of storage. Moisture content was less decreased in product C. It was observed in figure 4, that the correlation constant (R^2) of product hardness and moisture content is greater than 0.9(0.982) which were significant thus it follows the 1st order kinetics.

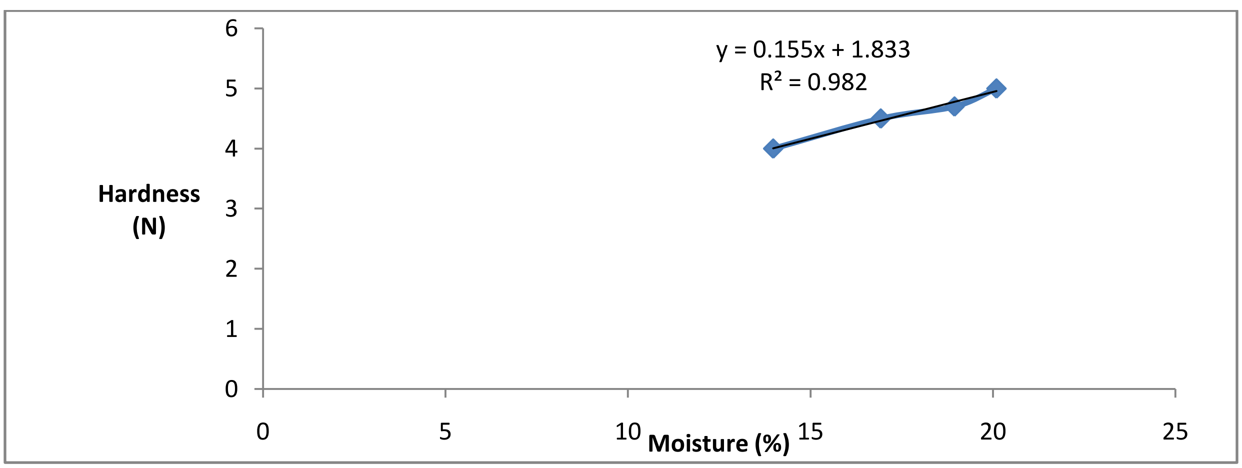


Figure 5.5 Relationship between hardness and moisture content of dhokla

From fig. 5.5, it was observed that due to loss of moisture, the product becomes harder. Thus, hardness of the product was affected by the moisture content. After storage, sample A becomes harder than sample B, C, and D as tomato has its high amount of moisture so moisture content increases when amount of fortification increases. So after 7 days of observation moisture content decreases which show that it increases the shelf life but on other hand after 7 days, it increases the hardness of the product but up to 4 days sample B and sample C were acceptable to the consumer.

5.3.5 Color

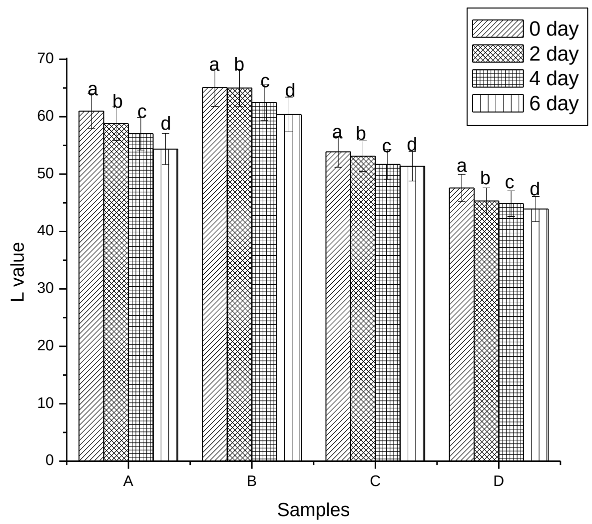


Figure 5.6: L* values for different dhokla samples.

Dhokla without tomato powder was denoted as A, 1%, 4% and 7% tomato powder incorporated dhokla were denoted as B, C and D respectively.

The color characteristic of dhokla was done to determine the product appearance and acceptability. From figure 5.6, it was observed that the whiteness (L*) was decreased due to incorporation of tomato powder of 4% and 7%, L* value was decreased in storage for all samples. It may be due to caramelization and browning reaction. In sample B, L* value was higher than all other samples at initial day. 4% tomato powder incorporated dhokla have less color degradation property than all other samples in storage.

5.3.6 Degradation kinetics

In figure5.7, C and C_0 are replaced by a and a_0 and b and b_0 respectively.

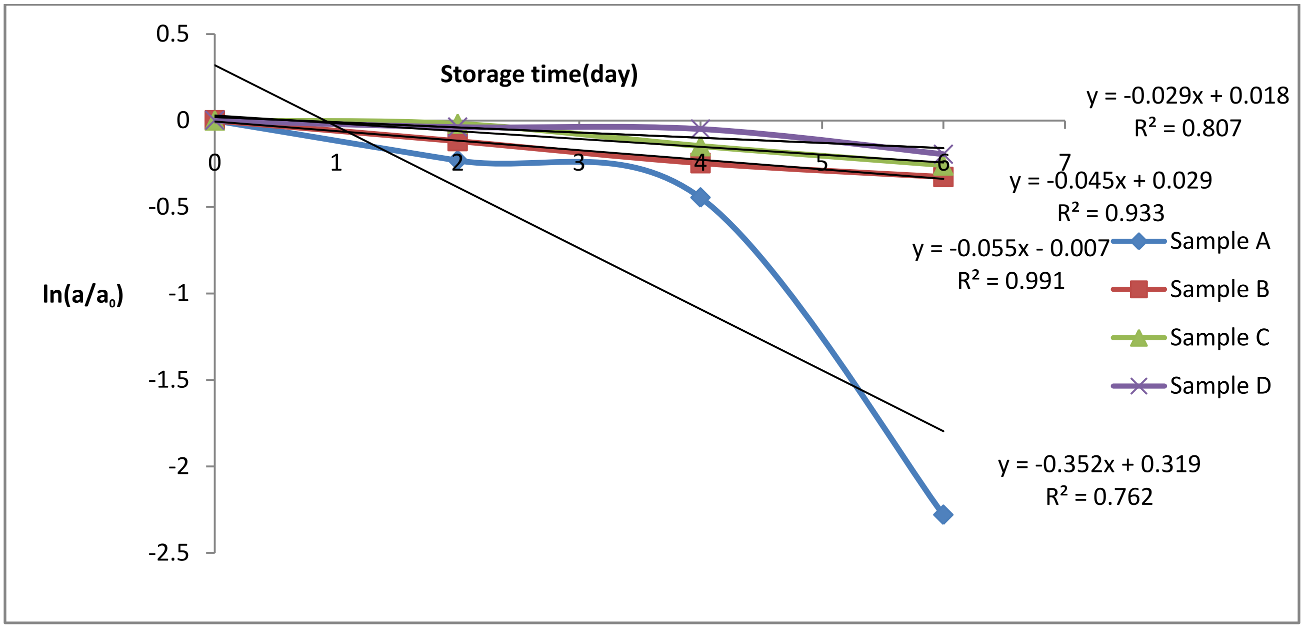


Fig. 5.7 Relationship between ln(a/a_0) and storage time (day) of dhokla samples

Dhokla without tomato powder was denoted as A, 1%, 4% and 7% tomato powder incorporated dhokla were denoted as B, C and D respectively.

From fig. 5.7 it was observed that the redness was increased in sample B, C and D due to fortification with tomato powder. It has been reported that tomato skins contained a high amount of lycopene (Wandawi et al. 1985). Lycopene from tomato oleoresin was readily absorbed and may act as an in vivo antioxidant. Tomato contains the carotene lycopene and tomatine, the most powerful natural antioxidants (Rao et al. 1998) which is reddish yellow in color. In sample A, color degradation was more than other three dhokla samples when they were stored at temperature 4º C. Since sample A is the control and is without fortification of tomato powder such that it is more whitish than other dhokla. From the correlation constant (R^2) it was also observed that sample A (R^2 = 0.762) while sample C and sample D having (R^2= 0.933 and 0.807). The degradation in color values indicated that the value of lightness showed a smooth decrease with respect to the values of redness and yellowness. The decrease in color values (“a”) could be associated with the carotenoid degradation and non enzymatic browning as indicated by Avila and Silva (1999); Ahmed and Ramaswamy (2005) and Nisha et al (2010).

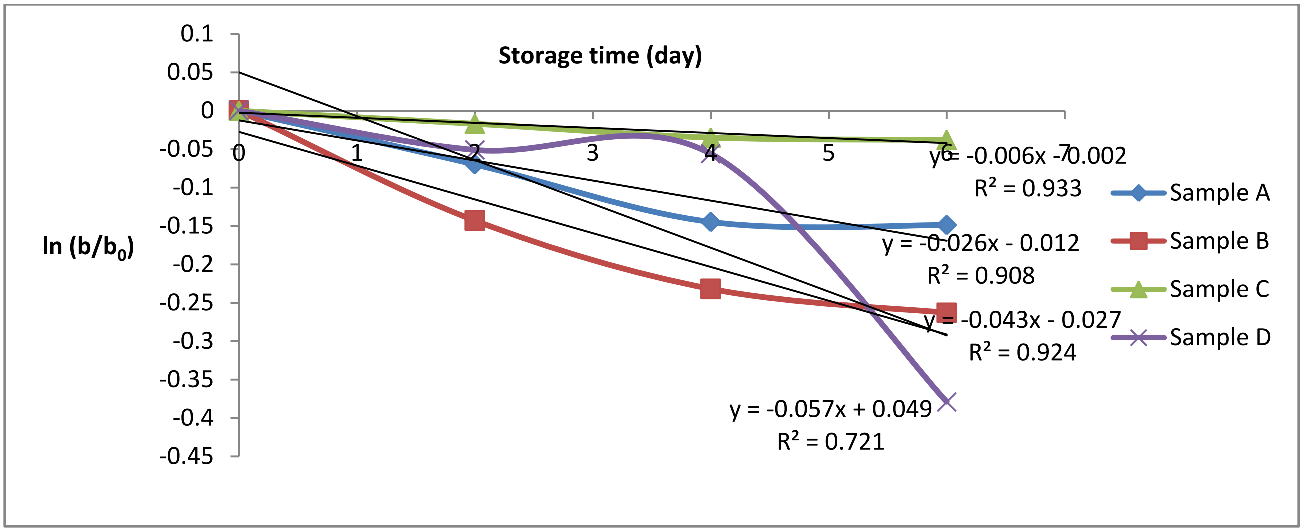


Figure 5.8 Relationship between ln(b/b_0) and storage time (day) of dhokla samples

Dhokla without tomato powder was denoted as A, 1%, 4% and 7% tomato powder incorporated dhokla were denoted as B, C and D respectively.

From fig. 5.8, it was observed that at 4ºC, yellowness of sample D degraded more than sample A though it was fortified with 7% (highest percentage) of tomato powder having the correlation constant of sample D (R^2 = 0.721) and sample A (R^2 = 0.908). Enzymatic browning is a serious problem with the oxidative enzymes, such as peroxidase and polyphenolase, may cause browning accompanied by changes in color, flavour and nutritive value during frozen storage and thawing of the product (Avila and Silva, 1999). The decrease in a value and b value indicated less red and less yellow in tomato powders. Color changes of tomato powders were affected by both storage time and temperature (Sousaet al. 2008).

5.3.7 Nutritional analysis

Nutritional analysis refers to the process to determine the nutrient content of food products. Here, mainly carbohydrate, protein and ash (mineral) content was measured.

Dhokla	Carbohydrate (%)	Protein (%)	Ash (%)
A	19.32±0.23[a]	8.75±0.09[a]	1.07±0.054[a]
B	20.54±0.15[b]	16.05±0.1[b]	1.36±0.068[b]
C	21.86±0.09[c]	22.27±0.15[c]	1.69±0.05[c]
D	24.33±0.1[d]	30.51±0.07[d]	1.98±0.09[d]

Table 5.1: Nutritional analysis of the dhokla

Dhokla without tomato powder was denoted as A, 1%, 4% and 7% tomato powder incorporated dhokla were denoted as B, C and D respectively. Means with the same superscript within the same column are not significantly different ($p<0.05$) as determined on Fisher's least significant difference test.

From Table 5.1, it was observed that in sample A, of carbohydrate (19.32), protein (8.75) and ash (1.07) were increased significantly when they were fortified with tomato powder. In sample A, carbohydrate, protein and ash content were 19.32, 8.75 and 1.07 % due to legumes and semolina. Legumes and semolina contains carbohydrate 14 g, 73 g; protein 5g and 13 g, which impart it while cooking. More than 75% of the dry weight of the plant world is carbohydrate in nature-particularly cellulose and lignin (Jim, 2001). Legumes which include beans, lentils, dried peas, soy, nut and seeds are rich source of protein (Palmer 2014). Tomato contains 3.9 g of carbohydrate and 0.9 g protein so when dhokla was fortified with tomato powder carbohydrate and protein content and increases significantly. Brodowski and Geisman (1980) reported that tomato pomace is an excellent source of tocopherol (vitamin E), which can be used as an antioxidant in broiler meat, and 13% more lysine than soy protein, which could substantially improve the protein quality of low lysine foods such cereal products. But the ash and fat content of legumes and semolina are so less that they are negligible. Minerals constitute about 8% of the dry matter content of tomatoes. Potassium and phosphate are the two major ones. Minerals have an effect on pH and titratable acidity and have buffering capacity as well; thus, they influence the taste of tomatoes (Petro-Turza, 1987). Crude protein and ash content values of the cookies containing tomato powder of 5.0, 7.5 and 10.0% were significantly higher than without tomato powder fortification in cookies (Chung et al. 2007).

5.3.8 Sensory Analysis

Sensory parameters (color, flavor, taste, texture and overall acceptability) are very useful to determine the food product quality characteristics. To study the consumer behavior and analyze their attitude towards the product, sensory methods are extremely important (Lawless and Heymann, 1999). A comparison of the sensory rating test scores for taste, color, appearance and acceptability attributes from different formulations is shown in figure 5.9. All the dhokla received mean scores ranging from 'neither like nor dislike' (5.00) to 'like very much' (9.00). It is known that product with high acceptance scores seem to have more success on the market. Whereas product that presented 'neither like nor dislike' score cannot be considered potential for market. Taking this into consideration in our study, assay number 1 shows the lowest value for all the analysis.

Color is the major attribute that is always evaluated by consumers when they buy foods (Calvo et al., 2001). In respect of color, the degree of liking of color varied significantly and up to 4 % fortification of tomato powder (C) color value increases than control (without fortification-A) and dhokla having 1 % fortification agent (B). The color value of sample A was 7.8, whereas in sample B and sample C, the color values were 8.33 and 8.86 respectively. In sample D (7% fortification) color value was decreased, i.e 8.375 which is less acceptable to the consumer for more red color in dhokla. The surface color was evaluated to become darker as the tomato powder level increased, which is due to the reddish color of tomato powder. Tripathi and Nath (1989) stated that non enzymatic browning in the dried tomato slices may be due to oxidation and polymerization of ascorbic acid, sugar caramalization and polymerization of lycopene. The same result was observed when tomato powder was incorporated in cookies from 0 to 10% (Chung, 2007).

Taste is a very important organoleptic parameter to analyze the food sample. Tomato is very appetizing, refreshing and has pleasing taste (Jayathunge et al., 2012). It was observed in figure 9 that scores of tomato powder incorporated dhokla (B and C) have better value than sample A. In sample D, the taste score was decreased significantly from 8.5 to 7.8 due to much sour taste in dhokla.

Flavor is one of the key parameters to attract the consumer to the food products. In sample A, the flavor was 7, which was mainly combination of legume and semolina flavor. After incorporation of 1% and 4% tomato powder the flavor score was 8.11 and 8.22, whereas in sample D (7% tomato powder incorporation) the score was decreased (7.63) which was due to characteristic smell of tomato in dhokla.

Texture is very useful visual property to select a food product. It was observed that in sample A, the texture value was 7.8, when fortification agent 1% tomato powder was incorporated, the value was decreased, i.e 7.54. At 4% level texture score was significantly increased and it was 8.56 and it was the maximum texture score among all dhokla. Figure 5.10 demonstrates the co relation analysis between texture and overall acceptability. R^2=0.917 proves that texture was highly correlated with overall acceptability which signifies that overall acceptability was dependent on texture score.

In term of overall acceptability index, it was observed that 1% and 4% tomato powder substituted dhokla were credited to be far superior than containing 7% tomato powder incorporation. In sample A, the overall acceptability score was 7.3, whereas sample B and C, the score was increased.

So, we can conclude that of all respect of sensory parameters sample C is the best among all dhokla samples.

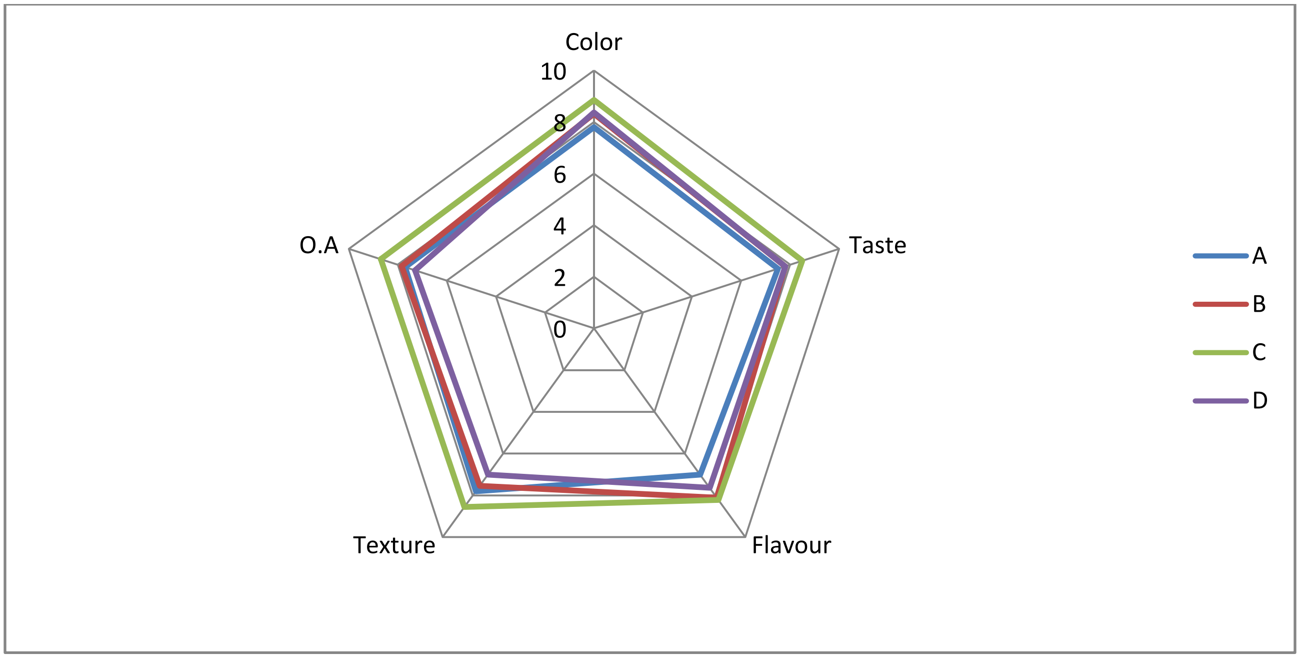


Figure 5.9 Sensory parameters analysis of dhokla

Dhokla without tomato powder was denoted as A, 1%, 4% and 7% tomato powder incorporated dhokla were denoted as B, C and D respectively.

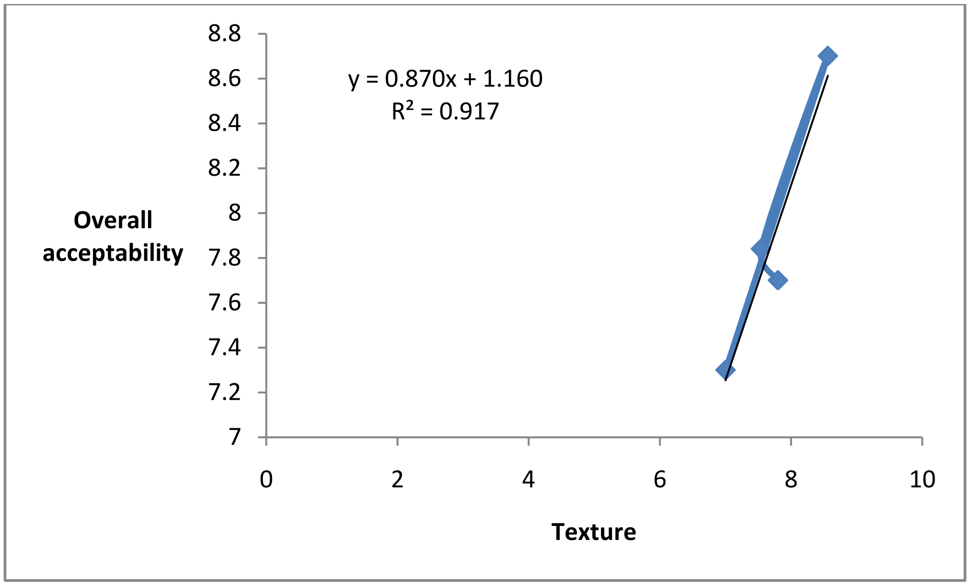


Figure 5.10 Co-relation analyses between texture and overall acceptability

5.4 CONCLUSION

Legumes are inexpensive sources of protein with high nutritional profile. Dhokla made with semolina and Bengal gram is a new approach to food processing industry. Incorporation of tomato powder in different percentages (1, 4 and 7%) has a significant impact on physico chemical, nutritional and sensory properties on dhokla prepared with Bengal gram and semolina. The research study represents that fortification of tomato powder affects color of dhokla. Tomato powder incorporation was directly proportional with redness (a value) and decreases whiteness (L value) of dhokla. Corelation constant of degradation kinetics follows first order equation. Acidity of dhokla was increased by incorporating tomato powder from 0.09 to 0.45. From nutritional point of view carbohydrate, protein and ash content of dhokla were increased from 19.32-24.33, 8.75-30.51 and 1.07-1.98 respectively. Antioxidant activity was increased in dhokla due to tomato powder incorporation. Vitamin C, phenolic and flavonoid content was increased from 8.26% to 30.22%, 2.34-7.57 and 0.2-0.77 respectively. The consumer panel revealed that 7% tomato powder incorporated dhokla (sample D) was inversely proportional to overall acceptability. 4% tomato powder incorporated dhokla (sample C) was found to be ideal on sensory, nutritional and other physiochemical properties.

CHAPTER 6

6. Optimization and preparation of instant tomato mix dhokla and storage study

6.1 Introduction:-

The life style of the people has changed a lot due to global industrialization and advancement of technologies. In this advancement of technologies the demand for ready to eat (RTE) foods in peoples like extruded foods, dhokla mix, vegetable soup, instant wheat porridge (Dalia) mix etc has increased. (Chauhan and Intelli, 2015). Ready to Cook (RTC) food segment has emerged from its early days of being a fringe alternative to home cooked meal or to eating out. In the RTE and RTC segments, and specifically in pasta, vermicelli and instant mix categories, the competitive landscape is largely dominated by 4-5 companies, including MTR, Gits, ITC, Bambino, and Kohinoor Foods. A wide variety of tomato products viz., juice, powder, puree, sauce, soup and traditionally chutneys, curries and pickles are prepared in India. Several instant chutney powders and chutneys based on mint, hibiscus, curry leaves and tamarind leaves, onion-chilly, raw tamarind pods and raw mangoes were reported (Rao et al, 2011). A balance of nutrients may be obtained by including whole cereals, vegetables, pulses and milk products, etc. Cereal proteins are generally deficient in some essential amino acids, to augment the protein quality of cereal based foods, the concept of cereal- legume complementation by blending cereal and legume flour can be applied (Abdel-Haleem, 2014). The processed ready-to- eat foods were very much important for mountainous terrains and Armed forces because instant mix foods have higher shelf life and it can be consume easily (Ayub Khan et al., 2014).

The medium semolina showed higher ash, protein and gluten content, a higher gluten extensibility but a lower gluten index and yellow color than coarser semolina. Semolina particle size is a key factor , fine semolina gives a higher yield upon milling and is preferred by the pasta industry since it shows a high hydration rate an permits a homogeneous hydration, thus facilitating the mixing process (Sacchetti et al., 2011).

Semolina is low-fat, high carbohydrate food offers a lot of energy along with a variety of other nutrients, including lots of protein and several important minerals as well as vitamins E and B. Tomatoes, the fruit of the species *Solanum lycopersicum*, are a good source of nutrients, bioactive compounds, lycopene, b-carotene, a-tocopherol, vitamin C, and total phenolic and flavonoids contents. (Choi et al. 2014) Incorporation of ß-carotene rich foods in human diet is therefore considered a cost effective. (Ravi et al. 2010) Due to similarities in the properties of semolina and tomato; tomato is used for the fortification; as semolina has low-fat, high carbohydrate food that offers a lot of energy and since the instant mix prepared required low- fat, low- calorie, and high energy; since, instant mix were made mainly for the busy life of all human being. So preparation of instant dhokla mix with semolina as a major ingredient and fortified with tomato powder will give one of the fruitful product.

Response-surface methodology (RSM) comprises a body of methods for exploring for optimum operating conditions through experimental methods. RSM is a useful method for studying the effect of several variables influencing the responses by varying them simultaneously and carrying out a limited number of experiments (Demirel and Kayan, 2012). The most common designs extensively used in RSM is the central composite design (CCD). The CCD is ideal for sequential experimentation and allows a reasonable amount of information for testing lack of fit while not involving an unusually large number of design points (Somayajula et al. 2011).

According to the RSM results, polynomial regression modeling was performed on the responses of the corresponding coded values (Lie et al. 2007)

Hence, by applying RSM we optimize the values and carried the limited number of experiments.

The objective of the research study is

- Preparation of instant mix with and without tomato powder, whose main ingredients are semolina and Bengal gram.
- Comparison of these two prepared instant mixes with market available instant dhokla mix (MTR) and analysis of physicochemical properties in storage.

6.2 Material and Methods:-

6.2.1 Materials:- Materials and chemical same as chapter 5.2.1 and 5.2.2.

6.2.2 Methods:-

6.2.2.1 Preparation of Instant tomato mix dhokla :-

Bengal gram (14 g), semolina (24 g), sugar (9 g), salt (2 g) and tomato powder (4 g) were measured using digital weighing balance. Then, they were mixed with 40 ml of water.

Then, they were poured in mixer grinder and the paste was made. Then, the paste was kept in the tray and was placed in hot air oven at 60ºC for 10 hours. Then, the dried paste was again placed in mixer grinder and the powder was obtained.

Powder was sieved through a standard 85 BSS mesh to obtain *dhokla* mix and stored in air tight containers.

Dhokla mix was rehydrated with water and leavening agent (ENO-fruit salt regular) and poured into a greased flat tray for steaming in a domestic pressure cooker to obtain *Dhokla*.

6.2.2.2 Evaluation for powder mix:-

6.2.2.2.1 Bulk density:-

1 g of powder was taken and 5 ml of distilled water was added in it. Then, they were mixed using Vortex mixer. The vortex was stopped after 1minute and the powder was allowed to settle down.

Then, the bulk density of the powder was calculated by Giami et al. 1992.

6.2.2.2.2 Reconstitution index:-

1 g sample was dissolved in 10 ml boiling water. Then, the mixture was agitated for 90 sec. and was transferred into 10 ml graduated cylinder. Then, the volume of sediment was recorded after setting for 30 min and reconstitution index was calculated by Onwuka 2005.

Rehydration ratio:-

1g sample was dissolved in 30ml of distilled water. Then, it was kept in hot air oven at 95 °C for 20 min. Then, the excess water was filtered out, the residue left was weighed and rehydration ratio was calculated (Bansal et al. 2013).

6.2.2.2.3 Oil absorption capacity:-

1 g sample was mixed with 10 ml of refined soybean oil and was kept at ambient temperature for 30 min. Then, it was centrifuged for 10 min. at 5000 rpm. Then, the oil absorption capacity was expressed as % oil bound per g of sample. (Sosulski et al. 1976)

6.2.2.2.4 Antioxidant compound:- same as chapter 4.2.5.1 and 4.2.5.2

6.2.2.2.5 Antioxidant activity:- same as chapter 4.2.5.3

6.2.2.2.6 Color :- same as chapter 4.2.6.4

6.2.2.2.7 pH:- Same as 5.2.6.1

6.2.2.2.8 Moisture:- same as 5.2.6.4

6.2.2.3 Experimental Design:

6.2.2.3.1 Response surface Methodology:

RSM is a collection of statistical and mathematical techniques useful for developing, improving, and optimizing processes in which a response of interest is influenced by several variables and the objective is to optimize this response (Durgadevi and Shetty, 2012). On the responses, it defines the effect of the independent variables that are alone or in combination. In addition to analyzing the effects of the independent variables, it provides a mathematical model, which describes the relationships between the independent and response variables (Myers and Montgomery, 1995). A central composite rotatable design (CCRD) was constructed using software package Statistica (1999) from StatSoft, OK, USA. RSM reduces the number of experimental trials needed to evaluate multiple parameters and their interactions (Durgadevi and Shetty, 2012).

A central composite rotatable design was employed to study and optimize the effect of process variables (factors) such as amount of water for reconstitution (X_1) and amount of baking powder (X_2) on the dependent variables (responses) such as whiteness (L*- value) (Y_1), moisture (Y_2) and pH (Y_3). The application of statistical experimental design techniques in bioprocess development and its optimization can result in enhanced product yields, closer conformance of the process output or response to target requirements and reduced process variability, development time and cost. On single factor analysis, process variables and their ranges were selected and independent variables were coded at five levels between −2 and +2. The coding of the variables was done by the following equation (Prakash Maran *et al.* 2013):

$x_i = (X_i - X_z)/Y_i$; i=1, 2, 3, . . . , k

where x_i is the dimensionless coded value of an independent variable;

X_i, the real value of an independent variable;

X_z, the real value of an independent variable at the center point; and

Y_i step change of the real value of the variable i.

It is recommended that five center points have taken in a central composite rotatable design with two factors and the total number of experiments (N) was calculated by the following equation:

$N=2^K +2K+Cp$

Where, K is the number of process variable, 2K is the number of the axial points on the axis of each design factor at a distance, Cp is the replicate number of the central point.

In this study, central composite rotatable design consists of 4 factorial points, 4 axial points and 5 center points. Totally 13 experiments were performed to optimize and study the effect of process variables on the response. From this information, the most accurate model was chosen which in all cases appears to be quadratic model.

The second-order response functions for the experiments were fitted to the following quadratic regression equation:

$Y = b_0 + b_1X_1 + b_2X_2 + b_{11}X_{12} + b_{22}X_{22} + b_{12}X_1X_2$

where X_1 is the amount of water for reconstitution; X_2 is the and amount of baking powder; b_0 is the value of the fitted response at the centre point (0, 0) of the design; b_1 and b_2 are the linear regression terms; b_{11} and b_{22} are the quadratic terms and b_{12} is the interaction term.

6.2.2.3.2 Experimental 2^3 full factorial design methodology :-

A 2^3 full factorial design was carried out to set the mathematical relationships and to represent how color (a* and b* values) of dhokla depends on storage temperature (A), storage time (B) and packaging type (C). Running order for each run was randomized in order to minimize possible systematic errors. Coded levels were given as (-1) and (+1) and responses (a and b value) of each run with two replicates were given. To get information about the effects of storage conditions, a mathematical model was established which gave the relation between the response (Y) and the factors. Thus, 2^3 factorial design model was set for each responses; a and b values separately. All factors and their interaction terms were taken into account. Model can be expressed as follows:

$$Y = \beta o + \beta_1 A + \beta_2 B + \beta_3 C + \beta_{12} AB + \beta_{13} AC + \beta_{23} BC + \beta_{123} ABC \qquad (1)$$

Where βo was the constant; β_1, β_2 and β_3 were coefficients for the coded variables A, B and C, respectively; β_{12}, β_{13}, β_{23} and β_{123} were the interaction effects between variables. In Figures 6.4 and 6.5, cube plots were presented to aid data interpretation which showed the combination of their factors with highest and lowest value of each effect at each corner. The main effects and interactions of factors on color were determined by ANOVA table.

6.2.2.3.3 Statistical analysis

Design expert Version 7.1.6 (Stat-Ease, Inc., Minneapolis, USA) was used to analyze the experimental data. Regression analysis and analysis of variance (ANOVA) were used to evaluate the experimental data and the ANOVA table was generated. Significant terms in the model (quadratic) for the response were found by analysis of variance and significance was judged by the F-statistic value calculated from the data. The experimental data was evaluated with various descriptive statistical analysis such as p value, F value, degrees of freedom (DF), sum of squares (SS), determination coefficient (R^2), adjusted determination of coefficient (R_a^2) and predicted determination of coefficient (R_p^2) to reflect the statistical significance of the developed quadratic mathematical model. After fitting the data to the models, the models (Response surface and Factorial) was used for the construction of three dimensional response and cube plots to predict the relationships between independent and dependent variables.

6.3 Result and Discussion:-

6.3.1 Bulk density

The term "bulk density" is frequently used by the manufacturers and consumer to characterize instant mix. Bulk density is important for instant mix powder for transportation. If the bulk density was high, less volume needed, so more amount of instant mix powder could be packed. Bulk density was observed for commercial mix, instant control mix and instant fortified mix in initial day as well as after 90 days storage in table 6.1. It was observed that bulk density of instant control mix and instant fortified mix gives same result with the commercial mix at initial day and storage and it increases at 90 days of storage. So it can be concluded that instant control mix and instant fortified mix are acceptable for transportation.

Table 6.1: Bulk density of different instant mixes in storage

Sample	0	30	60	90
MTR	0.24±0.012^{a}	0.24±0.01^{a}	0.52±0.09^{a}	0.91±0.21^{a}
MIX (control)	0.22±0.02^{a}	0.22±0.03^{a}	0.45±.06^{b}	0.43±0.10^{b}
MIX (fortified)	0.22±0.011^{a}	0.22±0.02^{a}	0.3125±0.04^{c}	0.712±0.16^{a}

Results are given as mean ± standard deviation Means with the same superscript within the same row are not significantly different ($p<0.05$) as determined on Fisher's least significant difference test.

6.3.2 Rehydration and reconstitution ratio:

Rehydration is the phenomenon that decides the effectiveness of the final product.Rehydration ratio and reconstitution index have correlation with each other. Mozumder et al (2012) reported that rehydration ratio is significantly affected by chemical pretreatment; gradually increased with time and water uptake. From table it was observed that there was significant difference between 0 day as well as after 90 days storage of rehydration and reconstitution index for the mixes. It was observed in table 6.2 that at initial day rehydration and reconstitution index of commercial mix, instant mix and fortified mixes are 2.65 and 2.2; 3.85 and 2.4; 4.02 and 1.8. After storage of 90 days rehydration and reconstitution index of commercial mix, instant mix and fortified mixes are 4.85 and 2.8 ; 6.72 and 4.92; 5.01 and 2.3. Least changes occur in instant fortified mix after 90 days of storage. The same result was observed in peach, palm and apricot fruits. At 0 day rehydration ratio of peach, palm and apricot were 4.16, 2.63 and 3.62 and after 90 days it was 3.99, 2.52 and 3.47.

Table 6.2: Rehydration and reconstitution ratio of instant mixes in storage

Sample	Rehydration ratio				Reconstitution index			
	0d	30d	60d	90d	0d	30d	60d	90d
MTR	2.65±0.24^{a}	2.92±0.22^{a}	3.78±0.1^{a}	4.85±0.25^{a}	2.2±0.21^{a}	2.38±0.22^{a}	2.6±0.3^{b}	2.8±0.15^{b}
MIX (control)	3.85±0.12^{b}	4.62±0.49^{b}	5.22±0.17^{c}	6.72±0.15^{c}	2.4±0.17^{a}	2.95±0.13^{b}	3.8±0.18^{c}	4.92±0.11^{c}
MIX (fortified)	4.02±0.19^{c}	4.22±0.11^{c}	4.65±0.09^{b}	5.01±0.39^{b}	1.8±0.07^{b}	1.92±0.3^{c}	2.05±0.06^{a}	2.3±0.3^{a}

Results are given as mean ± standard deviation Means with the same superscript within the same row are not significantly different ($p<0.05$) as determined on Fisher's least significant difference test.)

6.3.3 Oil absorption capacity (OAC)

Oil absorption capacity has been very useful in food system such as soups, gravies and dough The OAC also makes the mix suitable in facilitating enhancement in flavor and mouth feel when used in food preparation. Due to these properties, the protein probably could be used as functional ingredient in foods such as whipped toppings, sausages, chiffon dessert, angel and sponge cakes etc (Ogunbusola et al. 2014). From table 6.3 it was observed that oil absorption capacity was decreased after 90 days storage for the instant mixes.

Table 6.3: Oil absorption capacity of instant mixes in storage

Sample	0	30	60	90
MTR	$22.23±0.12^{b}$	$21.06±0.05^{c}$	$20.97±0.09^{c}$	$20.02±0.2^{b}$
MIX (control)	$22.2±0.2^{b}$	$20.63±0.09^{b}$	$18.352±0.1^{a}$	$15.697±0.15^{a}$
Fortified	$21.417±0.09^{a}$	$20.983±0.05^{a}$	$20.623±0.03^{b}$	$20.417±0.11^{b}$

Results are given as mean ± standard deviation Means with the same superscript within the same row are not significantly different ($p<0.05$) as determined on Fisher's least significant difference test.

6.3.4 Antioxidant compound and antioxidant activity:-

Tomato contains the major hydrophobic antioxidant lycopene and also contains hydrophilic antioxidants, such as vitamin C (ascorbic acid) and phenolic compounds including caffeic acid, rutin and quercetin. The effect of these hydrophilic antioxidants depends on many factors, such as cultivar, maturity, temperature and storage conditions (Kim and Chin 2015). Phenolic compounds have redox properties, which allow them to act as reducing agents, singlet oxygen quenchers, metal chelators, and hydrogen donors. Thus, they have strong antioxidant activity (Kaur and Kapoor, 2002). Phenolic and flavonoid content of commercial MTR mix, instant control mix and instant fortified mix were observed at initial day as well as storage in table .It was observed in table 6.4 that in all three samples phenolic and flavonoid contents were increased after 90 days storage. The increase in polyphenol content during storage may be due to the reaction of polymeric phenols with the water moiety to form monomers. It was also observed among three samples, phenol and flavonoid content was highest in instant fortified sample. Similar changed in polyphenol content in tomato were also observed by Cieslik *et al.* (2006).

Table 6.4: Antioxidant content analysis in different instant mixes in storage

Sample	Phenolic content (mg/g)				Flavonoid content (mg/g)			
	0d	30d	60d	90d	0d	30d	60d	90d
MTR	8.28±0.05[a]	8.77±0.06[b]	9.02±0.1[c]	9.43±0.04[d]	0.627±0.02[a]	0.655±0.01[b]	0.670±0.02[c]	0.741±0.08[d]
MIX (control)	8.02±0.05[a]	8.26±0.05[b]	8.58±0.03[c]	8.95±0.15[d]	0.645±0.09[a]	0.685±0.03[b]	0.722±0.06[c]	0.745±0.03[d]
MIX (fortified)	9.33±0.4[a]	9.56±0.21[a]	10.28±0.09[b]	10.82±0.05[c]	0.786±0.005[a]	0.814±0.04[b]	0.847±0.03[c]	0.852±0.1[c]

Results are given as mean ± standard deviation Means with the same superscript within the same row are not significantly different ($p<0.05$) as determined on Fisher's least significant difference test.

6.3.5 Color profile

Color profile analysis of instant mix powders is correlated with consumer preferences and powder characteristics. It was observed in table 6.5 that in commercial instant mix there is no significant difference of L value at 0 day and 30 days storage, but it has significantly changes with 90 days storage. In control mix and fortified instant mixes L value significantly decreased at 90 days than 0 day storage. Least browning was occurred in fortified instant mixes in storage. It was also observed that a* and b* value of three different instant mixes were significantly decreased in storage.

Table 6.5: Color profile analysis of different instant mixes in storage

Sample	L				a*				b*			
	0d	30d	60d	90d	0d	30d	60d	90d	0d	30d	60d	90d
MTR	87.61±0.17[a]	87.46±0.17[a]	86.34±0.14[b]	85.48±0.24[c]	0.90±0.10[a]	0.78±0.10[a]	0.68±0.02[b]	0.38±0.11[c]	17.48±0.29[a]	17.20±0.30[a]	16.26±0.42[b]	14.51±0.30[c]
MIX (control)	88.18±0.22[a]	87.68±0.15[b]	87.44±0.29[b]	85.22±0.15[c]	1.84±0.18[a]	1.46±0.18[b]	1.20±0.14[c]	0.86±0.14[d]	21.97±0.07[a]	20.14±0.27[b]	19.85±0.05[c]	19.05±0.09[d]
MIX (fortified)	79.33±0.27[a]	79.08±0.05[a]	78.67±0.23[b]	78.14±0.07[c]	7.54±0.13[a]	7.49±0.09[a]	7.14±0.06[b]	6.41±0.07[c]	21.55±0.19[a]	20.70±0.08[b]	20.03±0.09[c]	19.08±0.25[d]

Results are given as (mean ± standard deviation).

Means with the same superscript within the same row are not significantly different ($p<0.05$) as determined on Fisher's least significant difference test.

6.3.6 RSM (Central Composite Rotatable Design):

The total number of 13 experiments in Face centered central composite design were performed for different combinations of the process parameters in order to optimize and study the effect of independent parameters (water (X_1) and baking powder (X_2)) on the color parameter (L value) (Y_1), moisture (Y_2) and pH (Y_3) and the results are shown in Table 6.6.

The experimental data was fitted to the model to obtain regression equation. The sequential model sums of squares, lack of fit tests were carried out to decide about the adequacy of models. Regression coefficients were estimated by multiple regression analysis and the correlations were obtained which are given below:

$\text{L value} = 41.13 + 3.21 * X_1 + 0.17 * X_2 + 0.37 * X_1 * X_2 - 0.93 * X_1^2 - 0.61 * X_2^2$

$\text{Moisture} = 15.24 + 1.93 * X_1 + 0.31 * X_2 - 0.24 * X_1 * X_2 + (4.68*10\text{^}{-3}) * X_1^2 + 0.092 * X_2^2$

$\text{pH} = 6.98 + 0.97 * X_1 + 0.066 * X_2 - 0.04 * X_1 * X_2 + 0.15 * X_1^2 + 0.33 * X_2^2$

Table 6.6: The central composite design of independent variables and responses

Run	Water (X_1) (ml)	Baking Powder (X_2) (g)	L* value (Y_1)	Moisture (%) (Y_2)	pH (Y_3)
1	40	1.0	36.9	13.23	6.67
2	60	1.0	42.3	17.9	7.33
3	50	1.2	41.04	15.42	6.97
4	50	1.2	41.2	14.9	6.99
5	50	1.2	41.32	15.3	6.9
6	60	1.4	42.78	17.5	7.49
7	50	1.2	41.45	15.12	7.12
8	30	1.2	30.9	11.43	7.35

9	50	0.8	38.12	14.565	7.06
10	70	1.2	44.0	18.8	7.82
11	50	1.6	39.4	16.35	7.2
12	50	1.2	40.88	14.88	7.0
13	40	1.4	35.9	13.8	7.02

Table 6.7: Analysis of ANOVA in variance table showing the effect of treatment variables on color parameter l value (y_1), moisture (y_2) and ph (y_3)

Source	Sum of square			Degree of freedom			Mean square			F value			P value Prob>F		
	Y_1	Y_2	Y_3	Y_1	Y_2	Y_3	Y_1	Y_2	Y_3	Y_1	Y_2	Y_3	Y_1	Y_2	Y_3
Model	147.23	46.10	0.91	5	5	5	29.45	9.22	0.18	220.29	50.57	10.01	<0.0001	<0.0001	<0.0001
X_1-water	123.39	44.51	0.36	1	1	1	123.39	44.51	0.36	923.12	244.09	19.62	<0.0001	<0.0001	<0.0001
X_2-Baking Powder	0.35	1.17	0.052	1	1	1	0.35	1.17	0.052	2.59	6.39	2.86	0.1513	0.0393	0.0393
X_1X_2	0.55	0.24	9.025E-003	1	1	1	0.55	0.24	9.025E-003	4.10	1.29	0.50	0.0826	0.2934	0.2934
X_1^2	20.03	5.035E-004	0.49	1	1	1	20.03	5.035E-004	0.49	149.85	2.761E-003	26.98	<0.0001	0.9596	0.9596
X_2^2	8.46	0.19	0.024	1	1	1	8.46	0.19	0.024	63.25	1.03	1.34	<0.0001	0.3450	0.3450
Residual	0.96	1.28	0.13	7	7	7	0.13	0.18	0.018	-	-	-	-	-	-
Lack of	0.73	1.05	0.10	3	3	3	0.24	0.35	0.0	4.83	6.12	5.38	0.08	0.05	0.05

fit									34				12	63	63

Table 6.8: Determination co-efficient on process variables in Response Surface Model

Regression coefficient	Y_1	Y_2	Y_3
R^2	0.9937	0.9731	0.8773
Adjusted R^2	0.9892	0.9538	0.7897
Predicted R^2	0.9495	0.7995	-0.0149
CV %	0.92	2.79	1.89
Adeq precision	51.641	26.555	11.318

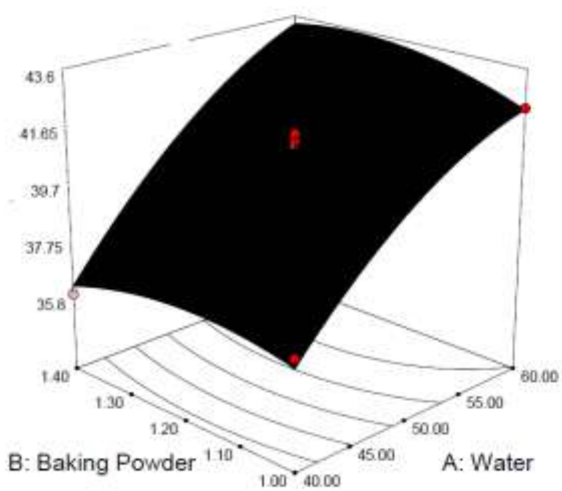


Figure 6.1: 3D model of the Response surface plot for L value

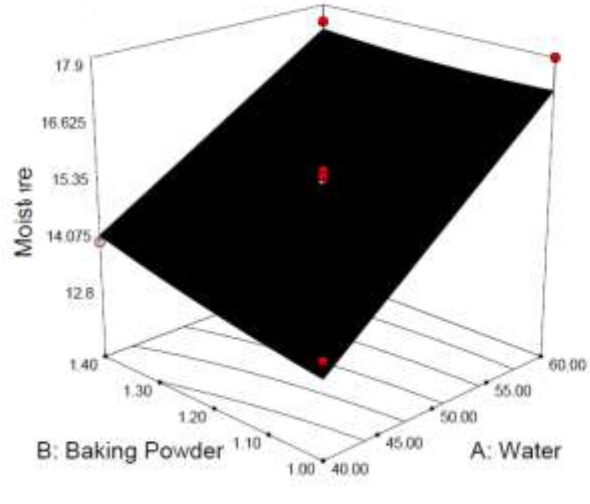


Figure 6.2: 3D model of Response surface plot for Moisture

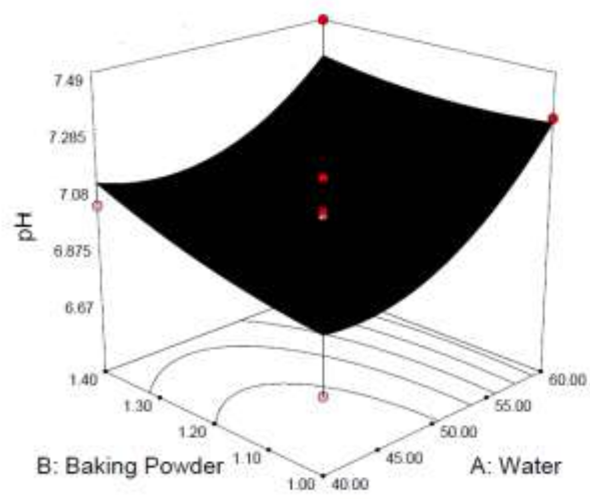


Figure 6.3: 3D model of Response surface plot for pH

6.3.7 Statistical analysis

Analysis of variance (ANOVA) and multiple regression analysis were used to analyze the experimental data. The statistical significance of the regression equation was evaluated by the corresponding F and p-values and it is presented in Table 6.7. The coefficient of variance (CV) is the ratio of the standard error of the estimate to the average value of the observed response defining by the reproducibility of the model.

For blackness to whiteness (L value), the model F and p-value was found to be 220.29 and <0.0001 which indicated that the model was highly statistically significant. The fitness of the model was studied through the lack of fit test. The lack of fit F-value of 4.83 and the associated p-value of 0.0812 was indicated the suitability of the model to predict the variations. The goodness of the fit of the model was evaluated by the determination co-efficient (R^2), adjusted determination co-efficient (R_a^2), predicted determination co-efficient (R_p^2) and co-efficient of variance (CV) and it was listed in Table 6.8. The R^2 value of the predicted model was 0.9937, while R_a^2 value was 0.9892, which exhibited the high degree of correlation between the experimental and predicted values. In this research study, the R_a^2 (0.9892) value was found to be smaller and very close to the R^2 (0.9937) which indicates that the factors and the responses have a very good co relation.

The low CV (0.92) clearly stated that, the deviations between experimental and predicted values are low, high degree of precision (51.641) and also showed a good reliability of the experiments.

For Moisture, the model F and p-value was found to be 50.57 and <0.0001 which was less than 0.05, indicated that the model was highly statistically significant. The lack of fit F-value of 6.12 and the associated p-value of 0.0563 was indicated the suitability of the model to predict the variations. In this research study, the R_a^2 (0.9538) value was close to the R^2 (0.9731) which indicates that the factors and the responses have a good co relation.

C.V= 2.79, shows that, the deviations between experimental and predicted values are low, showed a good reliability of the experiments.

For pH, the model F and p-value was found to be 10.01 and <0.0001 which was less than 0.05, indicated that the model was highly statistically significant. The lack of fit F-value of 5.38 and the associated p-value of 0.0563 was indicated the suitability of the model to predict the variations. In this research study, the R_a^2 (0.7897) value was close to the R^2 (0.8773) which indicates that the factors and the responses have a good co relation.

C.V= 1.89, shows that, the deviations between experimental and predicted values are low, showed a good reliability of the experiments.

Effects of the ingredients (Water and baking powder) on L value, moisture and pH :-

The response surface plots showed the relative effects of any two variables when the remaining variable was kept as constant. The response surface plots estimating the color value (L= whiteness), moisture and pH versus independent variables are shown in figure 1. The 3D response surfaces was plotted to better visualize the significant ($p < 0.0001$) interaction effects of variables on the whiteness (L value) of dhokla. Dhokla was redish in color as fortified with tomato powder, so when water added it changes from blackness to whiteness (L value) and values were found to be significant but when added with baking powder the values found to be insignificant i.e., (> 0.05). When double amount of water and baking powder was added it was found that both the values were significant which implies that when the amount of water increases the whiteness of Dhokla increases and as the amount of water is double thus it gives its effect on baking powder, hence, the value was found to be significant.

In case of moisture and pH, when water and baking powder was added the F and P values were found to be significant but when double amount of these were added; which means that the F and P values also increases ($P > 0.05$), thus the values found to be insignificant. Hence, it was found that the lack of fit for L value, moisture and pH were insignificant.

6.3.8 Experimental factorial design for color design:

Experimental factorial design is a cost effective method with minimum number of trials (Yann et al., 2005). Experimental factorial design was done for the optimum values set for optimization. To analyze the effects of storage conditions to retain color quality of Dhokla some mathematical model was set using factorial design. The factors of storage conditions were represented as A, B and C in the model as storage temperature, storage time and packaging type respectively. ANOVA results indicated that the model for a value and b value were both significant with F values of 262.26 and 324.06. Results showed that all three factors that is factor A, B and C were significant at $P > 0.05$. The values of Prob >F for each of three factors were found to be less than 0.05. Hence, the terms A, B, C, AB, BC and AC in both the models were statistically significant.

The regression models were fitted for the responses a and b and was expressed in the following equations described the effect of experimental variables and their interactions: (Bingol et.al., 2010)

$$\text{Response 1 (a)} = 19.77 - 2.57*A - 4.23*B + 3.30*C + 0.70*A*B - 0.12*A*C + 0.35*B*C \quad (2)$$

$$\text{Response 2 (b)} = 29.91 - 4.22*A - 9.63*B + 1.45*C + 0.43*A*B - 1.25*A*C + 1.56*B*C \quad (3)$$

Results showed that all three factors in both models had negative effect on color values. The result revealed that increase in storage time, increase in amount of air (O_2) in packaging material and increase in the storage temperature of Dhokla reduced their a and b values. The main coloring agent for the red color of tomato is due to lycopene (Lavelli and Scarafoni, 2011).

Table 6.9: Design matrix for the experiments

Run	Storage temperature (°C) (A)	Storage time (day) (B)	Packaging type (C)	a* value (Y_1)	b* value (Y_2)
1	4 (-1)	0(-1)	Glass container (-1)	24.05	42.8
2	30(+1)	7(+1)	Glass container (-1)	10	14.49
3	4 (-1)	0(-1)	Pouch (+1)	30.5	45.56
4	30(+1)	7(+1)	Pouch (+1)	17.35	18.5
5	30(+1)	0(-1)	Glass container (-1)	18.04	36.49
6	30(+1)	0(-1)	Pouch (+1)	23.4	33.29
7	4(-1)	7(+1)	Glass container (-1)	13.8	20.06
8	4(-1)	7(+1)	Pouch (+1)	21.03	28.07

Table 6.10: Analysis of variance for the factorial model of a*value (Y1) and b*value (Y2)

Source	Sum of square		Degree of freedom		Mean square		F value		P-value prob>F	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
Model	287.98	933.69	6	6	48.0	155.61	262.26	324.06	0.0472	0.0425
A- Temp	52.99	142.13	1	1	52	142.13	289.56	295.98	0.0374	0.0370
B- Time	142.89	741.51	1	1	142.89	741.51	780.76	15444.17	0.0228	0.0162
C- Packaging	87.05	16.76	1	1	87.05	16.76	475.67	34.91	0.0292	0.1067
AB	3.96	1.48	1	1	3.96	1.48	21.65	3.08	0.1348	0.3297

AC	0.12	12.40	1	1	0.12	12.40	0.64	25.82	0.5698	0.1237
BC	0.96	19.41	1	1	0.96	19.41	5.24	40.41	0.2622	0.0993
Residual	0.18	0.48	1	1	0.18	0.48	-	-	-	-
Cor total	288.16	934.17	7	7	-	-	-	-	-	-

Figure 6.4: Cube plot showing the predicted values from the coded model for the combinations of the –1 and +1 levels of the 3factors: a value

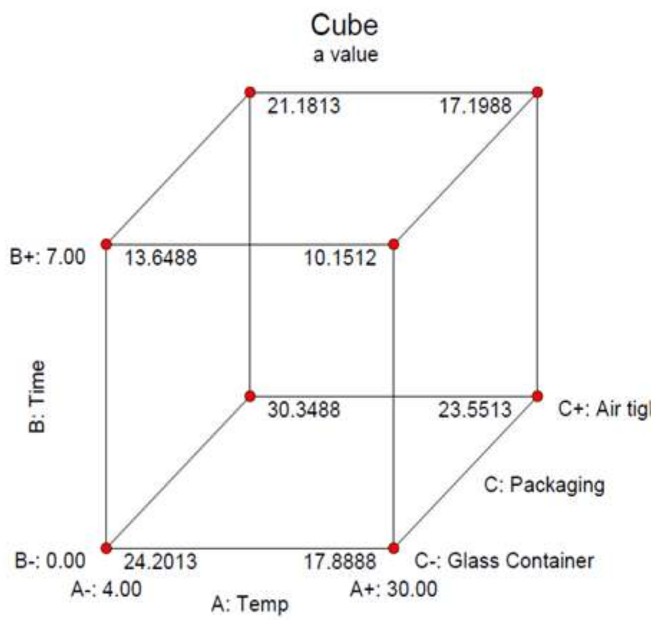
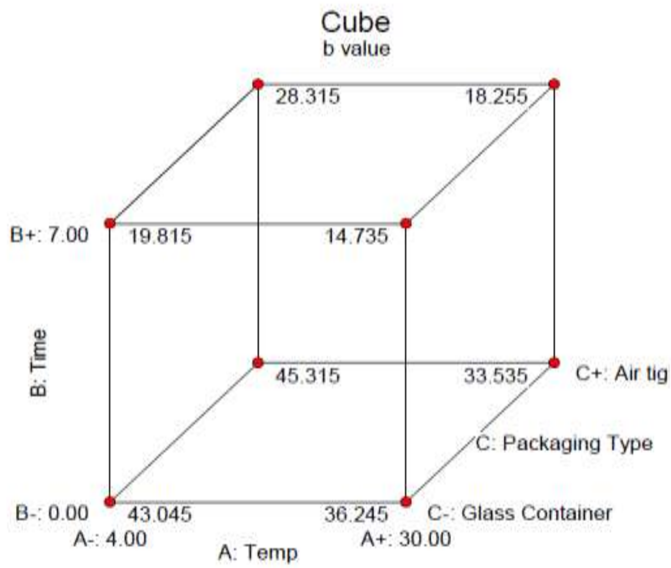


Figure 6.5: Cube plot showing the predicted values from the coded model for the combinations of the –1 and +1 levels of the 3factors: b value



Color changes may be attributed to non- enzymatic browning or mailard reactions (Cernîşev,2010). In both the models, storage time was found to be the most effective factor on color of Dhokla. Sharma and Le Maguer (1996) showed that lycopene loss was about 76% in dried tomato samples after 4 months of storage at room temperature. Baloch et al. (1997) found that carotenoid loss was above 50% after 20days storage in a dark place at 40°C. Hence, from the above experimental results we can conclude that the dhokla prepared at a temperature range of (+4to +30) °C for (0 to 30) days was correct.

In both the models, the highest effect of storage time on color was followed by storage temperature and packaging type. The color change was almost preserved at the range of +4 to 30°C the similar results were reported by Anguelova & Warthesen (2000). They found that stability of lycopene in tomato powders was not significantly affected by increasing in temperature from 6°C to room temperature.

Table 6.11: Determination co efficient on process variables in Factorial model

Regression coefficient	a* value	b* value
R^2	0.9994	0.9995
Adjusted R^2	0.9956	0.9964
Predicted R^2	0.9594	0.9671
CV %	2.16	2.32
Adeq precision	50.472	47.176

R^2 values using sum of squares (SS_{model}/SS_{total}) were calculated and they were found as 0.99 for both responses.

Conclusion:-

Hence, the study concludes that oil absorption capacity was decreased after 90 days storage for the instant mixes. The rehydration ratio and reconstitution ratio is significantly affected by chemical pretreatment; gradually increased with time and water uptake. The bulk density of instant control mix and instant fortified mix gives same result with the commercial mix at initial day and storage and it increases at 90 days of storage. So it can be concluded that instant control mix and instant fortified mix are acceptable for transportation. The color profile concludes that a* and b* value of three different instant mixes were significantly decreased in storage of 90 days. The antioxidant properties among three samples, the phenol and flavonoid content were highest in instant fortified sample. The study also showed that RSM design for Dhokla was found to be an effective tool to predict the relationship between the independent variables Water and Baking powder on responses namely color parameters (L* and b* values), moisture, pH and overall acceptability. From the study we conclude the optimum ratio of water and baking powder is 50 : 1.2 with optimum cooking time 6 minute. The 2^3 factorial design conclude that the higher the storage time was, the lower a and b values. Results of 3D modeling and their contours easily represented the direction of the sensitivity of color changes.

CHAPTER 7

FUTURE SCOPE:

- Fortification of tomato powder in encapsulated form and analysis of dhokla characteristics.
- Storage study of encapsulated tomato powder and non encapsulated tomato powder as well as study of morphological analysis.
- Study the microbiological characteristics, antinutritional factor of tomato powder as well as rawa dhokla.

REFERENCES :

A:

- Abano EE, Ma H and Qu W. 2011. Influence of Air Temperature on the Drying Kinetics and Quality of Tomato Slices. Journal of Food Processing and Technology, 2: 5.
- Abdel-Haleem A M. H, Azza A. O.2014. Preparation of Dried Vegetarian Soup Supplemented with Some Legumes. Food and Nutrition Sciences, 5, 2274-2285.
- Adenike AB 2012. The effect of pretreatment and drying on some vitamin contents of tomato powder. Annals Food Sci and Technol. 13(2) : 156-160
- Aghajanzadeh GA, Maheri SN, Mirzaei AA., Baradaran H.A. 2010.Comparison of nutritional value of tomato pomace and brewer's grain for ruminants using in vitro gas production technique. Asian Journal of Animal and Veterinary Advances, 5: 43-51.
- Aghbashlo M, Kianmehr, M. and Samimi-Akhijahani, H. 2008. Influence of drying conditions on the effective moisture diffusivity, energy of activation and energy consumption during the thin-layer drying of berberis fruit (*Berberidaceae*). Energ.Convers.Manage. 49: 2865–2871.
- Ahmed J and Ramaswamy S. 2005. Effect of temperature on dynamic rheology and colour degradation kinetics of date paste. Food and Bioproduct Processing. 83(C3): 198-202.
- Akdeniz B, Demirbüker KD and Bağdatlioğlu N Use of factorial experimental design for analyzing the effect of storage conditions on color quality of sundried tomatoes. Scientific Research and Essays Vol. 7(4), pp. 477-489, 30 January, 2012
- Akindahunsi AA and O yetayo FL 2006. Nutrient and anti nutrient distribution of edible mushroom pleurotus tuber regium tries singer,. Food Science & technology vol 39 (5): 548- 553
- Akpinar EK and Bicer Y 2004. Modeling of the drying of eggplants in thin-layers. International Journal of Food Science and Technology, 39, 1-9.
- Al-Harahsheh M., Al-Muhtaseb A.H., and Magee T.R.A., 2009. Microwave drying kinetics of tomato pomace: Effect of osmotic dehydration. Chem. Eng. Proces, 48, 524-531.

- Ali AA, Manal AAO, Sahar AAS, Abdullah HAA, Jun JZ, KAI YL. 2010. Tomato powder is more protective than lycopene supplement against lipid per oxidation in rats. Nutrition Research, 30: 66-73.
- Al-Muhtaseb AH, AL-Harahsheh M, Hararah M, Magee TRA. 2010. Drying characteristics and quality change of unutilized-protein rich-tomato pomace with and without osmotic pre-treatment. Industrial Crops and Products, 31: 171-177.
- Al-Wandawi H, AbdulRahman M, Al-Shaikhly K, Tomato processing wastes as essential raw materials source, J Agric Food Chem 33; 1985: 804–807.
- Amarowicz R, Carle R, Dongowski G., Durazzo, A., Galensa, R., Kammerer, D., Maiani, G. and Piskula, M.K. 2009. Influence of postharvest processing and storage on the content of phenolic acids and flavonoids in foods. Mol. Nutr. Food Res. 53, S151–S183.
- Anguelova T, Warthesen J (2000). Lycopene Stability in Tomato Powders. J. Food Sci., 65(1): 67-70.
- AOAC, 1990. Official Methods of Analysis, 15th ed., vol. 2. Association of Official Analytical Chemists, Inc. Arlington.
- Aslokar LV, Kakkar KK, Chakre OJ. 1992. Glossary of Indian medicinal plants with active principles. Part I (1st ed.). New Delhi: CSIR. p. 119.
- Avila I M and Silva C L 1999. Modelling kinetics of thermal degradation of color in peach puree. J Food Eng, 39, 161-166.

B:

- Bagheri H, Arabhosseini A, Kianmehr MH, Chegini G.R. 2013. Mathematical modeling of thin layer solar drying of tomato slices. Agricultural Engineering International: CIGR Journal, 15(1): 146-153.
- Baixauli, R., Salvador, A. and Fiszman, S. M. 2008a. Textural and Color Changes during Storage and Sensory Shelf Life of Muffins Containing Resistant Starch. Eur. J. Food Res. Technol., 226: 523–530.
- Balasubramanian S, Singh N, Ilyas S.M., Wanjari O.D. Effect of selected decorticated legumes protein on rheology of maize extrudate pastes. J Food Sci Technol 43(5), 590–594 (2006).
- Baloch WA, Khan S, Baloch AK (1997). Influence of chemical additives on the stability of dried tomato powder. Int. J. Food Sci. Tech., 32: 117-120.

- Bansal S, Kumar S, Alam M.S, Kumar M (2013) Optimization of Process Parameters for Multi-Layer- Cum Microwave Drying Of Oyster Mushrooms (Pleurotus Sajor Caju). Int. Journal of Engineering Research and Applications. Vol. 3, Issue 5, Sep-Oct 2013, pp.206-217.
- Barreiro JA, Milano M, Sandoval AJ (1997) Kinetics of colour changes of double concentrated tomato paste during thermal treatment. J. Food Eng. 33: 359-371.
- Beeby C., Potter O.E. 1992. Steam drying, in Drying. Eds. R. Toei and A. S. Majumdar. New York, Hemisphere Publication Corporation, 41-58.
- Beecher G.R. 1998. Nutrient content of tomatoes and tomato products. Proceeeding of the Society for Experimental Biology and Medicine, 218: 98-100.
- Benakmoum A., Abbeddou S, Ammouche A., Kefalas P., Gerasopoulos P.D. 2008. Valorisation of low quality edible oil with tomato peel waste. Food Chemistry, 110: 684-690.
- Bhowmik D, Kumar K.P. S , Paswan S , Srivastava S. 2012. Tomato-A Natural Medicine and Its Health Benefits. Journal of Pharmacognosy and Phytochemistry. 1(1): 33-43.
- Bingol D, Tekin N, Alkan M (2010). Brilliant yellow dye adsorption onto sepiolite using a full factorial design. App. Clay Sci., 50: 315-321.
- Boonkasem P , Sricharoen P , Techawongstein S and Chanthai S. 2015. Determination of ascorbic acid and total phenolics related to the antioxidant activity of some local tomato (Solanum lycopersicum) varieties. Der Pharma Chemica 7(4):66-70
- Boyaçioglu, M.H., D'Appolonia, B.L., 1994. Characterization and utilization of durum wheat for breadmaking. III. Staling properties of bread baked from bread wheat flours and durum wheat flours. Cereal Chemistry 71, 34-41.
- Boye, J.I., Zare, F., and Pletch, A. (2009). "Pulse proteins: Processing, characterization, functional properties and applications in food and feed.", *Food Research International, 43*(2), pp. 414-431. doi : 10.1016/j.foodres.2009.09.003
- Bruce, D.M., 1985. Exposed-layer barley drying, three models fitted to new data up to 150 ºC. Journal of Agricultural Engineering Research 32, 337–347.
- Brodowski, D., Geisman, J.R., 1980. Protein content and amino acid composition of protein of seeds from tomatoes at various stage of ripness. J. Food Sci. 45, 228–229, 235.

C:

- Calvo C, Salvador A, Fiszman SM. Influence of color intensity on the perception of color and sweetness in various fruit flavoured yoghurts. Eur. Food Res. Technol. 213: 99-103 (2001).
- Calvo MM, Garcia ML, Selgas M.D. 2008. Dry fermented sausages enriched with lycopene from tomato peel. Meat Science, 80: 167-172.
- Candogan K. 2002. The effect of tomato paste on some quality characteristics of beef patties during refrigerated storage. European Food Research and Technology, 215: 305-309.
- Canella M., Castriotta G. 1980. Protein composition and solubility of tomato seed meal. Lebensmittel-Wissenschaft and Technologie, 13 (1): 18-21.
- Cernîşev S (2010). Effects of conventional and multistage drying processing on non-enzymaticbrowning in tomato. J. Food Eng., 96: 114-118.
- Chauhan K, Sharma S, Agarwal N, Chauhan B. 2011. Lycopene of tomato fame: its role in health and disease. International Journal of Pharmaceutical Sciences Review and Research, 10 (1): Article-018.
- Chauhan A and Inteli. 2015. Product Development and Sensory Evaluation of Value Added Food Products Made by Incorporating Dried Cauliflower Green Leaves. J Nutr Food Sci 5:1.
- Chen HH, Hernandez C.E., and Huang TC 2005. A study of the drying effect on lemon slices using a closed-type solar dryer. Solar Energy, 78, 97-103.
- Choi Suk Hyun , Dong-Seok Kim, Nobuyuki Kozukue, Hyun-Jeong Kim, Yosuke Nishitani, Masashi Mizuno, Carol E. Levin, Mendel Friedman. 2014. Protein, free amino acid, phenolic, b-carotene, and lycopene content, and antioxidative and cancer cell inhibitory effects of 12 greenhouse-grown commercial cherry tomato varieties. Journal of Food Composition and Analysis 34:115–127.
- Chung H.J. 2007. *Quality attributes of cookies prepared with tomato powder*. Journal of Food Science and Nutrition, 12: 229-233
- Cieslik, E., Greda, A. and Adamus, W. 2006. Contents of polyphenols in fruit and vegetables. Food Chemistry 94: 135-142.

- Codex Alimentarius. (1991) General Principles for the Addition of Essential Nutrients to Foods – CAC/GL 09-1987 (amended 1989, 1991).

D:

- Deda MS, Bloukas JG, Fista GA. 2007. Effect of tomato paste and nitrite level on processing and quality characteristics of frankfurters. Meat Science, 76: 501-508.
- Demirel M and Kayan B (2012). Application of response surface methodology and central composite design for the optimization of textile dye degradation by wet air oxidation. International Journal of Industrial Chemistry 2012, 3:24.
- Dubey R, Shami T, Rao BK. 2009. Microencapsulation technology and application. Defence Science Journal, 59: 82-95.
- Durgadevi M and Shetty PH (2012). Effects of ingredients on Textural profile of fermented food, IDLI. SciVerse Science Direct ICBFS 2012: April7-8, 2012, Bangkok, Thailsndd Department of Food Sciece and Technology, Pondichery University 605014, India. APCBEE Procedia 2 (2012) 190 – 198.

E:

- Effat M. Rizk , Alaa T. El-Kady, Amany R. El-Bialy. 2014. Charactrization of carotenoids (lyco-red) extracted from tomato peels and its uses as natural colorants and antioxidants of ice cream. Annals of Agricultural Science 59(1): 53–61
- Elaine Marshall and Danilo Mejia. 2011. Tradational fermented foods and beverages for improved livelihood. Rural Infrastructure and Agro-Industries Division, Food and Agriculture Organization of the United Nations Rome.
- Elbadrawy E , Sello Amany. 2011. Evaluation of nutritional value and antioxidant activity of tomato peel extracts. Arabian Journal of Chemistry. doi:10.1016/j.arabjc.2011.11.011
- Erdman J.W.JR, Bierer TL, Gugger ET. 1993. Absorption and transport of carotenoids. Annals of the New York Academy of Sciences, 691: 76-85.
- Ertekin C and Yaldiz O 2004. Drying of eggplant and selection of a suitable thin layer drying Model. Journal of Food Engineering, 63, 349-359.

F:

- Farahnaky A, Arahnaky A, Abbasi J, Jamalian J, Mesbahi G. 2008. The use of tomato pulp powder as a thickening agent in the formulation of tomato ketchup. Journal of Texture Studies, 39: 169-182.
- Favaro-Trindade CS, Pinho SC, Rocha GA. 2008. Microencapsulação de ingredientesalimentício. Brazilian Journal of Food Technology, 11: 103-112.
- Fazaeli M, Tahmasebi M and Emam Djomeh Z. Characterization of food texture: application of Microscopic technology. Current Microscopy Contributions to Advances in Science and Technology (A. Méndez-Vilas, Ed.) 2012.
- Figiel A., 2010. Drying kinetics and quality of beetroots dehydrated by combination of convective and vacuum-microwave methods. J. Food Eng., 98, 461-470.

G:

- Gajic M, Zaripheh S, Sun F, Erdman J.W. 2006. Jr, Apo-8′-lycopenal and apo-12′-lycopenal are metabolic products of lycopene in rat liver. The Journal of Nutrition, 136(6): 1552-1557.
- García ML, Calvo MM, Selgas M.D. 2009. Beef hamburgers enriched in lycopeneusing dry tomato peel as an ingredient. Meat Science, 83: 45-49.
- Giami, S.Y; Amasisi, T. and Ekiyor, G. (1992). Comparison of Bread Making Properties of Composite Flour from Kernels of Toasted and Boiled African Bread fruit (*Treculia African decne*) seeds. J-Raw Material, 1(1): 16-25.
- Giovanelli G, Zanoni B, Lavelli V, Nani R. 2000. Water sorption, drying and antioxidant properties of dried tomato products. Journal of Food Engineering, 52: 135-141.
- G. Giovanelli, B. Zanoni, V. Lavelli, R. Nani, Water sorption, drying and antioxidant properties of dried tomato products, J. Food Eng. 52 (2002) 135–141.
- Gill, NS., K. Dhiman, J. Bajwa, P. Sharma and S. Sood. 2010. Evaluation of free radical scavenging, anti-inflammatory and analgesic potential of *Benincasahispida*seed extract. Int. J. Pharmacol. 6: 652-657.
- Giovanelli, G., Lavelli, V., Peri, C. and Nobili S. 1999. Variation in antioxidant compounds of tomato during vine and post-harvest ripening. Journal of the Science of Food and Agriculture, 79, 1583– 1588.

- Gouin S. 2004. Microencapsulation: Industrial appraisal of existing technologies. Food Science and Technology, 15: 330-347.
- Goula A.M., Adamopoulos K.G. 2005. Spray drying of tomato pulp in dehumidified air: II. The effect on powder properties. Journal of Food Engineering, 2005, 66: 35-42.
- Goula AM, Adamopoulos KG. 2005. Stability of lycopene during spray drying of tomato pulp. LWT Food Sci Technol. 38(5):479–487.
- Gould, W.A. 1983. Tomato Production, Processing and Quality Evaluation. Avi. Pub. Co., Westport, CO., 445.
- Gülay Ö, Seda E.B. 2014. Microencapsulation of Natural Food Colourants. International Journal of Nutrition and Food Science, 3(3): 145-156
- Gümüşay ÖA, Borazan AA, Ercal N, Demirkol O. 2015. Drying effects on the antioxidant properties of tomatoes and ginger. Food Chem. 15;173:156-62

H:

- Hasturk Sahin F, Aktas T, Orak H. and Ulger P. 2011. Influence of pretreatments and different drying methods on color parameters and lycopene content of dried tomato. Bulg. J. Agric. Sci., 17(6): 867-881.
- Hera, E., Ruiz-Paris, E., Oliete B., Gómez, M. (2012): Studies on the quality of cakes made with wheat-lentil composite flours. LWT-Food Sci. Technol. (in press) DOI: 10.1016/j.lwt.2012.05.00.
- HO L. 1996. The mechanism of assimilates partitioning and carbohydrate compartmentation in fruit in relation to the quality and yield of tomato. Journal of Experimental Botany, 47: 1239-1243.
- Holzapfel WH. 2002. Appropriate starter culture technologies for small-scale fermentation in developing countries, International Journalof Food Microbiology, Vol. 75, pp. 197– 212.

J:

- Jayathunge K.G.L.R., Kapilarathne R.A.N.S., Thilakarathne B.M.K.S., Fernando M.D., Palipane K.B and Prasanna P.H.P. Development of a methodology for production of dehydrated tomato powder and study the acceptability of the product, Journal of Agricultural Technology 2012 Vol. 8(2): 765-773.

- Jim Q. Primer on calf nutrition series. Structure and function of carbohydrates, 2001.
- Joshi N, Godbole S H &Pradnya K, Microbial and biochemical changes during dhoklafermention with special reference to flavor compounds, *J Food SciTechnol*, **26** (1989) 113-115.
- Jumah R., Banat F., AL-Asheh S., Hammad S. 2004. *Drying kinetics of tomato paste*. International Journal of Food Properties, 7: 253-259.

K:

- Kadam, M. L., Salve, R. V., Mehrajfatema, Z. M., & More, S. G. (2012). Development and evaluation of composite flour for Missi roti/chapatti. Food Process & Technology, 3 (1), 134-140.
- Kalt, W. 2005. Effects of production and processing factors on major fruit and vegetable antioxidants. J. Food Sci. *70*, 11–19.
- Kaur, M., Sandhu, K.S., Singh, N. (2007): Comparative study of the functional, thermal and pasting properties of flours from different field pea (Pisumsativum L.) and pegeon pea (Cajanuscajan L.) cultivars. Food Chem. 104 (3), 259-267.
- Kaur C and Kapoor HC, Antioxidant activity and total phenolic content of some Asian vegetables. Int J Food Sci Technol **37**:153–161 (2002).
- Kaya A., Aydin O., Demirtas C. (2007): Drying kinetics of red delicious apple. Biosystems Engineering, 96: 517–524.
- Khachik F., Beecher G.R., Smith J.C.JR. 1995. *Lutein, lycopene, and their oxidative metabolites in chem. prevention of cancer*, Journal of Cellular Biochemistry Suppliment, 1995, 22: 236-246.
- Khaled MY and Sayed M.M. Effect of Drying Methods on the Antioxidant Capacity, Color and Phytochemicals of Portulaca oleracea L. Leaves. J Nutr Food Sci 2014, 4:6
- Khan A, Anil Dutt Semwal, Gopal Kumar Sharma, Amarinder Singh Bawa. Studies on the optimization and stability of instant wheat porridge (Dalia) mix. J Food Sci Technol (June 2014) 51(6):1154–1160.
- Khan MA, Chitrashekarachar M, Semwal AD , Sharma GK. Studies on the Optimization and Storage Stability of Virgin Coconut Meal Incorporated Instant Sooji Halwa Mix. Food and Nutrition Sciences, 2012, 3, 1092-1099

- Khazaei J, Chegini G, Bakhshiani M. 2008. A novel alternative method for modelling the effect of air dry temperature and slice thickness on quality and drying kinetics of tomato slices: Superposition technique. Drying Technol 26:759-775.
- Kim H S and Chin K B. 2015. Evaluation of Different Drying Temperatures on physico-chemical and antioxidant properties of Water Soluble tomato Powders and on their use in pork patties. Journal of the Science of Food and Agriculture. DOI: 10.1002/jsfa.7141.
- King A.J., Zeidler G. 2004. Tomato Pomace May be a Good Source of Vitamin E in Broiler Diets. California Agriculture, 58(1): 59-62.
- Kohajdová Z , Karovičová J, Magala M. 2013. Rheological and qualitative characteristics of pea flour incorporated cracker biscuits. Croat. J. Food Sci. Technol. 5 (1): 11-17
- Krumbein A., Peters P., Bruckner B. 2004. Flavor compounds and a quantitative descriptive analysis of tomatoes (Lycopersiconesculentum Mill.) of different cultivars in short-term storage. Postharvest Biology and Technology, 32: 15-28.
- Kumar N and Kumar K 2011. Development Of Carrot Pomace And Wheat Flour Based Cookies. Journal of pure and applied science and Technology. 1(7):4-10

.**<u>L:</u>**

- Lana MM, Tijskens LMM 2006. Effects of cutting and maturity on on antioxidant activity of fresh cut tomatoes. Food Chem 97: 203-211.
- Laura D, Boccia GL and Lucarini M, 2013. Influence of heat treatment and carotenoid content of the cherry tomatoes. Foods., 2: 352- 363.
- Lavelli V, Torresani MC. 2011. *Modelling of lycopene-rich by-products of tomato processing*. Food Chemistry, 125: 529-535.
- Lavelli V, Scarafoni A (2011). Effect of water activity on lycopene and flavonoid degradation in dehydrated tomato skins fortified with green tea extract. J. Food Eng.
- Lavelli V., Scarafoni A. 2012. *Effect of water activity on lycopene and flavonoid degradation in dehydrated tomato skins fortified with green tea extract*. Journal of Food Engineering, 110: 225-231.
- Lawless HT, Heymann H. Sensory Evaluation of Food: Principles and Practices. Aspen Publishers, Gaithersburg, MD, USA. pp. 1-5 (1999)

- Lei L, Dai Q, Zhou M, Zhang X (2007) Decolorization of cationic red X-GRL by wet air oxidation: performance optimization and degradation mechanism. Chemosphere 68:1135–1142.
- Leonardi C., Ambrosino P., Esposito F. and Fogliano V. (2000). Antioxidant activity and carotenoid and tomatine contents in different typologies of fresh 'consumption tomatoes. Journal of Agricultural and Food Chemistry, 48, 4723-4727.
- Liu F, Cao X, Wang H, Liao X. 2010 Changes of tomato powder qualities during storage. Powder Technol. 204: 159-166.
- Lonnerdal B. Genetically modified plants for improved trace element nutrition. *Journal of Nutrition* 2003; 133: 1490-3S.
- Lowry OH, Rosenbrough NJ, Farr AL, Randell RJ. Protein measurement with folin phenol reagent. J BiolChem 193, 265–275 (1951)

M:

- Manay S & Shadaksharaswamy, *Foods: Facts and principles*, 2ndedn [New Age International (P) Ltd] 2001, 266.
- Marfil PHM, Santos EM and Telis VRN, 2008. Ascorbic acid degradation kinetics in tomatoes at different drying conditions. *LWT- Food Science and Technology*. **41:** 1642-1647.
- Maul F., Sargent S.A., Sims C.A., Baldwin E.A., Balaban M.O., Huber D.J. 2000. *Tomato flavor and aroma quality as affected by storage temperature*. Journal of Food Science, 65: 1228-1237.
- Myers RH, Montgomery DC (1995) Response surface methodology: Process and product optimization using designed experiments, John Wiley & Sons, Inc. New York.
- McMinn, W.A.M., 2006. Thin-layer modeling of the convective, microwave, microwave convective and microwave-vacuum drying of lactose powder. Journal of Food Engineering 72, 113–123.
- Miranda M, Maureira H, Rodriguez K, Vega-Galvez A. 2009. Influence of temperature on drying kinetics, physicochemical properties and antioxidant capacity of Aloe vera (*Aloe barbadensis*Miller) gel. J. Food Eng, 91, pp. 297-304.

- Moktan B, Roy A, & Sarkar P K, Antioxidant activities of cereal-legume mixed batters as influenced by process parameters during preparation of dhokla and idli, traditional steamed pancakes, International Journal of Food Sciences and Nutrition, June 2011; 62(4): 360–369.
- Moselhi SS and Al Mslmani MAB. 2008. Chemopreventive effect of lycopene alone or with melatonin against the genesis of oxidative stress and mammary tumours induced by 7, 12 dimethyl (a) benzanthracene in spraguedawely female rats. Molecular and Cellular Biochemistry 319:175-180.
- Mozumder NHMR, Rahman MA, Kamal MS, Mustafa AKM and Rahman MS. Effects of Pre-drying Chemical Treatments on Quality of Cabinet Dried Tomato Powder. *J. Environ. Sci. & Natural Resources*, 5(1): 253-265, 2012.

N:

- Nagamani G. 2014. Processing technology for tomato powder. International Journal of Scientific Research 3(2): 210-213.
- Nguyen ML, SCHWARTZ SJ 1998. *Lycopene stability during food processing*. Proceedings of the Society for Experimental Biology and Medicine, 218: 101–105.
- Nisha P, Singhal R and Pandit A. 2010. Kinetic Modelling of Colour Degradation in Tomato Puree (*Lycopersiconesculentum L.*). *Food Bioprocess Technol*., DOI 10.1007/s11947-009-0300-1.

O:

- Ogunbusola EM, Arinola SO and Adubiaro HA. Effect of Drying on the Physicochemical Properties of Ready-To- Cook Ogbono Mix (*Irvingia gabonensis*). Food Science and Quality Management, 2014. 33: 36-40.
- Oliveira GHH 2010. Característicasfísico-químicas do tomatesubmetidoaesforçocontrolado de compressão. Tesis. Universidade Federal de Viçosa, Viçosa, Minas Gerais, Brazil.
- Onwuk GI. 2005. Food Analysis and Instrumentation. Theory and Practice. Naphtali Prints. Surulere Lagos Nigeria. pp133 - 137.
- Osterlie M, Lerfall J. 2005. *Lycopene from tomato products added minced meat:Effect on Storage quality and color*. Food Research International, 38: 925-929.

P:

- Paiva SAR, Russell RM 1999. *ß-Carotene and Other Carotenoids as Antioxidants*. Journal of American College of Nutrition, 18(5): 426-433.
- Palmer S. Protein in vegetarian and vegan diets, Academy of Nutrition and dietetics, 2014.
- Parti M, 1993. Selection of mathematical models for grain drying in thin-layers. Journal of Agricultural Engineering Research 54, 339–352.
- Pathare P., Opara U. and AL-Said, F. 2013. Colourmeasurement and analysis in fresh and processed foods:A review. Food Bioprocess Technol. *6*, 36–60.
- Paulson KN and Stevens MA, Relationships among titratable acidity, pH and buffer composition of tomato fruit. *J Food Sci***39**:354–357 (1974).
- Petro-Turza, M. 1987. Flavor of tomato and tomato products. Food Rev. Int. 2 (3): 309-351.
- P. Sharma, H.S. Gujral, Antioxidant and polyphenol oxidase activity of germinated barley and its milling fractions. Food Chem 120, 673–678 (2010)

Q:

- Quaglia, G., 1988. Other durum wheat products. In: Fabriani, G., Lintas, C. (Eds.), Durum Wheat: Chemistry and Technology. American Association of Cereal Chemistry, St. Paul, Minn, pp. 263-274.

R:

- Raiola A, Rigano MM, Calafiore R, Frusciante L, and Barone A. Enhancing the Health-Promoting Effects of Tomato Fruit for Biofortified Food**. 2014.** http://dx.doi.org/10.1155/2014/139873
- Rajkumar P, Kulanthaisami S, Raghavan GSV, Garie PYY, Orsat V. 2007. *Drying Kinetics of Tomato Slices in Vacuum Assisted Solar and Open Sun Drying Methods.* Drying Technology, 25: 1349-1357.
- Ramakrishnan CV. 1979. Studies on Indian fermented foods. Baroda J Nutr 6:1–54.
- Rani M and Punia D. Nutrient content and sensory evaluation of dhokla prepared incorporating green beans powder. International Journal of Food and Nitritional sciences. 3(6):170-173
- Rao A.V., Agarwal S. 2000. Role of antioxidant lycopene in cancer and heart disease. Journal of American College of Nutrition, 19: 563-569.

- Rao, A.V., Waseem, Z., Agarwal, S., 1998. Lycopene content of tomatoes and tomato products and their contribution to dietary lycopene. Food Res. Int. 31, 737–741.
- Rao NG, Rao P P G, Balaswamy K. and Rao DG. 2011. Preparation of instant tomato pickle mix and evaluation of its storage stability. International Food Research Journal 18: 589-593.
- Ravi U, Menon L and Anupama M. Formulation and quality assessment of instant *dhokla* mix with incorporation of pumpkin flour. Jourrnal of Scientific & Industrial Research vol 69 december 2010, pp. 956-960.
- Reihaneh AG, Mehdi GD, 2010. Studies on Physiochemical Properties of Tomato Powder as Affected by Different Dehydration. World Academy of Science, Engineering and Technology International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering.
- Rizk E.M., EL-KadY A.T., EL-Bialy A.R. 2014. *Charactrization of carotenoids (lyco-red) extracted from tomato peels and its uses as natural colorants and antioxidants of ice cream*. Annals of Agricultural Science, 59(1): 53-61.
- Roberts J.S., Kidd D.R., Zakour O.P. 2008. Drying kinetics of grape seeds. Journal of Food Engineering, 89: 460-465.
- Rocha G.A., F´avaro-Trindade C.S., GROSSO C.R.F. 2012. *Microencapsulation of lycopene by spray drying: characterization, stability and application of microcapsules*. Food and Bioproducts Processing, 90 (1): 37-42.
- Rolle, R. & Satin, M. 2002. Basic requirements for the transfer of fermentation technologies to developing countries, *InternationalJournal of Food Microbiology* Vol 75, pp. 181– 187.
- R. Przybylski, Y.C. Lee, N.A. Eskin, Antioxidant and radical scavenging activities of buckwheat seed components. J Am Oil ChemSoc 75, 1595–1601 (1998)
- Roy A, Bijoy M &Prabir S K, Survival and growth of foodborne bacterial pathogens in fermenting batter of dhokla, *J Food SciTechnol*, **46** (2009): 132-135.

<u>S:</u>

- Sacchettia G, Giuseppe C, Domenico C, Lilia N, Dino M. 2011. Effect of semolina particle size on the cooking kinetics and quality of spaghetti. Procedia Food Science 1 1740 – 1745.

- Sánchez N.F.S., Blanco R.V., Gómez M.S.G., Herrera A.P., Coronado R.S. 2012. *Effect of rotating tray drying on antioxidant components, color and rehydration ratio of tomato saladette slices.* LWT - Food Science and Technology, 46: 298-304.
- Savadkoohi S., Farahnaky A. 2012. Dynamic rheological and thermal study of the heat-induced gelation of tomato-seed proteins. Journal of Food Engineering, 113 (3): 479-485.
- Senadeera, W., B.R. Bhari, G. Young, and B. Wijesinghe. 2003. Influence of shapes of selected vegetable material son drying kinetics during fluidized bed drying. J. Food Eng. 58:277-283.
- Sharma P and Gujral HS. Antioxidant and polyphenol oxidase activity of germinated barley and its milling fractions. Food Chem 120, 673–678 (2010).
- Sharma SK, Le Maguer M (1996). Kinetics of lycopene degradation in tomato pulp solids under di€erent processing and storage conditions. Food Res. Int., 29: 309-315.
- Shi J., LE M.M., Kakuda Y., Liptay A., Niekamp F. 1999. *Lycopene degradation and misomerization in tomato dehydratatio.*,Food ResearchInternational, 32: 15-25.
- Shi J., Le Maguer M. 2000. *Lycopene in tomatoes: chemical and physical properties affected by food processing*. Critical Reviews in Biotechnology, 20(4): 293-334
- Shi J., Qu Q., Kaku` DA.Y., Yeung D., Jiang Y. 2004. *Stability and synergistic effect of antioxidative properties of lycopene and other active components*.Critical Review Food Science and Nutrition, 44: 559-573.
- Shu B., Yu W., Zhao Y., Liu X. 2006. *Study on microencapsulation of lycopene by spray-drying*. Journal of Food Engineering, **76**(4): 664-669.
- Singh G., Arora S., and Kumar S., 2010. Effect of mechanical drying air conditions on quality of turmeric powder. J. Food Sci. Tech., 47(3), 347-350.
- Sivarajan, V. V., & Balachandran, I. (1994). Ayurvedic drugs and their plant sources (1st ed.). New Delhi: Oxford and IBH Publishing.
- Sim, K. S., Sri Nurestri, A. M. and Norhanom, A. W.2010. Phenolic content and antioxidant activity of*Pereskiagrandifolia Haw*. (*Cactaceae*) extracts.Pharmacognosy Magazine 6: 248-254.
- Sogi, D.S., Shivhare, U.S., Garg, S.K., Bawa, A.S., 2003. Water sorption isotherm and drying characteristics of tomato seeds. Biosystems Engineering 84 (3), 297–301.

- Sogi D.S., Bhatia R., Garg S.K., Bawa A.S. 2005. Biological evaluation of tomato waste seed meals and protein concentrate. Food Chemistry, 89: 53-56.
- Soma S. 2013.Development and evaluation of antioxidant activity of tomato based confectionary. International Food Research Journal, 20(6): 3167-3170.
- Somayajula A, Asaithambi P, Susree M, Matheswaran M (2011) Sono electrochemical oxidation for decolorization of reactive red. Ultrasonics Sonochem. doi:10.1016/j.ultsonch.2011.12.019.
- Sousa A.S.DE., Borges S.V., Magalhães N.F., Ricardo H.V., Azevedo A.D. 2008.Spray-Dried Tomato Powder: Reconstitution Properties and Color. Brazilian Archives of Biology and Technology, 51(4): 807-814.
- Sreerama, Y.N., Sashikala, V.B., Pratape, V.M., Singh, V. (2012): Nutrients and anti-nutrients in cowpea and horse gram flours in comparison to chickpea flour: Evaluation of their flour functionality. *Food Chem*. 131 (2), 462-468.
- Stahl W., Sies H. 1992. *Uptake of lycopene and its geometrical isomer, is greater from heat-processed than from unprocessed tomato juice in humans*. Journal of Nutrition, 122: 2161-2166.
- Stevens MA, Citrate and malate concentrations in tomato fruits: Genetic control and maturational effects. *J Am SocHorticSci***97**:655–658 (1972).

<u>T:</u>

- Tapiero H, Townsend D.M., Tew K.D. The role of carotenoids in the prevention of human pathologies, Biomed. Pharmacother. 58 (2004) 100–110.
- Toor R.K., Savage G.P. 2005. *Antioxidant activity in different fractions of tomatoes.*Food Research Internatinol, 38 (5): 487-494.
- Tripathi, R.N. and Nath, N. (1989). Effect of starch dipping on quality of dehydrated tomato slices.Journal of Food Science and Technology. 26(5):137-141.

<u>U:</u>

- Unison J.A., Hao Y., SU X., Zubik L. 1998. Phenol antioxidant quantity and quality in foods: Vegetables. Journal of Agricultural and Food Chemistry, 46(9): 3630- 3634.

- Upadhyaya A.K. , Gupta B , Garg S , Singh M , Pandey M. Mathematical Modeling of Hot Air Drying of Spinach Leaves in Universal Hot Air Oven. International Journal of Advanced Research in Computer Engineering & Technology. 1(4): 153-157
- Usha R Jr, Lakshmi M, Ranjani M. 2010. Nutritional, sensory and physical analysis of pumpkin flour incorporated into weaning mix. Malays J Nutr.16(3):379-87.

V:

- Vega, A., A. Andrés, P. Fito, and R. Lemus. 2007. Mathematical modeling of hot-air drying kinetics of red bell pepper (var. Lamuyo). J. Food Eng. 79:1460-1466.
- Vega-Gálvez, A., Di Scala K., Rodríguez K., Lemus-Mondaca, R, Miranda M, López J, Perez-Won, M. 2009. Effect of air-drying temperature on physicochemical properties, antioxidant capacity, colour, and total phenolic content of red pepper (*Capsicum annuum*,L. var. Hungarian). Food Chem, 117, pp. 647-653.
- Ventura M.R., Pieltin M.C., Castanon J.I.R. 2009. *Evaluation of tomato crop by-products as feed for goats*. Animal Feed Science and Technology, 154: 271-275.

X:

- Xu BJ, Chang S.K.C. A comparative study on phenolic profiles and antioxidant activities of legumes as affected by extraction solvents. J Food Sci 72, 159–166 (2007).

Y:

- Y. Kun, U.S. Lule, D. Xiao-Lin, Lycopene: its properties and relationship to human health. Food Rev. Int. 22, 309–333 (2006).
- Yu L., Perret J., Harris M., Wilson J., Haley S. Antioxidant properties of bran extracts from Akron wheat grown at different locations. J Agric Food Chem 51, 1566–1570 (2003).
- Yuanglang C., Vasupen K., Wongsuthavas S., Panyakaew P., Alhaidary A. 2010. *Growth performance in beef cattle fed rations containing dried tomato pomac.*, Journal of Animal and Veterinary Advances, 9: 2261-2264.

Z:

- Zaini, N.A.M., F. Anwar, A. Abdul Hamid and N. Saari. 2011. Kundur [Benincasahispida (Thunb.) Cogn.]: A potential source for valuable nutrients and functional foods. FoodRes. Int., 44:2368-2376.
- Zeinab Dehghan-Shoar, Allan K. Hardacre, Charles S. Brennan. 2010. The physico-chemical characteristics of extruded snacks enriched with tomato lycopene. Food Chem 123(4): 1117-1122
- Zielinski H and Kozlowska H. Antioxidant activity and total phenolics in selected cereal grains and their different morphological fractions. J Agric Food Chem 48, 2008–2016 (2000).
- Yann D, Didier H, Daniel B (2005). Utilisation of the experimental design methodology to reduce browning defects in hard cheeses technology. J. Food Eng., 68: 481-490.

LIST OF BOOKS AND OTHERS:-

- Madhavi DL and Salunkhe DK 1998. Tomato In: Salunkhe D K and Kadam S S, Editors, Handbook of vegetable science and technology: *Production, Composition, Storage, and Processing*, chapter 7, Marcel Dekker, New York, United States, 171-201.
- Mars G.J., Scher H.B.1990. *Controlled delivery of crop protecting agents*. Wilkens, R.M. (Ed) Taylor and Francis, London, 65-90.
- Papadakis SE, Gardeli C, Tzia C. 1998. *Raizin Extract Powder: Production, Physical and Sensory Properties.* In: Proceeding of the 11th International Drying Symposium ID's 98, Haldiki: Ziti Editions.
- Parnell TL, Suslow TV, Harris LJ 2004. *Tomatoes: Safe Methods to Store, Preserve, and Enjoy*. University of California, Division of Agriculture and Natural Resources.

List Of Publication:

- Sohini Ray, Rumki Saha, Utpal Raychaudhuri and Runu Chakraborty. Abstract on "Effect of temperatures on drying kinetics of tomato (*Solanum* lycopersicum L) and winter melon (*Benincasa hispida*) and analysis of color and antioxidant property" published in Book (International Journal of Clinical Nutrition and Souvenir) : IJCN:ISSN-0971-9210 on International Conference in Benaras Hindu University.
- Sohini Ray, Rumki Saha, Utpal Raychaudhuri and Runu Chakraborty. Different quality characteriscs of tomato (*Solanum* lycopersicum L) as a fortifying ingredients in food products:a review. Communicated to Technical Science Journal, Poland
- Sohini Ray, Rumki Saha, Utpal Raychaudhuri and Runu Chakraborty. development of tomato powder incorporated dhokla and its physicochemical, nutritional and sensory assessment. Communicated to Journal of Food Quality, Willey.

AWARDS:

First prize, awarded for the **"Effect of temperature on drying kinetics of tomato (*Solanum lycopersium L*) and wintermelon (*Benincasa hispida*) and analysis of color and antioxidant property"** in technical session on Fruits and vegetable processing in "International Conference on Recent Advances in Food Processing and Biotechnology" held at Centre of Food Science and Technology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi on April 5th and 6th, 2016.