Optimising the drying process for grape (Vitis vinifera L.) using pre-treatments to maximise quality retention

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ABSTRACT

Grape (*Vitis vinifera* L.) is a valuable fruit, but highly perishable as it has high water and sugar content. Drying grape is an option for shelf-life extension. Reducing moisture content can prevent micro-organism growth, deteriorative reactions and reduce weight and volume of the product. After drying, dried grape, so called raisin, represents a rich source of carbohydrate and organic compounds in concentration, especially phenolic compounds that are beneficial for consumers' health. However, the commercial practice of using chemicals for pre-drying treatment such as potassium carbonate has raised concern about food safety.

The research reported here aimed to examine an alternative method to increase drying effectiveness, while avoiding potassium carbonate use. Five pre-drying treatments (2% olive oil blanching, 2.5% K_2CO_3 plus 2% olive oil dipped, needled, halved and no-treatment control) were compared at two drying temperatures of 60 °C and 70 °C. The drying characteristics and appropriate models were investigated. Product quality including colour, pH, total soluble solids and acidity, total phenolic contents were assessed.

The results show that drying time of oil blanched-grapes was reduced by 42% at drying temperature of 60 °C and 50% at drying temperature of 70 °C compared to chemical treatment and more than 60% compared to the no-treatment control. The oil blanching treatment retained the highest total phenolic content and it is applicable into food processing. Statistical indicators (determination coefficient, sum square error and root mean squared error) showed the Logarithmic model best described the drying kinetics for all treatments.

Additional research is needed to test the convective drying method with a thick bed layer in order to scale up into industry. The low-cost oils such as canola, sun flower oils should also be examined to reduce the application of olive oil.

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a, c, n drying coefficients

k drying constant (min^{-1})

R drying rate ($g\ min^{-1}$)

d.b. dry basis

w.b. wet basis

M_w wet mass

M_d dry mass

X moisture content in a dry basis

X_e equilibrium moisture content (kg water/kg dry dasis)

X_o initial moisture content (kg water/kg dry dasis)

Y moisture content in a wet basis

MR moisture ratio

Xt moisture content at any time (kg water/kg dry dasis)

Δt delta time (min)

$X_{t+\Delta t}$ moisture content at time $t+\Delta t$ (kg water/kg dry dasis)

R^2 determination of coefficient

SSE sum of squares due to error

$RMSE$ root mean square error

T temperature (°C)

t drying time (min)

1. INTRODUCTION

1.1. Research background

Grapes (*Vitis vinifera* L.) are among the world's most important fruit crops. In 2014, the world production amounted to 74.5 million tonnes and its cultivation areas were about 7.1 million hectares (FAOSTAT, 2014). The world import-export value was about 1.8 billion USD in 2013. According to the Food and Agriculture Organization (FAO), the six leading grape producing countries were China (12.6 million tonnes), United States (7.2 million tonnes), Italy (6.9 million tonnes), France and Spain (6.2 million tonnes), and Turkey (4.1 million tonnes). In New Zealand, grapes are popular and tasty fruits and grape production was estimated to be 445 thousand tonnes and its cultivation areas presented about 33.8 thousand hectares in 2014 (FAOSTAT, 2014). Sauvignon Blanc, Cabernet Sauvignon, Pinot Noir, Chardonnay, Merlot and Pinot Gris are currently the most common types planted in New Zealand. New Zealand is a major wine producing nation, exporting into over 90 countries and its export value of wine was over $ 1.5 billion in 2016 (Winegrowers report, 2017). In addition, some table grape cultivars (Muscat, Black Beauty) are also popular in New Zealand.

Grapes are valuable and seasonal fruits which are widely grown in temperate regions. They are nutritious with high sugar, vitamins, carbohydrate and minerals content. They are also a rich source of antioxidants (Breska et al., 2010). Grapes are classified as berries rich in juice, but this makes them highly perishable in the post-harvest period and marketing. Fresh grapes are susceptible to various physiological breakdowns and diseases after harvest (Ciccaresa et al., 2013). As fresh grapes deteriorate rapidly at ambient conditions less than two months after harvest, they must be consumed or processed into various products to reduce post-harvest quantitative and qualitative losses.

Drying or dehydration is one of the oldest and most important methods for preserving food, including grapes (Defraeye, 2017). Reducing moisture content can prevent not only micro-organism growth, but also minimise unwanted deteriorative reactions (Perussello et al., 2012). It can reduce weight and volume of the product and therefore transportation cost and dried grapes can be stored under ambient conditions (Esfahani et al., 2015). During the dehydration process, there are many desirable changes (physical, chemical, and biochemical) which are affected by dehydration conditions and physicochemical characteristics of grape materials including fruit size, sugar content, and the property of wax layers on the fruit surface (Esmaiili et al., 2007). It is necessary to consider the requirement of product quality simultaneously with cost-benefits in commercial practices to select suitable drying methods. Convective drying, a thermal dehydration method, is frequently used for dehydration of horticultural produce (Sturm et al., 2014). This method often has shorter drying time and less contamination of the product compared to open sun or solar drying methods. This technique is controllable and reasonable production cost and can be applied in commercial practice.

Grapes are processed into various products including dried grapes, called raisins. The world raisin production in about 1.5 million tonnes in 2014, an increase of 10% between 2000 and 2014 (FAO report, 2016). The United States, Turkey, Iran and China are the major raisin producers and the grape drying industry represents an economically profitable business (Breska et al., 2010). Raisins can be stored over an extended period of 6-12 months at ambient temperature (Bhat et al., 2012). Raisins can be used as snacks or used as a raw material for processing various products such as sweet wine, cake and ice-cream. Raisins retain the carbohydrate and organic compounds of the fresh fruit in concentrated form. Raisins are also valued for their medicinal properties and are popular as a good source of minerals (e.g. potassium, magnesium) and fibre (Dev et al., 2008). In addition, dried fruits are fat and cholesterol free, and have high amount of pure fructose, the main sugar content in fruit that is absorbed directly into the bloodstream during digestion. Raisins represent a rich source of phenolic compounds that are beneficial for consumers' health (Adiletta et al., 2016). Among the dried fruit stuffs, raisins have the highest total phenolic contents and levels of antioxidant that neutralise free radicals (Zhao et al., 2008). Those phenolic compounds are also the main cause of browning reactions under enzymatic oxidation, which play a key role in appearance quality of raisins.

Grape skin has an outer waxy layer that reduces drying rates. Therefore, a chemical or physical treatment is often applied before drying to reduce skin resistance and, thus increase water diffusion through the waxy layer. Pre-treatments have been shown to improve drying capacity and product quality of raisins. Chemicals (e.g. potassium carbonate, sodium hydroxide, ethyl oleate) application before drying increased moisture diffusion and reduced dark colour development on the raisins (El-Sebaii et al., 2002). However, chemical residue may raise consumers' concerns in food safety (Adiletta et al., 2016). Recent studies using physical treatments including using half cut grape fruit or superficial abrasion of peel had higher drying rate than whole fruit drying (Thakur et al., 2010), but those methods were time consuming methods or had quality loss.

1.2. Research aims and approach

Pre-drying treatments and drying regimes may have profound effects on raisins' quality and drying kinetics. Research question is if there is a low-cost, safe and practical alternative (avoid chemical additive use) for raisin processing. This study aimed to investigate practical and non-toxic pre-treatments and the drying conditions in order to replace current chemical treatment methods. The hypothesis of the study is breaking down waxy surface and/or tissue structure of the fruit by heat or mechanical treatments may increase moisture removal. Some physical treatments and oil were investigated and compared with current commercial practices. In this study, olive oil was used as an emulsion for pre-drying treatment. Olive oil is not classed as a chemical additive because olive oil is consumed as food with high quality.

The specific objectives of the study were:

- To test the effects of various pre-treatment on the drying rate, quality attributes and compared with current commercial chemical treatments.

- To examine how drying temperature affecting drying time and the quality of raisins.

- To assess the appropriate empirical models available in the literature in order to represent drying kinetics.

LITERATURE REVIEW

2.1. Characteristics of fresh grape

2.1.1. Living fruit

Grapes are non-climacteric fruits with low physiological metabolism in the postharvest period (Adiletta et al., 2016, Ciccaresa et al., 2013). Its respiration rate is low, but the fruit loses dry matter because of its metabolism. The shelf life of fresh grapes is only about 2 weeks at cold condition storage and marketing. Because of having high water content (about 80%) and high nutrition, grapes are subjected to deteriorate after harvest.

2.1.2. Grape cuticle

The grape skin plays a significant role in controlling the shelf life of fresh grapes and it strongly affects the dehydration process. The skin has cuticle layer and epidermal cell layers with lenticels and wax layers (Esmaiili et al., 2007). The wax is outer layer and naturally has hydrophobic characteristics. The cuticle plays a significant role in preventing water loss and serving as a protective barrier against microbial attack and physical injuries (Serratosa et al., 2008). Cuticular wax in grapes is a complex mixture of alcohols, aldehydes and esters mostly formed by an insoluble C16 and C18 fatty acid in which oleanolic acid, a cyclic triterpenoid acid consist of 60% of the total wax (Esmaiili et al., 2007).

During drying, the presence of waxes in the skin cuticle is an obstacle to drying as this reduce moisture diffusion rates (Zemni et al., 2016). The low moisture diffusion rate due to this hydrophobic barrier on the fruit skin may result in a time-consuming drying process. It can prevent water evaporation from fruit to the environment and slow down heat transfer from the hot air to the fruit.

2.1.3. Aroma

Aroma is one of the important factors that contribute to the grape and raisin quality. Hundreds of aroma compounds in grapes have been found in some previous studies and there are several key volatile compounds such as lactones, alcohols, phenols and benzenoids (Ghesta et al., 2015). The volatile compounds vary from cultivar to cultivar. Ghesta et al. (2015) stated that volatile compounds in grapes are present in free and bound form; the bound part mostly exist in the form of hydrophilic, non-volatile and flavourless glycosylated molecules. The volatiles of raisins depend on dehydration techniques and drying parameters.

2.1.4. Phenolic compounds and antioxidants

There has been increasing consumer interest in natural antioxidants (Fang and Bhandari, 2011, Mermelstein, 2008). Phenolic compounds in grapes are a significant quality aspect and they give specific functional and sensory characteristic in colour. Raisins are a rich source of dietary phenolics that are beneficial for health (e.g. phenolic acids, flavonoids and anthocyanins). They contain a significant levels of antioxidants, pre-biotics and organic acids such as tartaric acid that work synergistically with fibre to maintain a healthy digestive system (Jeszka-Skowron et al., 2017, Zemni et al., 2016).

Phenolic compounds are the key substrates for colour-change processes during drying. They are chemical compounds which have at least one benzene ring with one or more –OH groups that can bond to methyl, methoxyl, amino or glycosyl groups (Beckman, 2000). Phenolics are mostly present within the cell vacuole and cell membrane of fruits. Phenolics mostly exist in glycosylated compounds such as xanthone glycosides and flavonoid glycosides (Beckman, 2000). Glycosidase enzymes hydrolyse the glycoside bond to release the phenolics. Phenolics are stored in fruit as three forms of flavonoids (flavonols, flavanones, isoflavones, anthocyanins…); phenolic acids (ferulic acid, p-coumaric acid, caffeic acid, chlorogenic acid, gallic, vanillic, ellagic, syringic acids); and tannins (proanthocyanidins, gallotannin or tannic acid) (Haminiuk et al., 2012).

Amounts of phenolics in grapes can vary with harvest date, ripening stage, cultivar, climate, soil, location and storage conditions (Pantelic et al., 2016). Moreover, polyphenols in grapes are distributed unevenly. Most of total soluble phenolics (60–70%) are present in the seed, 28–35% are in the skin, and only 10% are found in the flesh. Proanthocyanidins and flavan-3-ols are the most abundant phenolic compounds found in the grape seeds, while hypodermal cells of the skin are rich in flavonols (Pantelic et al., 2016).

Raisins have a higher concentration of phenolics such as flavonol glycosides compared to grapes as flavonol glycosides were not sensitive to enzymatic oxidation. However, some phenolics such as procyanidins and flavan-3-ols were completely degraded during the drying process, according to Karadeniz et al. (2000). Raisins have also significant antioxidant compounds and the compounds vary from cultivars to cultivars (Zhao et al., 2008). For example, A95-27 grape cultivar had three time higher in a concentration of total phenolics than Thompson seedless grapes (Breksa et al., 2010).

Antioxidants are affected by drying temperature and high temperature has been found to reduce phenolic compounds and their antioxidant activity. When red grape pomace peels were tested to dry at 100 and 140 °C, antioxidants significantly reduced in both total extractable polyphenols (18.6 and 32.6%), condensed tannins reduced about 11.1 and 16.6%, and the antioxidant activity decreased 28 and 50%, respectively (Larrauri et al., 1997). Adletta et al. (2016) found that drying Red Globe grapes at 50 °C preserved antioxidant activity when compared with drying at 60 °C or 70 °C.

2.1.5. Enzymes

There are two main browning enzymes involved in the browning processes of plant tissues. The key enzyme group is polyphenol oxidase, which is a copper-containing enzyme present in most plants. Most of the polyphenol oxidase is located in plastids, including chloroplasts of cells. When the tissue is disrupted, polyphenol oxidase is de-compartmented and comes into contact with substrates released by damaged vacuoles (Loveys et al., 1992). Polyphenol oxidase converts monophenols into quinones with different spectral characteristics which depend on the monophonols and pH (Robard et al., 1999).

The second enzyme group is comprised of peroxidases which are common in plant tissues. Peroxidases are iron-containing enzymes which catalyse phenolics using active oxygen from the peroxide group. Peroxidases are thermally resistant enzymes. Peroxidases are oxide-reductive enzymes and are often located in the outermost cell layer of fruits. Peroxidases have an important role in cell defence and they oxidise phenolics by generating a hydrogen peroxide group (Jiang et al., 2004, Zhu et al., 2008).

2.2. Drying method selection

2.2.1. Benefits of dehydration

Like many fruits and vegetables, fresh grapes are composed of, on average, 80% water content and 20% dry matter. Therefore, they are highly deteriorative. Drying may be one of the best options to convert a surplus crop into a shelf-stable commodity and is commonly used to extend the shelf life of grapes. Raisins are typically dried to achieve shelf stability and therefore moisture is removed to the point where the water activity of the product is effective in preventing microbial and bio-chemical deteriorations. Drying process also converts fresh grapes into raisins which possesses nutritional and organoleptic characteristics (Femenia et al., 1998). Additionally, moisture removal is also an effective method to lower transportation costs by reducing the weight of the product, to maintain the legal regulations and other economic benefits.

2.2.2. Dryer types for drying grapes

Raisins are generally produced either by traditional methods in a sunny or shaded area or using mechanical drying (Esmaiili et al., 2007). They are the predominantly used techniques for grape drying to obtain raisins ready-to-eat or used in sweet winemaking.

Sun drying is a traditional and low-cost method and consists of an air exposure of the products in an open sun or shade and the process often takes at least several days to reach the required moisture content (Pangavhane and Sawhney, 2002). Drying times can be even longer depending on the particular weather conditions. In addition, dust contamination, insect infections, animal attack, intense solar radiation causing colour deterioration, and fungi-producing toxins (e.g. ochratoxin A), can deteriorate the final product (Amer et al., 2010; Serratosa et al., 2008; Sen et al., 2016). This means raisins may need to be passed through a cleaning process for removal of contaminants (e.g. small stones, soil, leaves, dust, etc.) (Castillo-Tellez et al., 2016).

Indirect solar drying methods for raisin production have been developed which are safer and more rapid compared to open sun drying. This method requires low capital and operating costs and is also environmentally friendly (Devahastin and Pitaksuriyarat, 2006), but the process still takes some days to reach the target moisture for the final product. Therefore, physical and microbial deterioration problems can occur as the product which does not dry during nighttime may become cool and wet. Dried grapes obtained from open sun or solar driers have low quality due to uncontrolled drying conditions and environment.

Higher required quality for horticultural produce led to the development of alternate drying technologies. Various mechanical drying methods are used in the drying of horticultural products, and hot air convective drying is the most widely used method in postharvest and processing technology (Sturm et al., 2014). The convective method can alleviate the shortcomings of the solar methods. The method is rapid and controlled, but requires investment for dryer equipment and has higher operation costs than solar drying (Pangavhane and Sawhney, 2002). The convective mechanical dryers are based on the convective drying which involves the use of specific dryers with a hot air flow (50–80 °C) with a controlled velocity. Convective drying can be applied for high volume of materials. With convection drying, product quality could be achieved with reasonable cost and reliability compared to other methods. In food industries, continuous convective dryers are often used with three basic types including conveyor-belt, fluidized bed, and rotary dryers (Marinos-Kouris et al., 1998).

There are some advanced methods with the combined use of various drying methodologies including cabinet or tray, fluidized bed, spouted bed, microwave heating, ohmic, freeze, vacuum, osmotic, heat pump drying (Chapchaimoh et al., 2016; Colak and Hepbasli, 2009; Hii et al., 2013). Applying heat during dehydration through conduction, convection, and radiation are the fundamental techniques which are used to remove moisture from the products to evaporate, and forced air is applied to accelerate the moisture removal (Dev and Raghavan, 2012). However, those techniques require high investments and higher cost for operations and may not also be suitable to high volume quantity of materials.

2.3. Factors that affect convective drying rates

2.3.1. Heat and mass transfer

Drying is a dual process of heat transfer from the heating source to the material and mass transfer (moisture) from the interior of the product to its surface and then to the surrounding air (Avci et al., 2001; Moreira et al., 2000; El-Ghetany 2006; Ho et al., 2001; Jain and Tiwari, 2004). Drying process is necessary to remove a large amount of the moisture to a level where water activity within the product is low to minimise spoilage by microorganisms or chemical reactions. In general, the drying process takes place in two phases (Jomlapelatikul et al., 2016). In the first stage, drying occurs on the product surface (Can, 2007). Firstly, when heat is transferred from the hot surrounding air to the surface of the material, the absorbed energy has increased its temperature sufficiently for the water vapour pressure of the product moisture to exceed the vapour pressure of the surrounding air. Therefore, water starts to vaporise from the surface of the moist material. Secondly, a part of this heat is transferred to the interior of the product, causing a rise in temperature and formation of water vapour. Moisture from the interior of materials moves to the surface by diffusion. The moisture from the interior transfers to the surface to replace the loss of moisture there by evaporation. This process is dependent on not only the drying conditions, but also the nature of the product and its moisture content.

In the initial stages, the moisture removal is rapid as the excess moisture on the surface of grapes are much higher than in the drying air. This is known as the constant rate drying period (Can, 2007). After a certain amount of water has evaporated from the material, the drying rate slows down. The evaporation rate is reduced and the temperature of the products tends to rise. This stage of the drying process is called the falling rate period (El-Ghetany, 2006). The falling period requires longer drying time as moisture evaporates from the product more slowly than in the first stage. Jomlapelatikul et al. (2016) stated that the maximal temperature for maintaining drying for fruits and vegetables was not allowed to be higher than 75 °C.

It is necessary to maintain suitable drying rate for controlling the drying process effectively. The heat transfer and evaporation rates must be closely controlled parameters to guarantee optimum drying rates.

2.3.2. Hot air temperature and humidity

Drying air temperature plays a key role as the principle factor in the transfer of heat to the moist material and moisture to drying air by convection, and conduction from the surrounding air mass. During drying, heat is supplied to sufficiently increase the vapour pressure of the moisture held within the materials and significantly decrease the relative humidity of the drying air. This increases the moisture carrying capacity and ensures a sufficiently low equilibrium moisture content during drying process. These processes continue until the vapour pressure of the moisture held in the product equals the vapour pressure in the atmosphere. At this point the rate of moisture removal from the product to the environment and absorption from the environment are in equilibrium, and the material moisture content at this condition is known as the equilibrium moisture content. Under ambient conditions, the drying process is slow as the environment has high relative humidity. Increase of hot air temperature has the most significant influence on the vapour pressure of air. (Ekechukwua and Norton, 1999).

2.3.3. Air velocity

Air velocity is an important parameter in drying processes. Air carries away the moisture vapour released from the product to the surrounding environment. This helps to maintain the difference between the vapour pressure of the moisture in the product and that in the atmosphere. The high air velocity is regarded as a shrinkage factor (Sturm et al., 2014). In most food dehydration processes, the velocity is recommended to be less than 3 m/s (Castillo-Tellez et al., 2016).

2.4. Process changes in drying

There are some important physical characteristics of the raisin product that change during the drying process including colour, texture, chemical changes affecting the flavour and nutrient content, and shrinkage (Dev and Raghavan, 2012).

2.4.1. Water loss

The first important parameter of raisin quality is moisture content (Fouskaki et al., 2003). After drying, moisture in raisins is typically reduced to around 20% wet basis (Dev et al., 2008). If raisins are too dry, their flavour and nutrition are diminished, while if they are too wet, the quality can be reduced during storage at ambient temperature.

Water activity is also a significant factor affecting raisin quality. To control microbial spoilage and deteriorative effects of the chemical reactions, it is necessary to remove a large amount of the moisture to certain levels where the water activity of the product is sufficiently low to ensure that the product is microbiologically and enzymatically stable (Mabrouk et al., 2006; Wray and Ramaswamy, 2015). Water activity and moisture content at the equilibrium stage have a strong correlation referred to as a moisture sorption isotherm. The water activity of products is usually required to be less than 0.7 to ensure stability during the ambient condition without necessitating expensive continuous refrigerated or frozen storage (Wray and Ramaswamy, 2015).

2.4.2. Colour changes

Colour quality is one of the most important aspects for determining raisin quality (Sturm et al., 2014). Consumers' appreciation of a product is associated with product colour and other attributes like the raisins' taste, hygiene and nutrition. The change of colour is due to pigments condensation and formation from enzymatic and non-enzymatic reactions (Sturm et al., 2014). Many factors affecting raisin colour quality include pre-treatment of grapes, drying conditions and drying methods. There are three main types of discolouration, including Maillard reaction, caramelisation and enzymatic discolouration.

The Maillard reaction is a non-enzymatic browning reaction involving a reducing sugar (e.g. fructose) and amino acids. Reducing sugars and amino acids are both present in significant quantities in grapes. Therefore, raisins are susceptible to colour changes during drying because of the Maillard reaction (Zhao et al., 2008) and the reaction is facilitated at 50 °C and pH 4–7. The Maillard reaction may enhance the formation of brown pigments during drying process and products of

Maillard reaction depend on reactants, temperature, pH, water activities, and oxygen presence (Moreno et al., 2007).

Caramelisation also involves in the discolouration reactions which occur at high drying temperatures and pH values between 3 and 9. This reaction involves sugars, producing sweet nutty flavor and brown color. The brown colours are produced by three groups of polymers: caramelans, caramelens and caramelins. During the caramelisation process, volatile chemicals such as diacetyl are released, producing the characteristic caramel flavour.

The enzymatic discolouration occurs when polyphenol oxidase enzymes come in contact with phenolic compounds (mostly caftaric acid in grapes) due to cell membrane de-compartmentisation. This increases the concentration of phenolic compounds, the substrates of the polyphenol oxidase, and the involvement of oxidation of phenolic compounds leads to browning process during raisin dehydration. The browning reactions take place with the involvement of polyphenol oxidase enzymes. These enzymes catalyse the oxidation of phenolic compounds to quinones in the presence of oxygen, which subsequently evolve to brown pigments. The brown color results from the formation of quinones (Queiroz et al., 2008, Robard et al., 1999, Chidtragoola et al., 2011). The quinones are relatively unstable and then undergo further reaction. Thereafter, non-enzymatic condensation of the quinones takes place to form polymeric compounds. They can react with other phenolic compounds to form condensation products (Robard et al., 1999). Melanins with black colour may formed at the end of this oxidative polymerization process (Queiroz et al., 2008).

2.4.3. Shrinkage

Shrinkage is an important phenomenon occurring during dehydration due to water loss of the product (Bennamoun and Belhamri, 2008). The moisture removal results in changing textures and shrinkage. Shrinkage of the grapes during drying causes an increase in thickness of the waxy cuticle which reduces the permeability of water (Sawhney et al., 1999). The fruit volume significantly reduces during drying process as the fruit loose its moisture, but there is almost no change in the skin surface area. Consequently, the shrinkage occurs in almost all drying techniques.

The degree of shrinkage is dependent on the drying conditions including temperature, air humidity and air velocity levels (Sturm et al., 2014). Mathematical drying models involve heat and moisture transfer equations with suitable initial and boundary conditions of materials (Moreira et al., 2000). Shrinkage of grapes during drying takes place simultaneously with moisture evaporation from the materials and thus it may affect the moisture evaporation rate. Volume changes and deformation of grapes are dependent on several factors like grape geometry, dehydration conditions and methods (Moreira et al., 2000).

2.5. Pre-drying treatments

2.5.1. Chemical treatments

Recent studies have examined pre-treatments for grapes to alter the structure of the waxy layer and fruit structure, and then reduce drying time. Therefore, a chemical or physical pre-treatments can be applied prior to dehydration to reduce skin heat resistance and water evaporation of the fruit skin (Zemni et al., 2016). Recent studies have shown that chemical pre-treatments reduce drying times, and possibly improve raisin quality (colour, texture, and flavour).

Dipping grapes in ethyl or methyl oleate emulsions for dehydration has been shown to increase the drying rate and improve the quality of appearance (Vázquez et al., 2000). Ethyl esters of fatty acids in the C10–C18 range were found to be the most effective dipping materials for increasing the drying rate. Ethyl oleate and ethyl linolenate at 2% were showed to be most effective. Ethyl oleate is supposed to dissolve the waxy components on the grape skin that acts as a moisture barrier. Ethyl oleate may cause the formation of surface micro-pores in fruit skin and therefore, increase internal water diffusion of materials.

Treatments of grapes with sodium hydroxide or potassium carbonate (K_2CO_3) are widely used in commercial raisin production. Pre-drying treatment with sodium hydroxide for grape dehydration has been found to reduce drying time and improve the appearance of raisins (Vázquez et al., 2000). These chemical solutions soften grape skin which increases the permeability and accelerates the drying rate (Esmaiili et al., 2007; Zemni et al., 2016). Sodium hydroxide has also been shown to cause micro cracking in grape cuticle (Pahlavanzadeh et al., 2001). Treatment with 0.25% sodium hydroxide at 82 °C for 5–10 seconds led to cracking in the fruit skin and so reduced drying time (Dev et al., 2008). Vazquez et al. (2000) supposed that potassium carbonate solution could remove wax on fruit surface and fatty compound causing cell collapse in dry skin, and partially break ester bonds in pectins, which contributes to boosting moisture removal.

Combinations of chemicals have been shown to improve the moisture diffusion rate and also product quality. The mixture of oil and potassium carbonate may slow down browning enzymatic activity. Vázquez et al. (2000) found that pre-treatment with a mixture solution of potassium carbonate and olive oil at 60 °C for 3 minutes significantly reduced drying time. Pre-treatment with a mixture of 2% ethyl oleate and 0.5% sodium hydroxide reduced drying times for sun or mechanical dryers and also improved raisin quality (Tulasidas et al., 1996). Combination of sodium hydroxide and citric acid dipping reduced drying time. The mixture was also shown to dilute pectic compounds and xyloglucans of cells (Femenia et al., 1998). The ethyl oleate emulsion containing potassium carbonate pre-treatment shortened the drying time at 50 °C by about 25%, compared to samples without pre-treatment (Serratosa et al., 2008).

Treatments with sulphur compounds such as sodium meta-bisulphite and sulphur dioxide have been reported to increase drying rate, reduce the discolouration possibly due to both enzymatic and non-enzymatic browning reactions during dehydration process and the storage period of raisins (Femenia et al., 1998; Vázquez et al., 2000).). A sample pretreated with SO_2 at 900 ppm for 6 hours had light-colored raisins (Esmaiili et al., 2007). Sulphur compounds can inhibit polyphenol oxidase and also minimise the degree of non-enzymatic Maillard reaction by reducing the pH of materials. Modification of pectic polysaccharides may be also caused by potassium metabisulphite solution leading to cell wall structure collapse.

2.5.2. Physical treatments

Physical treatments are possible alternatives to reduce drying time without using chemicals. Many pre-treatments such as microwaves and pulsed electric field have been shown to improve moisture diffusivity due to increasing cell wall permeability.

Di Matteo et al. (2000) examined removal of the waxy layer from the grape skin using an inert abrasive material and found that the method reduced drying time as effectively as ethyl oleate treatment. El-Ghetany (2006) also indicated that the superficial abrasion of the grape skin was as effective as the traditional chemical dipping method, and hence, the drying time of pre-treated grapes was up to four times shorter than the drying time of untreated grapes. A similar finding was reported by Thakur et al. (2010) but the authors found that their abrasion treatment gave comparatively less attractive colour appearance. Adietta et al. (2016) carried out peel abrasion with sandpaper lined in a rotating drum and found treated samples reduced drying time (up to 1/3) as compared to untreated control.

A more recent pre-treatment method is pulsed electric field, which was found to cause cell damage, tissue softening and facilitating water passage from fruit materials (Dev and Raghavan, 2012). Dev et al. (2008) studied the effectiveness of a pulsed electric field pre-treatment and reported that pulsed electric field pre-treatment had similarity in drying kinetics to chemical dip and had the potential to avoid the use of chemicals in raisins processing.

Another novel treatment is ohmic pretreatment which has been tested for drying grapes. Ohmic heating can make micro cracks on the fruit skin and result in increasing moisture diffusion during the early drying phase. Salengke and Sastry (2005) reported that the grape samples treated with an alternating current at 14 V/cm field strength and 30 Hz, 60 Hz and 7.5 kHz frequencies showed increased drying rate, especially at low electrical frequencies. The impact of the ohmic pretreatment on equilibrium moisture content of the products was clear at 0.75 or higher water activities, but no impact at low to moderate water activities was found.

High hydrostatic pressure has been recently studied to improve drying process. High hydrostatic pressure increased fruit cell permeability, which enhanced moisture diffusion and drying rates (Dev and Raghavan 2012). The hydrostatic pressure damages the cell wall structure and leave the cells more permeable, which contributes to increasing moisture and solute transfer. This method retained the antioxidants which are present in the material being dried (Dev and Raghavan 2012).

Microwave heating applied in convection drying has been reported to increase drying rate for many food products such as seafood (Bantle et al., 2013). The microwave energy absorption by water molecules in the interior of the fruits can accelerate moisture evaporation. The method does not need any chemical pre-treatments. However, fruit at high moisture contents can have unwanted partial puffing in the dried structure. This method can be considered a good option to traditional finish-drying techniques when the product has low moisture content.

Bai et al. (2013) investigated the application of high-humidity hot air impingement blanching for grapes at a range of temperatures from 90 to 120 °C and for 30, 60, 90, and 120 seconds before drying. The results clearly showed that at 110 °C for 90 s followed by air drying at 60 °C were the best conditions of the ones considered in the study. The treatment resulted not only in significantly increased drying rate, but also effectively reduced darkening. The raisin had desirable green–yellow or green colour.

Overall, physical treatments have been shown to enhance drying process. The interactions between pre-treatment factors and fruit may lead to different microstructural modification of the cuticle as well as the cell compositional changes.

2.6. Drying kinetics

The mathematical modelling of drying kinetics is valuable in understanding the heat and moisture transfer occurring during the dehydration process of grapes, and for optimisation and control (Aregawi et al., 2014). The accuracy of determination of heat and moisture distribution parameters of the model is dependent on assumptions to formulate the model (Esmaiili et al., 2007).

The mathematical models of drying kinetics can be classified into theoretical, semi-theoretical and empirical models. The empirical and semi-theoretical models are easy to use, but they are only valid within temperature ranges, relative humidity and air velocity in which they were obtained. However, the theoretical (or phenomenological) models can be applied to an operation range, being applied in simulation strategies (Pilatti et al., 2006). The thin-layer drying models are commonly used to understand the drying behaviour of horticultural produce (Tripathy and Kumar, 2008).

Moisture ratio, moisture diffusivities, activation energy and specific energy consumption are key indicators to assess and characterise heat and mass transfer processes during drying.

2.6.1. Drying rate

The dry basis moisture content was calculated using the following equation:

$$X = \frac{M_w}{M_s} \qquad (1)$$

where X is the moisture content in a dry basis (d.b.), M_w is the mass of water in the sample (kg), and M_s is the mass of solids in the sample (kg). If the drying process is allowed to continue until all the moisture has been removed, the dry basis moisture content can be determined from:

$$X = \frac{M_i - M_f}{M_f} \qquad (2)$$

where M_i is the initial sample mass and M_f is the final sample mass.

In other expression, the moisture can be calculated on wet basis using the following equation:

$$Y = \frac{M_w}{M_w + M_s} \qquad (3)$$

where Y is the moisture content in a wet basis (w.b.). Wet basis and dry basis moisture contents can be related by:

$$Y = \frac{X}{1 + X} \qquad (4)$$

The drying rate (R) is defined as the moisture change in unit time that characterises the speed of the drying process and is calculated using the following equation (Bai et al., 2013; Ceylan et al., 2007; Li et al., 2017; Zlatanovic et al., 2013):

$$R = \frac{\Delta X}{\Delta t} = \frac{X_t - X_{t+\Delta t}}{\Delta t} \qquad (5)$$

where X_t and $X_{t+\Delta t}$ (g moisture/g dry matter) are the dry-basis moisture contents at time t and $t+\Delta t$, respectively.

2.6.2. Moisture ratio

The moisture ratio (*MR*) during drying is calculated as follows (Ceylan et al., 2007):

$$MR = \frac{X_t - X_e}{X_0 - X_e} \qquad (6)$$

where X_0 and X_e are initial dry-basis moisture content and equilibrium moisture content, respectively. X_t is moisture content at time t of drying.

In some case, X_e can be neglected because its value is very small compared to X_o and X_t values. Therefore, the moisture ratio can be expressed as (Yao-Xuan et al., 2014):

$$MR = \frac{X_t}{X_0} \qquad (7)$$

2.6.3. Effective diffusivity

During the dehydration process, the moisture diffusivity is an important parameter to calculate the moisture transfer inside the material (Azzouz et al., 2016). To construct the model of diffusivity of moisture transfer and the activation energy, the following simplifying assumptions were considered: form a thin drying layer and negligible volume shrinkage; heat losses through the dryer walls are negligible; moisture and initial temperature of the fruit were uniform; constant temperature; dimensional heat and mass transport in the fruit; the diffusion of moisture occurs in the microspores; variations in temperature and humidity in the drying air are negligible. The Fick's second law of diffusion is given by (Chayjan et al., 2011; Di Matteo et al., 2000; Johann et al., 2016):

$$\frac{\partial X}{\partial t} = \nabla\left(D_e . \nabla(X)\right) \qquad (8)$$

Where X is moisture content, t is drying time (s) and D_e is diffusivity of moisture representing the conductive term of all moisture transfer mechanisms ($m^2.s^{-1}$).

In the case of thin layer drying, with assumptions of 1) one dimensional moisture diffusivity and 2) uniform moisture distribution and negligible external resistance, Eq. (8) can be simplified for sphere and slab respectively as follows:

$$X = X_e + \frac{6}{\pi^2}(X_0 - X_e)\sum_{1}^{\infty}\frac{1}{n^2}\exp(\frac{-D_e n^2 \pi^2 t}{r^2}) \qquad (9)$$

$$X = X_e + \frac{8}{\pi^2}(X_0 - X_e)\sum_{1}^{\infty}\frac{1}{(2n+1)^2}\exp\left(\frac{-D_e (2n+1)^2 \pi^2 t}{4L^2}\right) \qquad (10)$$

Where *r* is radius of the grape (m), *n* is the number of terms taken into consideration (1, 2…)

Moisture ratio *MR* and D_e have correlation under the equation with assumptions constant effective diffusivity; negligible shrinkage; uniform initial moisture content; negligible external resistance. Equations (9) and (10) can be expressed in terms of moisture ratio as follows (Bingol et al., 2012; Can, 2007; Chayjan et al., 2011; Esmaiili et al., 2007):

$$MR = \frac{X - X_e}{X_0 - X_e} = \frac{6}{\pi^2}\sum_{1}^{\infty}\frac{1}{n^2}\exp\left(\frac{-D_e n^2 \pi^2 t}{r^2}\right) \qquad (11)$$

$$MR = \frac{X - X}{X_0 - X_e} = \frac{8}{\pi^2}\sum_{1}^{\infty}\frac{1}{(2n-1)^2}\exp(\frac{-D_e (2n-1)^2 \pi^2 t}{4L^2}) \qquad (12)$$

For long drying times, the first term in Equations (7–8) is sufficient to give a good estimate for *MR* for sphere and slab, respectively (Esmaiili et al., 2007):

$$MR = \frac{6}{\pi^2}\exp\left(\frac{-D_e \pi^2 t}{r^2}\right) \qquad (13)$$

$$MR = \frac{8}{\pi^2}\exp\left(\frac{-D_e \pi^2 t}{4L^2}\right) \qquad (14)$$

Equations (9) and (10) can be simplified as:

$$MR = k_1.\exp(-k_2 t) \qquad (15)$$

In addition to Equation (15), many semi-empirical equations which are derived from Fick's law or obtained based on mass transfer governing equations (non-

Fickian approaches), are used as models of the drying process (Yao-Xuan et al., 2014; Johann et al., 2016), as listed in Table 2.1.

Table 2.1. Mathematical models given by various authors for moisture ratio curves

Model no.	Name	Model equation
1	Newton (Lewis)	$MR = exp(-kt)$
2	Page	$MR = exp(-kt^m)$
3	Modified Page	$MR = exp(-(kt)^m)$
4	Henderson and Pabis	$MR = a*exp(-kt)$
5	Logarithmic model	$MR = a*exp(-kt^m) + c$
6	Wang and Singh	$MR = 1 + at + bt^2$
7	Verna	$MR = a*exp(-kt) + (1 - a)*exp(-k_1 t)$

The models in Table 2.1 have been used by a number of researchers to describe grape drying (Esmaiili et al., 2007). The parameters *k*, *m*, *a* and *b* are determined by experimentation.

2.7. Study directions

Convective drying has been widely applied for processing raisins. Currently, pre-drying treatment using chemicals such as ethyl oleate, potassium carbonate, sodium hydroxide have been reported to increase moisture diffusion and reduce drying time. Chemical dipping before drying is used in commercial practice. However, the chemical treatments lead to the consumers' concern about health problem (Adiletta et al., 2016). Several studies have employed physical alternatives, but the results were still limited by poor quality of final products, impractical application, or production cost. Grape abrasion may lead to significant amount of fruit juice loss. Cutting seems impractical application for grapes as time consuming and consumers' preference of whole fruit. A better physical or non-toxic chemical pre-treatments (such as hot oil dipping, needling on peels) could be examined to minimise the shortcoming of current methods and to make the processing safer for human health.

Moreover, effective modelling for each drying method is highly significant for process simulation and the development of reliable design procedures. The understanding of drying parameters as a function of product characteristics and drying process variables is necessary to optimise the design process. The drying behaviour and other characteristics by using a thin layer drying models needs to be tested. The influence of drying conditions (drying temperature) and pre-treatments in convection drying on drying kinetics and quality aspects of raisins need to be examined.

The specific objectives of the study were:

- To test the effects of various pre-treatment on the drying rate, quality attributes and compared with current commercial chemical treatments.

- To investigate how drying temperature affecting the quality of raisins.

- To assess the appropriate empirical models available in the literature in order to represent drying kinetics.

3. METHODS

3.1. Materials

Australian grown grapes were purchased from the local markets in Hamilton, New Zealand. Fruit were de-stemmed, washed and left to dry in ambient air for 30 minutes. Grapes with uniform size were selected for drying tests. The chemicals used in this research include: olive oil, potassium carbonate, Folin−Ciocalteu phenol reagent (Sigma–Aldrich), Gallic acid (Sigma–Aldrich).

3.2. Experimental design

The experiment design was summarised in the Figure 3.1.

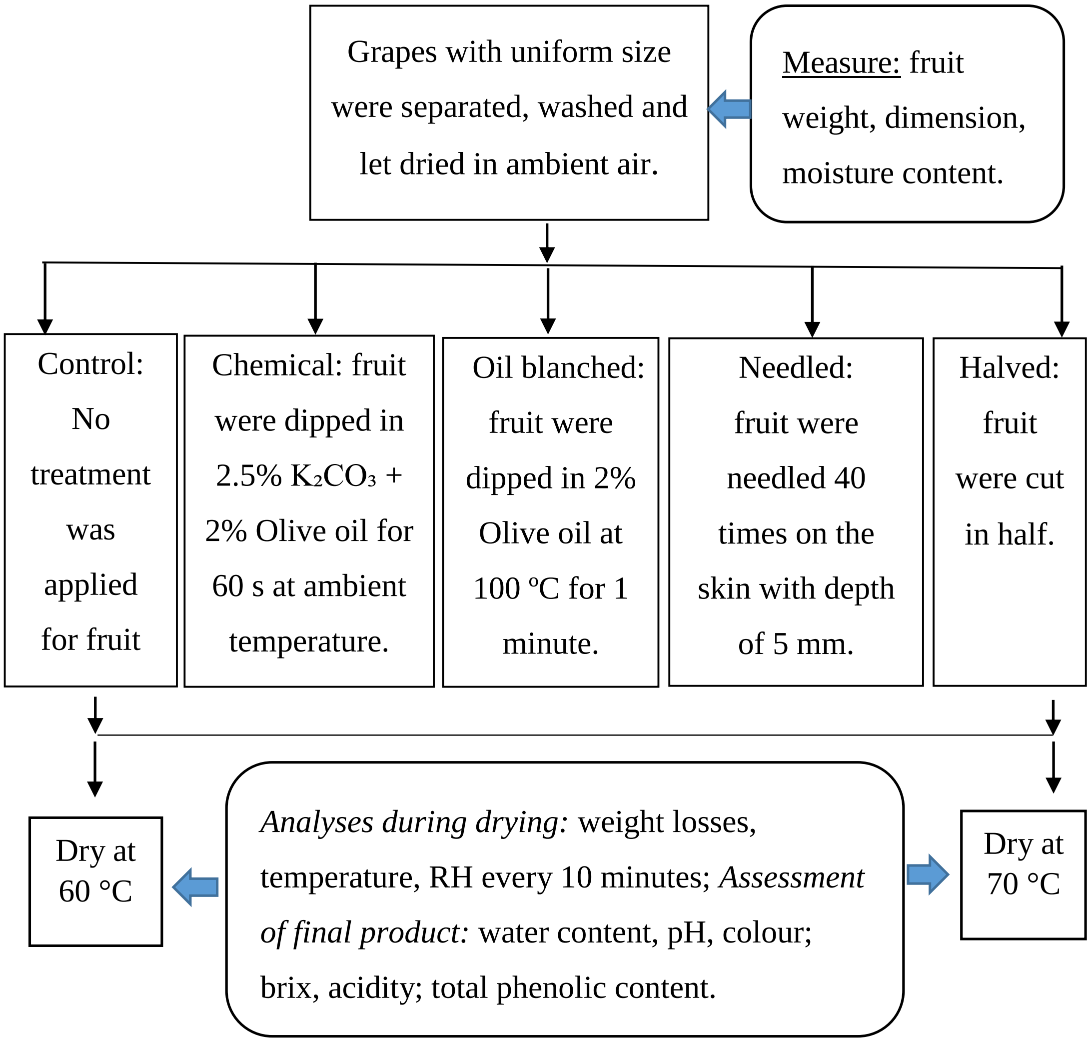

Figure 3.1. Flow chart of experimental design

3.3. Equipment

3.3.1. Dryer

This study used a 'GUNT CE130' tunnel convective dryer. Hot air drying was performed in the oven and air flow is horizontal over the trays/samples (Figure 3.2). The drying chamber structure is a horizontal rectangular metallic chamber with a dimension of 350 mm x 350 mm x 2340 mm (Gunt, 2017). The chamber has four drying trays, which contain the product to be dried and the dimension of a tray are 398 x 320 mm. Fan power is 33 W with maximum output of 700 m^3 h^{-1}. The fan operates at different voltages in order to supply variable speeds within the drying chamber from 0 - 2.5 ms^{-1}. The thermal energy source required for the dehydration process is provided by an electric heater and its power is 6750 W with adjustable temperature limiter. Measuring ranges from 0 - 100 % for relative humidity and 0 - 125 °C for temperature. The balance (KERNKB 10000-N1) with measuring range between 0 - 1000 g ± 0.01 g is connected to the dryer. The velocity for food dehydration processes is recommended to be less than 3 m s^{-1} (Castillo-Tellez et al., 2016).

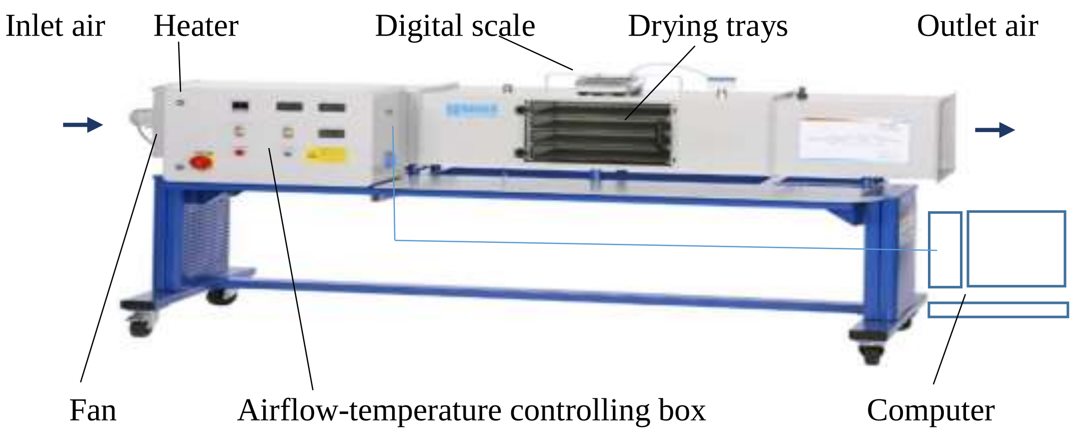

Figure 3.2. Dryer appearance and schematic diagram

3.3.2. Other instruments

Minolta CR-300 colorimeter and UV−visible spectrophotometer were used to measure colour and total phenolic compounds.

3.4. Procedures

The dryer was set to the desired temperature and air flow velocity 15 minutes before the start of the experiment such that steady state conditions were achieved. The velocity (around 1 m s^-) and drying temperature were selected for each batch (Gazor and Roustapour, 2015). The weight loss was recorded every 10 minutes during drying until a constant weight was obtained (i.e. differences in weight between 2 consecutive measurements over intervals of 10 minutes was about than 0.5 g. Data (mass, air velocity, temperature…) were recorded automatically using a computer connected to the dryer and the balance.

In each drying batch, samples of grape were distributed over one tray in a single layer. This experiment investigated two drying temperatures, at 60 °C and 70 °C under the air velocity of ~1 m/s. There were two replications for each treatment and 0.5 kg samples for each drying batch. There were five pre-drying treatments which were in Table 3.1.

Table 3.1. Treatments before drying process

Treatments	*Description*
Control	No pre-treatment;
Chemical dipped (commercial control)	Grapes were dipped in a solution of 2.5% K_2CO_3 + 2% olive oil for 60 s at ambient temperature (Chayjan et al., 2011);
Oil Blanched	Grapes were blanched in 2% olive oil at 100 °C for 60s;
Needled	Grapes were needled 40 times using a needle;
Halved	Grapes were cut in half.

3.5. Drying kinetics and assessments

3.5.1. Moisture content

The moisture contents of fruit were determined by oven drying at 105 °C till the constant weight reached (about 24 hours). The moisture content on dry basis was calculated using the Equation (1) in Chapter 2.

3.5.2. Moisture ratio

Moisture ratio was calculated by using the Equation (6) in Chapter 2.

3.5.3. Drying rate

Drying rate (*R*, g min^{-1}) was calculated from moisture content (*X*, kg water / kg dry basis) using the equation (5) in Chapter 2.

3.5.4. Models

The experimental thin-layer drying data of horticultural produce materials have been fitted to the drying models (Esmaiili et al., 2007; Johann et al., 2016; Yao-Xuan et al., 2014). Three models were used to test the fitness of the drying kinetics (Table 3.2).

Table 3.2. Empirical models to describe drying kinetics

Model	*Empirical formula*
Newton (Lewis)	MR = exp(-kt)
Page	MR = $\exp(-kt^n)$
Logarithmic	MR = $a*\exp(-kt^n) + c$

This study selected Newton, Page and Logarithmic models because they are the fundamental models to express the basic equation (11), (12) and (15).

3.5.5. Weight and dimension of grapes

The weights, diameters and lengths of 20 raisins were measured using a balance and Vernier callipers (Zemni et al., 2016).

3.5.6. Colour measurement

The colour of the dried grapes was evaluated by a Minolta CR-300 colorimeter (Konica Minolta Sensing Americas Inc., Ramsey, NJ) and colour parameters were determined based on L*, a* and b* values (lightness, redness/greenness and yellowness/blueness, respectively).

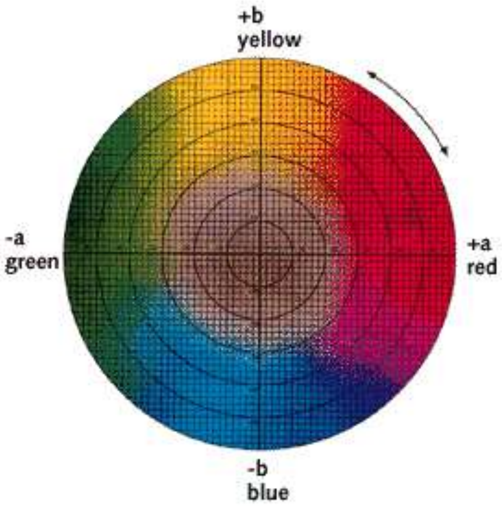

Figure 3.3. Colour chart (Konica Minolta, 2007)

Chroma (C*) and hue angle (h°) values were calculated using a* and b* values as following:

hue angle (°): $h = \arctan(b/a)$ (16)

and chroma: $C^* = \sqrt{a^{*2} + b^{*2}}$ (17)

For each colour feature, five measurements were done (Larrauri et al., 1997).

3.5.7. pH, titratable acidity and total soluble solid

In order to measure pH, titratable acidity and total soluble content of raisins, an aqueous extract was prepared according to the method of Zemni et al. (2016) with some modification. Briefly, 25 g of raisins were macerated with 50 mL of de-ionized water for 3 min. The resulting musts were boiled for 1 h, while water was added every 15 min. The samples were then cooled at room temperature for 30 min and diluted to 195 mL with deionized water. Raisin extracts were filtered using Whatman no. 4 filter papers.

pH of raisin: pH was measured at 20 °C using a pH meter.

Total soluble solids (TSS) Total soluble solids (TSS) were measured using a hand-held refractometers. Unit measurement (%) is the gram of total soluble solids per 100 gram of raisin weight.

Acidity: Titratable acidity was determined by titrating 10 mL of raisin extract to pH 8.1 with 0.1 N NaOH and expressed as mg of tartric acid content/100 g of g sample (Thakur et al., 2010), as following:

$$\text{Acidity (\%)} = (\text{ml NaOH titer} \times 0.0075) \times 100 / \text{ml juice} \qquad (18)$$

3.5.8. Total phenolic contents

Ten gram of raisins was homogenised and 3 gram of homogenised fruit was mixed with 30 mL of methanol containing 1% HCl for 1 h at room temperature (Pavlovic et al., 2016). The extract was placed in the dark at 4 °C for 24 h and then filtered, and the clear supernatant was collected. The amount of total phenolics was determined using indicator of Folin−Ciocalteu. Briefly, 0.1 mL of the sample extracts and 7.9 mL of ultrapure water were mixed with 0.5 mL of Folin−Ciocalteu reagent, and the solution was incubated for 6 min at room temperature. Next, 1.5 mL of 20% sodium carbonate was added. After 30 min at 40 °C, absorbance was measured at 765 nm using a Shimadzu spectrophotometer. A standard curve was generated with 0, 50, 100, 500, 1000 and 1250 mg gallic acid/L. A mixture of water and the reagent was used as a blank. The results (total phenolic contents) were expressed as milligram gallic acid equivalent (GAE) per gram of raisin weight (Pantelic et al., 2016).

3.6. Statistical analyses

The experiment had a completely randomised design. The one-way and single factor analysis of variance with the least significant difference at 95% confidence interval was used to test the significant differences of food quality attributes between treatments.

Nonlinear regression analyses were performed for thin-layer models with regard to moisture ratio versus time. The accuracy of the model equation was decided on the basis of coefficient of determination (R^2), sum of squares due to error (*SSE*), and root mean square error (*RMSE*) (Thakur et al., 2010; Bingol et al., 2012):

$$SSE = \sum_{1}^{n} (MR_{\text{experimental},i} - MR_{\text{predictied},\ i})^2 \qquad (19)$$

$$RMSE = \sqrt{\frac{1}{n} . \sum_{1}^{n} (MR_{\text{experimental},i} - MR_{\text{predictied},\ i})^2} \qquad (20)$$

4. RESULTS AND DISCUSSION

4.1. Fruit physical characteristics

All raw measurement data are available in the Appendix. Physical characteristics of fruit are important factors for drying. The average radius of grapes was 26.0 ± 0.9 mm in length; 25.0 ± 1.2 mm in diameter. The grape weight average was 4.67 ± 0.7 g. Fruit water content (wet basis) were determined by drying fruit at 105 °C and the result are shown in the Table 4.1.

Table 4.1. Water content of fresh grape materials

Date	Moisture content (%, wet basis)
16 March 2017	83.3 ± 1.13
27 March 2017	86.3 ± 0.22
31 March 2017	82.4 ± 0.47
3 April 2017	83.0 ± 0.46
9 May 2017	82.1 ± 0.97
15 May 2017	82.9 ± 0.05
17 May 2017	80.9 ± 0.39

(± Standard deviation)

The moisture contents of grapes bought in the market varied from time to time. Moisture content of fresh grape may depend on the fruit maturity, storage time and storage and selling conditions.

4.2. Drying rate changes during the drying process

Figure 4.1 shows the individual points of drying rate of grape at drying temperature of 60 °C. In general, drying rate reduced rapidly for all five treatments. The drying rate graph indicates that there was only a single, approximately linear-falling rate period. There does not appear to have any critical moisture contents where there is a sudden change in drying rate.

The treatments had a significant effect on drying rate of grapes. The control showed the lowest moisture removal rate, while the halved grape recorded the highest drying rate. The needling treatment had the second highest drying rate. The oil blanched sample showed higher reduction rate in moisture content compared to the chemical treated sample. This result was consistent with the finding of Vazquez et al. (2000) who showed that treatment with an aqueous solution of K_2CO_3 plus olive oil at 60 °C reduced remarkably drying time compared to control.

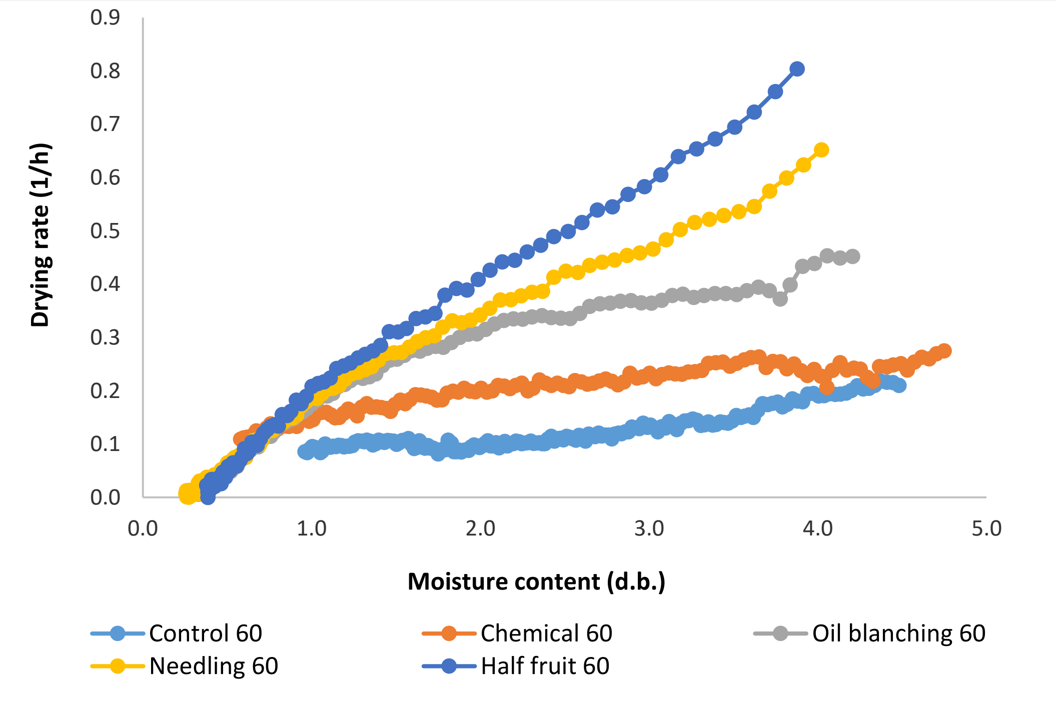

Figure 4.1. Drying rate changes with moisture content at 60 °C

The halved grapes showed the highest drying rate possibly because of changes in thickness. Moisture diffuses fast from inner to the surface of the halved fruit compared to any whole fruit samples because the moisture diffusion pathway is smaller in thinner materials than thick materials (Olawale and Omole, 2012). The other reason was due to partial removal of the skin barrier in halved grape compared to whole grape. Hot oil blanching increased drying rate faster than chemical treatment possibly because of cells de-compartmentisation. Heat from hot oil changed the tissue structure and waxy layer.

Figure 4.2 shows the drying rate of different treatments at 70 °C. It can be seen that linear-falling drying rates were observed except for needling treatment possibly because of uneven distribution of holes.

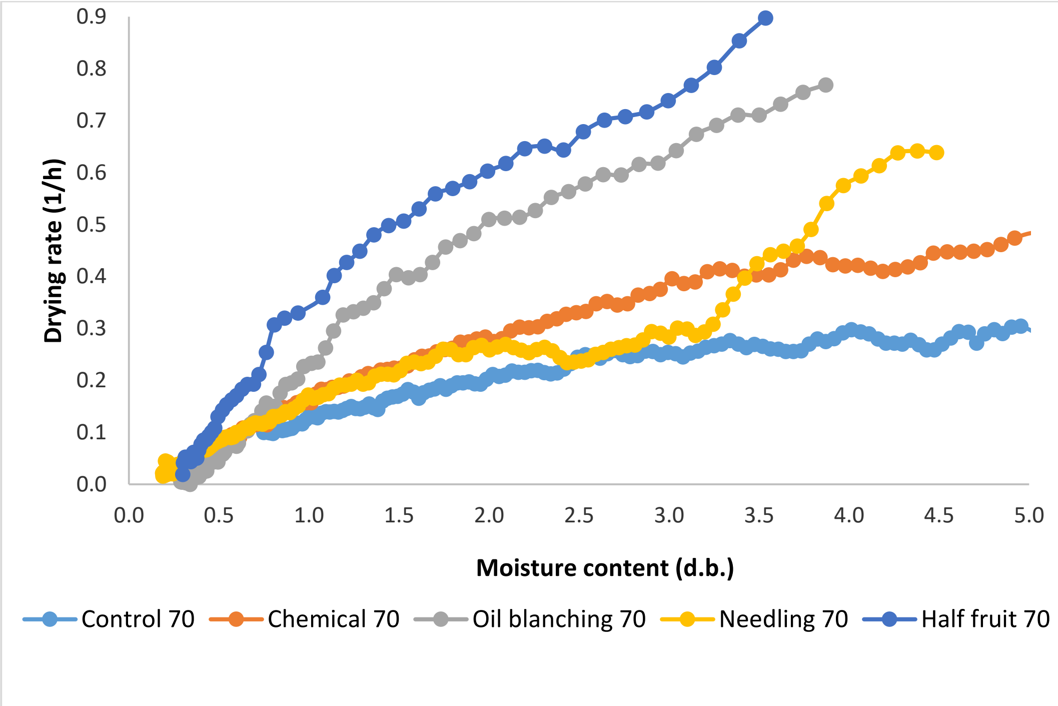

Figure 4.2. Drying rate changes with moisture content at 70 °C

Similar results were found to grapes dried at 60 °C. Control had the lowest reduction in drying rate, while halved fruit had the highest drying rate. However, at 70 °C, oil blanched sample had the second highest drying rate. Similar to drying at 60 °C, the thinner materials are, the faster the moisture diffuse and evaporate from the core to the surface of the materials. Moreover, higher surface tension resulting at hot oil dipping is also expected to lead to faster drying rate.

4.3. Moisture ratio changes during the drying process

Figure 4.3 shows the individual points of drying curve of moisture ratio changes with drying time for all five treatments at 60 °C. There was a consistant moisture ration changes for second replication (Apprendix B).

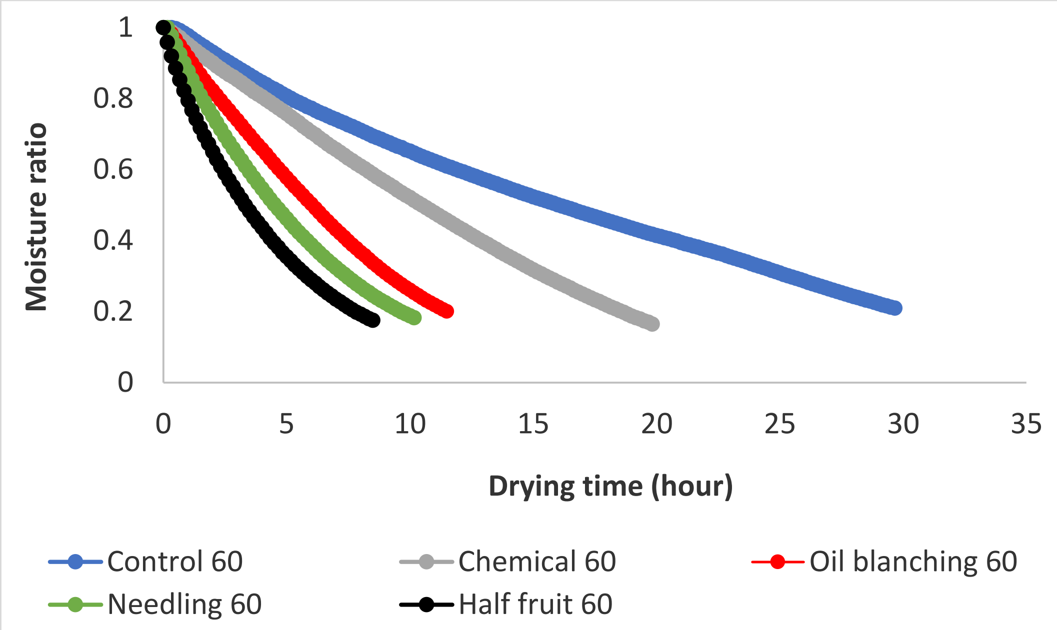

Figure 4.3. Moisture ratio changes during drying at 60 °C

Drying time of halved grape was about 9 hours, while the control took the longest drying time with nearly 30 hours. The capacity of moisture removal increased in halved fruit sample as it had less the skin compared to other whole fruit treatment. Oil blanching treatment took about 11 hours, nearly 50% shorter than chemical treatment. Needling treatment had slightly shorter than oil blanching. Similarly, Thakur et al. (2010) indicated that scratchy surfaced berries was more effective with shorter drying time than chemical treated berries.

Figure 4.4 demonstrates a reduction of moisture ratio in drying time of different treatments at 70 °C. Halved grape had the shortest drying time (about 7 hours), while the control took the longest (about 24 hours) to reach the same moisture content. The capacity of moisture removal increased in halved grapes as it had less the skin compared to other whole fruit treatment. Similarly, the halved fruit sample took less time to dry in comparison with berries with superficial abrasion of peel/waxy cuticle and whole berries (Thakur et al., 2010). Oil blanching treatment had much shorter drying time than any other whole fruit treatments as hot dipping may soften the skin and flesh structure. Hot water dipping was also found effectively to cherry (Gazor and Roustapour, 2015). Gazor and Roustapour (2015) showed that boiling water pre-drying treatment reduced drying time compared to ethyl oleate treatment.

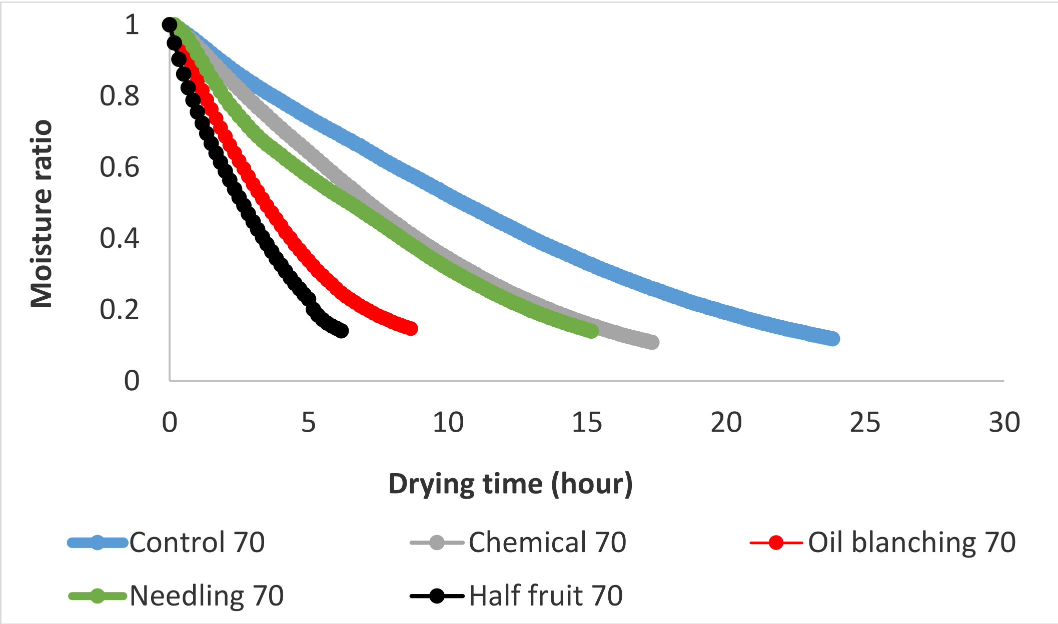

Figure 4.4. Moisture ratio changes during drying at 70 °C

At 70 °C, needling and chemical treatment had a similar effect in moisture ratio, while at 60 °C moisture ratio of needled fruit significantly reduced faster than chemical treated sample. Thus, needling may not help to reduce moisture ratio at the drying temperature of 70 °C compared to at the temperature of 60 °C.

4.4. Effect of drying temperature on drying behaviour

Figure 4.5 presents the effect of drying temperature on moisture ratio changes between 60 °C and 70 °C for oil blanching treatment, chemical treatment and control. The moisture ratio reduced fast with the increase of drying temperature from 60 °C to 70 °C for the treatments and control. As expected, drying temperature was a significant factor on drying process.

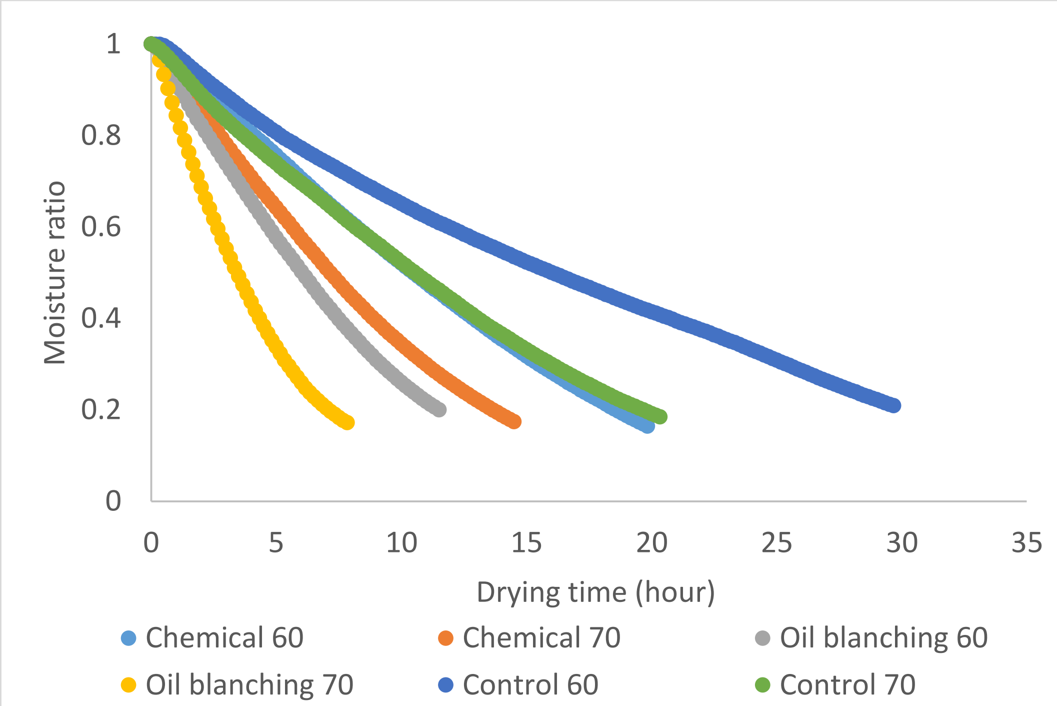

Figure 4.5. Effect of drying temperatures on moisture ratio of chemical treatment, oil blanching treatment and control

Figure 4.5 clearly illustrates that oil blanching treatment had shorter drying time than chemical treatments at both 60 °C and 70 °C, respectively. Even, oil blanching at 60 °C had shorter drying time than chemical treatment at 70 °C. This can be explained that oil blanching reduced wax skin layer resistance and softened the tissue structure as well, while chemical (K_2CO_3) was expected to reduce only wax layer of the fruit surface. Oil blanching reduced drying time about 42% at 60 °C and 50% at 70 °C compared to chemical treatment. Higher surface tension resulting at hot oil dipping is also expected to lead to faster drying rate. Olawale and Omole, (2012) also indicated that blanching could lead to inner structure changes of fruit, which facilitate moisture diffusion.

Figure 4.6 compares the impact of pre-drying treatment on the variation of drying rate with moisture content at 60 °C and 70 °C between oil blanching, chemical treatment and control.

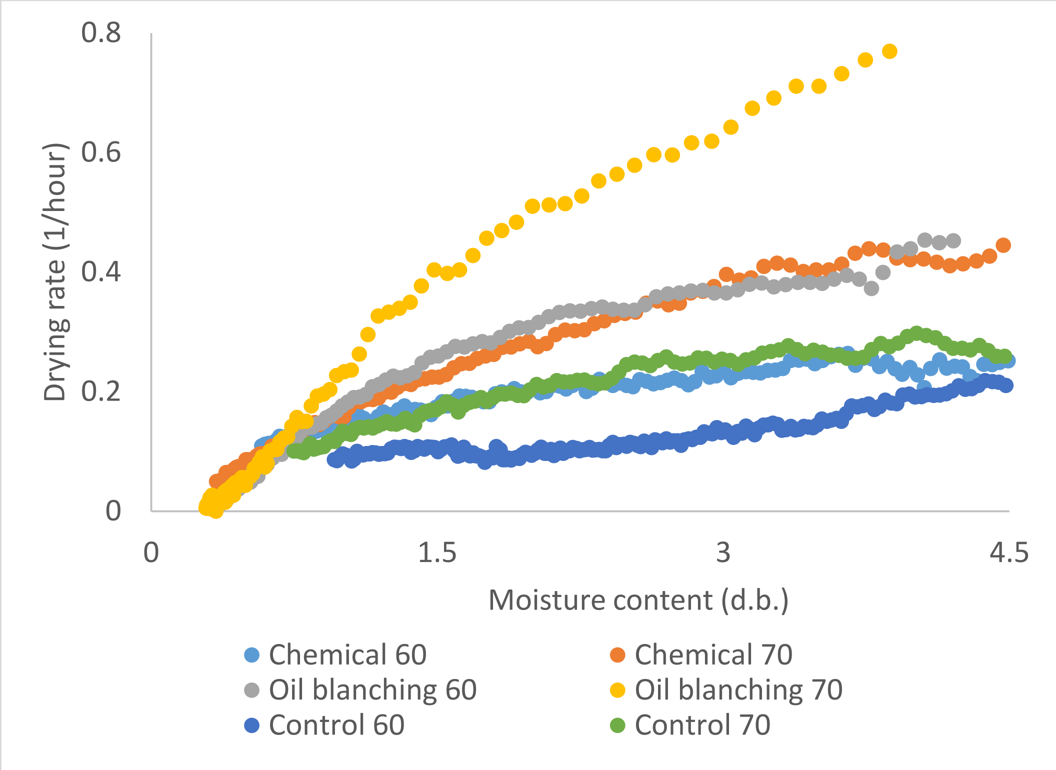

Figure 4.6. Effect of drying temperature (60 °C and 70 °C) on correlation of drying rate and moisture content (d.b.) of chemical treatment, oil blanching treatment and control

Oil blanching had higher in drying rate reduction than chemical treatment at both 60 and 70 °C. Control at 60 °C showed the lowest drying rate, while hot oil treatment had the highest drying rate. Oil blanching at 60 °C had similar trend with Chemical at 70 °C. Olawale and Omole (2012) found that drying rate of sweet potato slices increased with the drying temperature and samples with hot water dipping had shorted drying time than samples without hot water dipping. This confirms that wax removal by blanching is more effective than chemical dipping. It is noted that for moisture contents below 1.0 (d.b.), the drying rate is largely independent of pre-drying treatment since all the curves appear to be superimposed on each other.

Table 4.2 presents the effect of temperature on drying time of each treatment to reach the same moisture content of dried grape (1.0 dry basis). Drying time decreased significantly when drying temperature increased from 60 °C to 70 °C for all treatments and control.

To be specific, oil blanching had the highest reduction in drying length, nearly 40%. This reconfirmed that modification of tissue structure and waxy layer would facilitate water removal from fruit to environment during drying process. The decrease of drying time of chemical treatment and the control were 18.9 and 26.3 %, respectively. Similarly, increasing air temperature from 50 to 70 °C was found to reduce drying time of Quercus significantly (Tahmasebi et al., 2011).

Table 4.2. Drying time decrease with increase of temperature from 60 to 70 °C.

Treatment	Drying time at 60 °C (hour)	Drying time at 70 °C (hour)	Decrease in drying time (%)
Control	29.2	21.5	26.3
Chemical	18.5	15.0	18.9
Oil blanching	11.0	6.7	39.1

4.5. Drying model selection

Three thin layer-drying models (Page, Newton and Logarithmic models mentioned in Table 2.1 - Chapter 2 and Table 3.2 - Chapter 3), were used for correlating the drying kinetic data and to predict drying curves. Table 4.3 shows the fitting parameters of the three selected models for five treatments which were dried at 60 °C and 70 °C. It can easily be observed the effect of different treatments through the Newton model with drying constant k (min^{-1}); the higher the drying constant k was, the faster the rate of moisture removal. When dried at 60 °C, halved grapes had the highest moisture removal as it had the highest drying constant (12.0818). It was followed by needled samples (9.3015) and oil blanched samples (7.5461). Chemical and control had the lowest drying constant k with 4.3685 and 2.6974, respectively. At the drying temperature of 70 °C, the halved grapes also had the fastest moisture loss, but the oil blanched was the second fastest, which was almost two-fold faster than chemical treated fruit (Table 4.3).

Table 4.3. Fit parameters of thin-layer drying models for five treatments at 60 °C and 70 °C

T °C	Treatment	*Page*		*Newton*	*Logarithmic*			
		n	***k***	***k***	***A***	***c***	***N***	***k***
60	Control	1.105	3.074	2.697	0.992	0	1.126	3.116
	Chemical	1.344	7.537	4.369	0.966	0	1.444	8.398
	Oil blanch	1.156	10.118	7.546	1.032	0.002	1.070	8.893
	Needled	0.987	9.048	9.302	0.941	0.056	1.179	15.980
	Halved	0.903	9.643	12.082	0.918	0.059	1.065	16.231
70	Control	1.244	6.284	4.319	0.969	0	1.324	6.808
	Chemical	1.273	10.548	6.480	0.989	0	1.297	10.859
	Oil blanch	0.968	11.328	12.229	0.933	0.068	1.221	25.879
	Needled	1.120	8.891	7.155	0.983	0	1.151	9.212
	Halved	1.073	21.019	17.2623	0.973	0.002	1.112	22.667

The values of R^2, *RMSE* and *SSE* for the three thin-layer drying models are presented in Table 4.4. The goodness of fit of thin layer-drying models were assessed by using fundamental statistical parameters R^2, *RMSE* and *SSE*; the closer R^2 is to 1, and *RMSE* and *SSE* are to 0, the better the predictive ability of the model (Olawale and Omole, 2012). The R^2 values for all three models ranged from 0.9861 to 0.9998, indicating a good fit for all treatments. However, the logarithmic model was found to be the best model with the highest R^2 values and the lowest *RMSE* values for almost all treatments at both drying temperatures of 60 °C and 70 °C.

Table 4.4. Fit statistics of thin-layer drying models for five treatments at 60 °C and 70 °C

T °C	Treatment	Page			Newton- Lewis			Logarithmic		
		R^2	***RMSE***	***SSE***	***R^2***	***RMSE***	***SSE***	***R^2***	***RMSE***	***SSE***
60	Control	0.9971	0.012	0.013	0.9961	0.019	0.021	0.9972	0.012	0.012
	Chemical	0.9974	0.014	0.027	0.9861	0.048	0.308	0.9984	0.011	0.016
	Oil blanch	0.9958	0.019	0.052	0.9933	0.030	0.129	0.9953	0.019	0.054
	Needled	0.9927	0.023	0.092	0.9929	0.024	0.093	0.9998	0.004	0.003
	Halved	0.9967	0.015	0.022	0.9969	0.022	0.048	0.9995	0.005	0.003
70	Control	0.9979	0.013	0.023	0.9916	0.037	0.193	0.9986	0.010	0.014
	Chemical	0.9997	0.005	0.003	0.9949	0.041	0.217	0.9998	0.004	0.002
	Oil blanch	0.9872	0.031	0.123	0.9879	0.031	0.125	0.9997	0.004	0.002
	Needled	0.9973	0.014	0.031	0.9966	0.024	0.082	0.9974	0.014	0.029
	Halved	0.9973	0.014	0.013	0.9962	0.018	0.021	0.9975	0.014	0.012

Figure 4.7 compares the experimental data with the predicted data using the Logarithmic model for five treatments at 60 °C, respectively. These fits were typical of all curves fitted to experimental data using the Logarithmic model. The prediction using the Logarithmic model in Figure 4.7 illustrates moisture ratio values banded along black line. Thus, the Logarithmic model is able to describe the drying behaviour of grapes. Similarly, Adiletta et al. (2016) showed that logarithmic model models was highly appropriate for drying grapes.

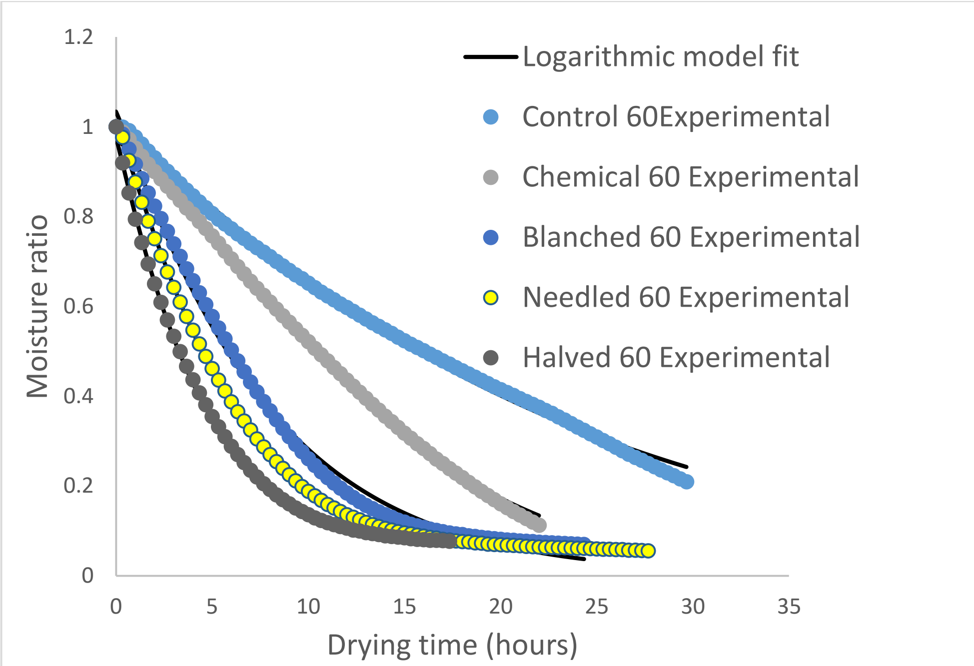

Figure 4.7. Logarithmic models fit into moisture ratio changes for five treatments during drying at 60 °C

Figure 4.8 presents the goodness of fit of the experimental data into the Logarithmic model for five treatments at 70 °C. The results were similar to the data collected during drying at 60 °C. Logarithmic model could be used as a model to express drying behaviour and to design the dryer for grapes.

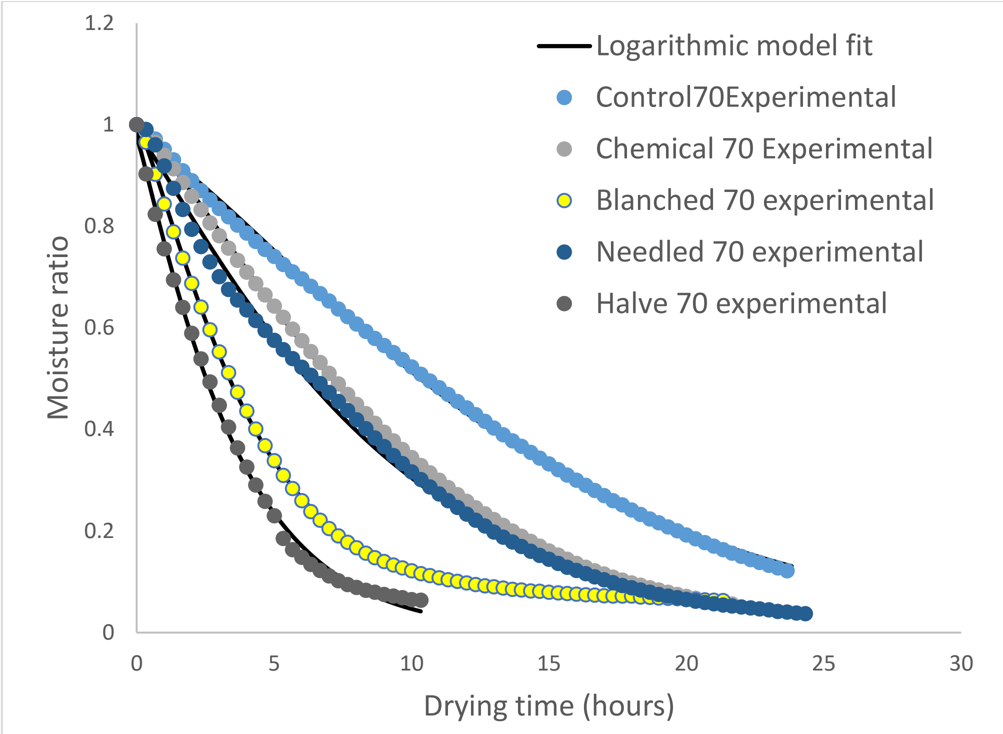

Figure 4.8. Logarithmic models fit into moisture ratio changes for five treatments during drying at 70 °C

4.6. Colour assessments of dried grapes

The final appearance of food products is of commercial importance. The colour measurements in average of two replications were measured in terms of lightness (L*) and coloration (a* and b*) values and expressed in term of L* and C* and h^{o}_{ab} -hue angle (Table 4.5). The results showed significant differences in colour attributes among treatments.

Table 4.5. Chromatic parameters of under different treatments

Drying temperature (°C)	Pre-drying treatments	Raisin colour	L*	C^*_{ab}	h^o_{ab}
	Control	Dark brown	25.0	6.7	51.2
	Chemical	Reddish brown	23.5	8.4	40.1
60	Oil Blanched	Reddish brown	23.6	8.7	44.0
	Needled	Light brown	28.7	11.3	58.9
	Halved	Light brown	32.0	13.7	67.4
	LSD0.05		*1.43*	*1.08*	*3.25*
	Control	Dark brown	25.3	10.2	47.7
	Chemical	Reddish brown	23.1	8.2	41.2
70	Oil Blanched	Reddish brown	23.9	9.6	43.3
	Needled	Light brown	31.0	14.1	64.5
	Halved	Light brown	28.4	12.1	57.7
	LSD0.05		*0.72*	*1.22*	*2.79*

Lightness L* value varied from 23 to 32. Similarly, Bai et al. (2013) reported variable L* values of Thomson seedless raisins subjected to different pre-treatments ranged from 22.20 to 54.33. Needling treatment and cutting in half had the highest L* value, while control had the lowest L* value. High L* indicates their light colour. Chemical treatment and oil blanching had similar L* value at both 60 °C and 70°C. The lightness depends not only on the drying method, drying parameters but also on the pre-drying treatment (Zemni et al., 2016).

On the other hand, all samples had hue angles (h^*_{ab}) which were less than π/2. That indicates a predominance of red coloration over the green and a predominance of yellow coloration over the blue. Samples had chroma indices (C^*), expressing the colour intensity or saturation, ranged from 6.7 to 13.7, which was consistent with the findings of Rybka et al. (2015) and Zemni et al. (2016). Hue (h°) values varied between 40.7 – 60.7°. The results was in concordance with those reported by Rybka et al. (2015) in Italian cultivar raisins (34.5° to 77.1°) depending on the drying time and conditions. It was obvious that the colour of dried grapes could be highly influenced by the pre-treatment conditions.

When chroma indices (C^*) and hue angles (h^*_{ab}) of each samples were assessed using the colour chart in Figure 3.3, the colour of all dried samples was brown on the quarter of red-yellow. It was consistent with the photos of samples in Figure 4.9 where all treatments had brown colour and shrinkage due to water loss. There were almost no effect of temperature on appearance among the samples dried at 60 °C and 70 °C. However, there were differences in raisin appearances among treatments at the same drying temperature. The Control had poor appearance quality with dark colour, while grapes with chemical treatments or oil blanching treatments had attractive appearance with reddish-brown colour. The needled fruits had sticky surface due to juice leak after treatment. Halved grapes had light and poor colour.

Figure 4.9a. Photos of raisin samples of control and chemical treatment and then dried at 60 °C (left) and 70 °C (right)

Figure 4.9b. Photos of raisin samples of oil blanching, needling, and halving, and then dried at 60 °C (left) and 70 °C (right)

4.7. Sensorial evaluation

The sensorial values (flavour and appearance in average of two replications) were evaluated by the author on personal assessment with the score from 1 (dislike) to 9 (very like) as shown in Table 4.6. In general, oil blanched samples retained the best flavour, while maintained the attractive appearance compared to other treatments and control at both 60 °C and 70 °C. Heat treatment may stop bioactive reactions which retained raisin's flavour and colour.

Table 4.6. Sensorial evaluation of different treatments

Drying temperature (°C)	Pre-drying treatments	Flavour (0-9)	Appearance (0-9)
60	Control	6.1	6.9
	Chemical	6.7	6.9
	Oil Blanching	7.4	8.0
	Needling	6.0	7.3
	Cut in half	6.0	5.4
70	Control	5.9	6.0
	Chemical	6.7	6.9
	Oil Blanching	7.0	7.6
	Needling	5.9	6.9
	Cut in half	6.0	6.1

4.8. Other attribute assessments

The proximate compositions of raisin samples are presented in average of two replications in Table 4.7. There were slight differences in pH with values ranging from 3.8 to 4.0. Meanwhile, there were significant differences in total soluble solid (TSS) and total phenolics. The lowest total soluble solid were recorded for chemical dipping at both 60 ℃ and 70 ℃. The reason was possibly that the potassium carbonate may affect the soluble matter of grapes. Hot oil treatments had highest total phenolic contents (806.8 and 968.1 mg of gallic acid equivalent (GAE) /g of dried grape) compared to other treatments and control. This can be explained of inactivation of phenolic enzymes at high temperature, which retained highest total phenolic contents.

Table 4.7. Quality attributes of different treatments and means for pH, acidity, total soluble solid, total phenolic content are significantly different (P < 0.05) by LSD.

Drying temp. (°C)	Pre-drying treatments	pH	Acidity (%)	Total soluble solid (%)	Total phenolic content (mg/g)
60	Control	4.0	2.3	74.1	699.5
	Chemical	4.0	1.5	62.8	548.1
	Oil Blanched	4.0	1.8	73.8	806.8
	Needled	4.0	1.9	72.1	566.1
	Halved	3.9	1.7	75.9	514.8
	LSD0.05	*0.06*	*0.05*	*0.89*	*8.8*
70	Control	3.8	1.9	73.7	569.5
	Chemical	3.9	1.8	69.7	696.1
	Oil Blanched	3.9	1.9	74.9	968.1
	Needled	3.9	2.0	74.6	646.8
	Halved	3.9	2.0	74.9	577.5
	LSD0.05	*0.05*	*0.10*	*5.75*	*37.6*

Phenolics are the substrates in the biochemical discolouration process and this process involves the reactions of browning enzymes: polyphenol oxidases and peroxidases (Beckman, 2000; Du Plooy et al., 2009). Polyphenol oxidases catalyse the conversion of monophenols into quinones (Chidtragoola et al., *20*11), while peroxidases oxidise phenolics by generating a hydrogen peroxide group (Jiang et al., 2004). Melanin is a final product of polymeration with a black colour (Queiroz et al., 2008). The activity of enzyme reaction reduced total phenolic content in raisin (Breksa et al., 2010). Treatment with hot oil solution may inactivate browning enzymes. Therefore, hot oil blanching retained the highest phenolic contents compared to other treatments and controls. The activity of polyphenol oxidases may be inhibited by temperatures of 70 - 90 °C (Queiroz et al., 2008). Peroxidases, thermal resistant enzymes, can be completely inactivated when treated with at 94 °C for 5 - 7 minutes (Ndiaye et al., 2009).

4.9. Significance of research findings

The significance of these results could improve industrial scale raisin production. Oil blanching does not require higher investment for equipment or time. It follows the same steps and the same time length as chemical dipping. However, it may require extra energy for heating the water solution of 2 % of oil to 100 °C. It would increase cost for extra energy consumption, but it would decrease the cost of chemical use.

Moreover, the new option can decrease drying time significantly. Therefore, it could save production cost for energy consumption for drying and increase the processing capacity. The new alternative can raise the selling price as no addictive chemical are used, which contribute to better human health. Drying temperature for oil blanching should be at 70 °C to reduce drying time by 40% time compared to at 60 °C.

5. CONCLUSION

The pre-drying treatments tested in the study had profound effects on moisture removal capacity and drying behaviour of grapes at both drying temperature of 60 °C and 70 °C. All treatments reduced significantly drying time compared to the control. That means treatments before drying grapes contribute to reduced energy consumption.

Oil blanching had similar quality appearance to chemical treatment with reddish colour. However, oil blanching shortened drying time by 42% at drying temperature of 60 °C and by 50% at drying temperature of 70 °C compared to chemical treatment. Oil blanching retained the highest total phenolic contents, which are important anti-oxidants. Halving the grapes reduced drying time the most, but this method seems to be impractical as poor appearance and may reduce consumer preference.

Three selected models were shown to highly fit into the experimental data of all treatments at both drying temperature of 60 ºC and 70 ºC. However, the logarithmic model has been found to be the best describing the kinetics of thin layer drying of grape for all treatments dried at both 60 °C and 70 °C.

Drying temperature is an important factor. Drying time decreased by 18-40% when increase drying temperature from 60 to 70 °C depending on treatments. It is advised that oil blanching should be used as pre-drying treatment and drying with oil blanching treatment should take place at 70 °C as drying time reduce nearly 40% compared to at 60 °C.

6. RECOMMENDATIONS

This study has shown that pre-drying treatments are important step to reduce waxy skin resistance of grapes, and then increase drying rate. Oil blanching treatment show significantly in moisture removal compared to other treatments. This means combination with tissue structure modification can enhance drying rate of grapes. In case consumers' preference is whole dried fruit. Oil blanching showed the most effective and consumer-friendly option. Oil blanching can replace the current commercial method with potassium carbonate. The method using hot oil treatment would be suitable for industrial application as it is a simple step. However, additional work is required before applying oil blanching into commercial practice. The following recommendations are made:

- Assess the use of grapes used for processing wine, raisin instead of table grapes.
- Investigate options to use cheaper oils such as canola oil, sun flower oil for blanching to reduce material cost.
- To scale up, more research should be done on the convective drying method with thick drying bed instead of a thin-drying modelling for drying grapes.

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8. APPENDICES

8.1. Raw Data

8.1.1. Raw data for control sample at 60 °C (replicate 1)

Raisin Drying data: Control grapes at 60 degC			
Air speed		1 m/s	
Air temperature		60 degC	
Relative humidity		35%	
Treatment		Control	
Replicate number		1	
Date:		9-May-17	
Initial moisture content		4.6 dry basis	
Time:	Mass-m	Moisture content	dX/dt
h:min:s	g		1/h
12:03:00 PM	310.21	4.572	
12:13:00 PM	308.85	4.548	0.172
12:23:00 PM	307.02	4.515	0.197
12:33:00 PM	305.19	4.482	0.210
12:43:00 PM	303.12	4.445	0.216
12:53:01 PM	301.19	4.410	0.217
1:03:01 PM	299.1	4.372	0.218
1:13:02 PM	297.14	4.337	0.210
1:23:02 PM	295.2	4.302	0.205
1:33:02 PM	293.34	4.269	0.204
1:43:03 PM	291.42	4.235	0.210
1:53:03 PM	289.45	4.199	0.201
2:03:03 PM	287.69	4.168	0.196
2:13:04 PM	285.81	4.134	0.194
2:23:04 PM	284.09	4.103	0.193
2:33:04 PM	282.22	4.069	0.195
2:43:05 PM	280.48	4.038	0.191
2:53:05 PM	278.67	4.006	0.191
3:03:05 PM	276.94	3.974	0.196
3:13:06 PM	275.04	3.940	0.194
3:23:06 PM	273.34	3.910	0.180
3:33:06 PM	271.7	3.880	0.181
3:43:06 PM	269.98	3.849	0.185
3:53:06 PM	268.26	3.819	0.175
4:03:06 PM	266.73	3.791	0.170
4:13:06 PM	265.1	3.762	0.179
4:23:07 PM	263.4	3.731	0.177
4:33:07 PM	261.82	3.703	0.175
4:43:07 PM	260.16	3.673	0.176
4:53:07 PM	258.55	3.644	0.163
5:03:07 PM	257.13	3.619	0.150
5:13:07 PM	255.76	3.594	0.155
5:23:07 PM	254.25	3.567	0.152
5:33:08 PM	252.93	3.543	0.150
5:43:08 PM	251.46	3.517	0.154
5:53:08 PM	250.07	3.492	0.144
6:03:09 PM	248.79	3.469	0.140
6:13:09 PM	247.48	3.445	0.141
6:23:09 PM	246.18	3.422	0.142
6:33:10 PM	244.85	3.398	0.137
6:43:10 PM	243.64	3.376	0.136
6:53:11 PM	242.33	3.353	0.142
7:03:11 PM	241.01	3.329	0.136
7:13:11 PM	239.8	3.307	0.135
7:23:12 PM	238.5	3.284	0.145
7:33:12 PM	237.11	3.259	0.147
7:43:12 PM	235.77	3.235	0.144
7:53:12 PM	234.43	3.211	0.144
8:03:12 PM	233.1	3.187	0.139
8:13:13 PM	231.85	3.165	0.128
8:23:13 PM	230.73	3.144	0.137
8:33:13 PM	229.31	3.119	0.142
8:43:13 PM	228.09	3.097	0.130
8:53:14 PM	226.89	3.075	0.133
9:03:14 PM	225.62	3.053	0.123
9:13:15 PM	224.6	3.034	0.130
9:23:15 PM	223.2	3.009	0.136
9:33:15 PM	222.08	2.989	0.131
9:43:16 PM	220.76	2.965	0.140
9:53:16 PM	219.49	2.943	0.129
10:03:16 PM	218.36	2.922	0.130
10:13:17 PM	217.07	2.899	0.133
10:23:17 PM	215.9	2.878	0.123
10:33:17 PM	214.78	2.858	0.123
10:43:18 PM	213.61	2.837	0.120
10:53:18 PM	212.56	2.818	0.121
11:03:18 PM	211.37	2.797	0.119
11:13:18 PM	210.35	2.778	0.110
11:23:18 PM	209.33	2.760	0.117
11:33:19 PM	208.17	2.739	0.117
11:43:19 PM	207.15	2.721	0.115
11:53:19 PM	206.03	2.701	0.121
12:03:19 AM	204.91	2.681	0.114
12:13:20 AM	203.91	2.663	0.117
12:23:20 AM	202.74	2.642	0.119
12:33:20 AM	201.7	2.623	0.106
12:43:20 AM	200.77	2.606	0.113
12:53:20 AM	199.6	2.585	0.117
1:03:20 AM	198.6	2.567	0.108
1:13:21 AM	197.6	2.549	0.110
1:23:21 AM	196.56	2.531	0.113
1:33:22 AM	195.5	2.512	0.115
1:43:22 AM	194.43	2.492	0.108
1:53:22 AM	193.49	2.475	0.112
2:03:23 AM	192.36	2.455	0.111
2:13:23 AM	191.43	2.438	0.106
2:23:24 AM	190.39	2.420	0.115

2:33:24 AM	189.3	2.400	0.109
2:43:24 AM	188.36	2.383	0.101
2:53:24 AM	187.42	2.366	0.101
3:03:25 AM	186.48	2.350	0.103
3:13:25 AM	185.51	2.332	0.102
3:23:25 AM	184.58	2.315	0.102
3:33:25 AM	183.62	2.298	0.106
3:43:26 AM	182.61	2.280	0.103
3:53:26 AM	181.71	2.264	0.102
4:03:26 AM	180.71	2.246	0.101
4:13:27 AM	179.83	2.230	0.105
4:23:27 AM	178.77	2.211	0.106
4:33:27 AM	177.86	2.195	0.101
4:43:27 AM	176.89	2.177	0.101
4:53:28 AM	175.98	2.161	0.097
5:03:28 AM	175.09	2.145	0.105
5:13:28 AM	174.03	2.126	0.102
5:23:29 AM	173.2	2.111	0.093
5:33:29 AM	172.3	2.095	0.103
5:43:29 AM	171.29	2.077	0.097
5:53:30 AM	170.5	2.063	0.097
6:03:30 AM	169.49	2.044	0.107
6:13:30 AM	168.52	2.027	0.102
6:23:31 AM	167.6	2.010	0.097
6:33:31 AM	166.72	1.995	0.094
6:43:32 AM	165.86	1.979	0.097
6:53:32 AM	164.92	1.962	0.099
7:03:32 AM	164.03	1.946	0.095
7:13:32 AM	163.16	1.931	0.088
7:23:33 AM	162.39	1.917	0.090
7:33:33 AM	161.49	1.901	0.088
7:43:33 AM	160.75	1.887	0.086
7:53:33 AM	159.9	1.872	0.089
8:03:33 AM	159.1	1.858	0.086
8:13:33 AM	158.3	1.843	0.086
8:23:33 AM	157.5	1.829	0.102
8:33:34 AM	156.4	1.809	0.108
8:43:34 AM	155.5	1.793	0.089
8:53:35 AM	154.74	1.779	0.091
9:03:35 AM	153.81	1.763	0.088
9:13:35 AM	153.1	1.750	0.082
9:23:36 AM	152.29	1.735	0.091
9:33:36 AM	151.42	1.720	0.093
9:43:37 AM	150.57	1.705	0.093
9:53:37 AM	149.7	1.689	0.098
10:03:37 AM	148.76	1.672	0.093
10:13:38 AM	147.98	1.658	0.100
10:23:38 AM	146.91	1.639	0.107
10:33:38 AM	146	1.622	0.094
10:43:39 AM	145.17	1.608	0.092
10:53:39 AM	144.29	1.592	0.101
11:03:39 AM	143.3	1.574	0.110
11:13:40 AM	142.24	1.555	0.108
11:23:40 AM	141.3	1.538	0.107
11:33:41 AM	140.25	1.519	0.103
11:43:41 AM	139.39	1.504	0.100
11:53:41 AM	138.4	1.486	0.106
12:03:41 PM	137.42	1.468	0.107
12:13:42 PM	136.42	1.450	0.107
12:23:42 PM	135.43	1.433	0.103
12:33:42 PM	134.5	1.416	0.106
12:43:43 PM	133.47	1.397	0.108
12:53:43 PM	132.5	1.380	0.101
1:03:43 PM	131.59	1.364	0.099
1:13:43 PM	130.67	1.347	0.106
1:23:44 PM	129.62	1.328	0.108
1:33:44 PM	128.67	1.311	0.105
1:43:44 PM	127.68	1.293	0.106
1:53:44 PM	126.7	1.276	0.107
2:03:44 PM	125.7	1.258	0.104
2:13:44 PM	124.77	1.241	0.098
2:23:45 PM	123.89	1.225	0.096
2:33:45 PM	122.98	1.209	0.096
2:43:45 PM	122.1	1.193	0.095
2:53:46 PM	121.21	1.177	0.098
3:03:46 PM	120.29	1.161	0.098
3:13:46 PM	119.39	1.145	0.096
3:23:46 PM	118.51	1.129	0.096
3:33:47 PM	117.6	1.112	0.094
3:43:47 PM	116.76	1.097	0.096
3:53:47 PM	115.82	1.080	0.100
4:03:47 PM	114.9	1.064	0.087
4:13:48 PM	114.2	1.051	0.084
4:23:48 PM	113.34	1.036	0.091
4:33:48 PM	112.52	1.021	0.094
4:43:49 PM	111.6	1.005	0.096
4:53:49 PM	110.74	0.989	0.091
5:03:50 PM	109.91	0.974	0.085
5:13:50 PM	109.17	0.961	0.086
Data End			

8.1.2. Raw data for control sample at 70 °C (replicate 1)

Raisin Drying data: Control grapes at 70 degC			
Air speed		1 m/s	
Air temperature		70 degC	
Relative humidity		35%	
Treatment		Control	
Replicate number		1	
Date:		29-Mar-17	
Initial moisture content		6.3 dry basis	
Time:	m, Mass	Moisture content d	dX/dt
h:min:s	g		1/h
10:53:19 AM	377.27	6.299	
11:03:19 AM	375.87	6.272	0.206
11:13:20 AM	373.72	6.231	0.277
11:23:20 AM	371.1	6.180	0.331
11:33:20 AM	368.01	6.120	0.363
11:43:20 AM	364.85	6.059	0.374
11:53:20 AM	361.57	5.996	0.384
12:03:21 PM	358.23	5.931	0.394
12:13:21 PM	354.78	5.864	0.404
12:23:21 PM	351.27	5.796	0.402
12:33:22 PM	347.86	5.730	0.392
12:43:22 PM	344.51	5.665	0.379
12:53:23 PM	341.33	5.604	0.369
1:03:23 PM	338.16	5.543	0.360
1:13:24 PM	335.13	5.484	0.345
1:23:24 PM	332.21	5.427	0.349
1:33:24 PM	329.11	5.367	0.347
1:43:25 PM	326.24	5.312	0.322
1:53:25 PM	323.56	5.260	0.322
2:03:26 PM	320.7	5.205	0.316
2:13:26 PM	318.12	5.155	0.312
2:23:26 PM	315.33	5.101	0.306
2:33:26 PM	312.84	5.053	0.290
2:43:27 PM	310.34	5.004	0.297
2:53:27 PM	307.72	4.954	0.305
3:03:27 PM	305.09	4.903	0.303
3:13:28 PM	302.5	4.853	0.291
3:23:28 PM	300.08	4.806	0.298
3:33:28 PM	297.37	4.753	0.290
3:43:28 PM	295.08	4.709	0.272
3:53:28 PM	292.68	4.663	0.293
4:03:29 PM	290.03	4.611	0.294
4:13:29 PM	287.61	4.565	0.282
4:23:29 PM	285.17	4.517	0.270
4:33:29 PM	282.95	4.474	0.259
4:43:29 PM	280.71	4.431	0.259
4:53:30 PM	278.49	4.388	0.269
5:03:30 PM	276.08	4.341	0.277
5:13:31 PM	273.71	4.296	0.270
5:23:31 PM	271.43	4.252	0.272
5:33:32 PM	269.02	4.205	0.272
5:43:32 PM	266.74	4.161	0.280
5:53:33 PM	264.19	4.111	0.290
6:03:33 PM	261.74	4.064	0.294
6:13:33 PM	259.13	4.014	0.298
6:23:34 PM	256.61	3.965	0.292
6:33:34 PM	254.1	3.916	0.281
6:43:35 PM	251.77	3.871	0.275
6:53:35 PM	249.36	3.825	0.280
7:03:36 PM	246.94	3.778	0.270
7:13:36 PM	244.7	3.734	0.257
7:23:37 PM	242.51	3.692	0.256
7:33:37 PM	240.29	3.649	0.256
7:43:38 PM	238.1	3.607	0.261
7:53:38 PM	235.8	3.562	0.261
8:03:38 PM	233.6	3.520	0.266
8:13:39 PM	231.22	3.474	0.269
8:23:39 PM	228.96	3.430	0.264
8:33:39 PM	226.68	3.386	0.270
8:43:40 PM	224.3	3.340	0.277
8:53:40 PM	221.91	3.293	0.270
9:03:40 PM	219.65	3.250	0.267
9:13:40 PM	217.31	3.204	0.264
9:23:41 PM	215.1	3.162	0.257
9:33:41 PM	212.89	3.119	0.253
9:43:41 PM	210.74	3.077	0.246
9:53:42 PM	208.66	3.037	0.252
10:03:42 PM	206.4	2.993	0.254
10:13:42 PM	204.28	2.952	0.250
10:23:43 PM	202.1	2.910	0.256
10:33:43 PM	199.87	2.867	0.257
10:43:44 PM	197.68	2.825	0.248
10:53:44 PM	195.6	2.784	0.246
11:03:44 PM	193.44	2.743	0.250
11:13:44 PM	191.3	2.701	0.258
11:23:45 PM	189	2.657	0.252
11:33:45 PM	186.96	2.617	0.243
11:43:46 PM	184.81	2.576	0.248
11:53:46 PM	182.69	2.535	0.250
12:03:47 AM	180.51	2.492	0.245
12:13:47 AM	178.47	2.453	0.233
12:23:47 AM	176.5	2.415	0.222
12:33:48 AM	174.64	2.379	0.215
12:43:48 AM	172.8	2.343	0.213
12:53:48 AM	170.97	2.308	0.215
1:03:48 AM	169.09	2.271	0.219

1:13:48 AM	167.19	2.235	0.219
1:23:48 AM	165.32	2.199	0.216
1:33:49 AM	163.47	2.163	0.216
1:43:49 AM	161.6	2.127	0.218
1:53:50 AM	159.71	2.090	0.210
2:03:50 AM	157.98	2.057	0.208
2:13:50 AM	156.13	2.021	0.212
2:23:51 AM	154.33	1.986	0.203
2:33:51 AM	152.64	1.953	0.193
2:43:52 AM	151	1.921	0.194
2:53:52 AM	149.3	1.889	0.197
3:03:52 AM	147.6	1.856	0.196
3:13:52 AM	145.93	1.823	0.196
3:23:53 AM	144.23	1.791	0.190
3:33:53 AM	142.66	1.760	0.183
3:43:53 AM	141.07	1.729	0.190
3:53:53 AM	139.39	1.697	0.184
4:03:54 AM	137.9	1.668	0.182
4:13:54 AM	136.26	1.636	0.176
4:23:54 AM	134.86	1.609	0.166
4:33:55 AM	133.4	1.581	0.178
4:43:55 AM	131.8	1.550	0.183
4:53:56 AM	130.25	1.520	0.174
5:03:56 AM	128.8	1.492	0.169
5:13:56 AM	127.33	1.464	0.168
5:23:56 AM	125.9	1.436	0.166
5:33:57 AM	124.47	1.408	0.160
5:43:57 AM	123.14	1.382	0.145
5:53:57 AM	121.98	1.360	0.147
6:03:58 AM	120.6	1.333	0.155
6:13:58 AM	119.31	1.308	0.149
6:23:58 AM	118.04	1.284	0.146
6:33:59 AM	116.8	1.260	0.146
6:43:59 AM	115.52	1.235	0.150
6:54:00 AM	114.22	1.210	0.146
7:04:00 AM	113	1.186	0.143
7:14:01 AM	111.76	1.162	0.139
7:24:01 AM	110.6	1.140	0.141
7:34:02 AM	109.33	1.115	0.139
7:44:02 AM	108.2	1.093	0.140
7:54:03 AM	106.92	1.069	0.137
8:04:03 AM	105.84	1.048	0.128
8:14:03 AM	104.71	1.026	0.130
8:24:04 AM	103.6	1.004	0.133
8:34:04 AM	102.41	0.981	0.125
8:44:04 AM	101.45	0.963	0.117
8:54:05 AM	100.4	0.942	0.118
9:04:05 AM	99.42	0.924	0.114
9:14:06 AM	98.43	0.904	0.108
9:24:06 AM	97.56	0.888	0.107

9:34:07 AM	96.59	0.869	0.105
9:44:07 AM	95.75	0.853	0.104
9:54:07 AM	94.8	0.834	0.113
10:04:07 AM	93.81	0.815	0.104
10:14:07 AM	93	0.799	0.098
10:24:08 AM	92.12	0.782	0.099
10:34:08 AM	91.29	0.766	0.101
10:44:08 AM	90.38	0.749	2.299
10:54:08 AM	89.56		

8.1.3. Raw data for chemically treated sample at 60 °C, (replicate 1)

Raisin Drying data: Chemically treated grapes at 60			
Air speed		1 m/s	
Air temperature		60 degC	
Relative humidity		35%	
Treatment		Chemically treated grap	
Replicate number		1	
Date:		22-Mar-17	
Initial moisture content		5.0 dry basis	
t	m, Mass	Moisture cc	dX/dt
h:min:s	g		1/h
12:48:55 PM	372.88	4.961	0.173
12:58:55 PM	371	4.930	0.210
1:08:56 PM	368.5	4.891	0.246
1:18:56 PM	365.87	4.848	0.288
1:28:56 PM	362.5	4.795	0.296
1:38:57 PM	359.7	4.750	0.275
1:48:57 PM	356.76	4.703	0.270
1:58:57 PM	354.08	4.660	0.260
2:08:58 PM	351.34	4.616	0.263
2:18:58 PM	348.59	4.572	0.254
2:28:58 PM	346.04	4.531	0.239
2:38:59 PM	343.6	4.492	0.251
2:48:59 PM	340.8	4.448	0.249
2:58:59 PM	338.41	4.410	0.245
3:09:00 PM	335.69	4.366	0.246
3:19:00 PM	333.29	4.328	0.218
3:29:01 PM	331.14	4.293	0.225
3:39:01 PM	328.59	4.253	0.241
3:49:01 PM	326.11	4.213	0.243
3:59:02 PM	323.53	4.172	0.239
4:09:02 PM	321.12	4.133	0.253
4:19:02 PM	318.25	4.087	0.239
4:29:02 PM	316.14	4.054	0.207
4:39:02 PM	313.94	4.018	0.228
4:49:03 PM	311.39	3.978	0.240
4:59:03 PM	308.93	3.938	0.229
5:09:04 PM	306.61	3.901	0.238
5:19:04 PM	303.97	3.859	0.250
5:29:04 PM	301.39	3.818	0.242
5:39:04 PM	298.93	3.778	0.255
5:49:05 PM	296.08	3.733	0.256
5:59:05 PM	293.6	3.693	0.244
6:09:05 PM	290.99	3.652	0.264
6:19:05 PM	288.1	3.605	0.262
6:29:05 PM	285.52	3.564	0.258
6:39:05 PM	282.71	3.519	0.252
6:49:05 PM	280.27	3.480	0.246
6:59:06 PM	277.57	3.437	0.254
7:09:06 PM	274.97	3.395	0.253
7:19:06 PM	272.3	3.353	0.252
7:29:07 PM	269.72	3.312	0.239
7:39:07 PM	267.32	3.273	0.236
7:49:07 PM	264.8	3.233	0.235
7:59:07 PM	262.41	3.195	0.231
8:09:08 PM	259.98	3.156	0.232
8:19:08 PM	257.57	3.117	0.234
8:29:08 PM	255.11	3.078	0.231
8:39:09 PM	252.76	3.040	0.223
8:49:09 PM	250.46	3.004	0.233
8:59:09 PM	247.9	2.963	0.226
9:09:09 PM	245.74	2.928	0.224
9:19:10 PM	243.23	2.888	0.233
9:29:10 PM	240.88	2.850	0.217
9:39:10 PM	238.71	2.816	0.211
9:49:11 PM	236.47	2.780	0.218
9:59:11 PM	234.16	2.743	0.223
10:09:11 PM	231.83	2.706	0.219
10:19:11 PM	229.6	2.670	0.215
10:29:12 PM	227.35	2.634	0.213
10:39:12 PM	225.16	2.599	0.217
10:49:12 PM	222.82	2.562	0.220
10:59:13 PM	220.58	2.526	0.208
11:09:13 PM	218.48	2.492	0.211
11:19:14 PM	216.19	2.456	0.214
11:29:14 PM	214.01	2.421	0.211
11:39:14 PM	211.8	2.386	0.214
11:49:14 PM	209.54	2.350	0.221
11:59:15 PM	207.2	2.312	0.205
12:09:15 AM	205.26	2.281	0.200
12:19:15 AM	203.03	2.245	0.215
12:29:15 AM	200.78	2.209	0.211
12:39:16 AM	198.64	2.175	0.204
12:49:16 AM	196.52	2.141	0.209
12:59:16 AM	194.28	2.106	0.211
1:09:17 AM	192.13	2.071	0.200
1:19:17 AM	190.11	2.039	0.198
1:29:17 AM	188	2.005	0.205
1:39:17 AM	185.84	1.971	0.199
1:49:17 AM	183.86	1.939	0.199
1:59:17 AM	181.68	1.904	0.205
2:09:17 AM	179.59	1.871	0.198
2:19:18 AM	177.56	1.838	0.199
2:29:18 AM	175.43	1.804	0.196
2:39:18 AM	173.47	1.773	0.183
2:49:18 AM	171.61	1.743	0.183
2:59:19 AM	169.66	1.712	0.188
3:09:19 AM	167.69	1.681	0.190

3:19:20 AM	165.69	1.649	0.192
3:29:20 AM	163.68	1.616	0.193
3:39:20 AM	161.67	1.584	0.184
3:49:20 AM	159.84	1.555	0.176
3:59:20 AM	158	1.526	0.183
4:09:20 AM	156.03	1.494	0.174
4:19:21 AM	154.37	1.468	0.162
4:29:21 AM	152.66	1.440	0.167
4:39:21 AM	150.89	1.412	0.169
4:49:21 AM	149.14	1.384	0.170
4:59:22 AM	147.34	1.355	0.170
5:09:22 AM	145.6	1.327	0.176
5:19:22 AM	143.67	1.297	0.170
5:29:22 AM	142.06	1.271	0.153
5:39:23 AM	140.47	1.245	0.162
5:49:23 AM	138.69	1.217	0.166
5:59:23 AM	137.01	1.190	0.158
6:09:24 AM	135.39	1.164	0.150
6:19:24 AM	133.88	1.140	0.150
6:29:24 AM	132.27	1.114	0.155
6:39:24 AM	130.65	1.088	0.160
6:49:24 AM	128.94	1.061	0.160
6:59:25 AM	127.32	1.035	0.157
7:09:25 AM	125.66	1.009	0.146
7:19:26 AM	124.27	0.986	0.143
7:29:26 AM	122.68	0.961	0.152
7:39:27 AM	121.09	0.936	0.147
7:49:27 AM	119.62	0.912	0.134
7:59:28 AM	118.3	0.891	0.136
8:09:28 AM	116.78	0.867	0.134
8:19:29 AM	115.51	0.846	0.134
8:29:29 AM	113.98	0.822	0.139
8:39:29 AM	112.62	0.800	0.129
8:49:29 AM	111.29	0.779	0.128
8:59:30 AM	109.96	0.758	0.138
9:09:30 AM	108.41	0.733	0.130
9:19:31 AM	107.24	0.714	0.115
9:29:31 AM	106.01	0.695	0.122
9:39:31 AM	104.69	0.673	0.125
9:49:31 AM	103.4	0.653	0.117
9:59:32 AM	102.24	0.634	0.110
10:09:32 AM	101.1	0.616	0.113
10:19:32 AM	99.88	0.597	0.112
10:29:33 AM	98.77	0.579	0.109
10:39:33 AM	97.6	0.560	1.737

8.1.4. Raw data for chemically treated sample at 70 °C, (replicate 1)

Raisin Drying data: Chemically treated grapes at 70 c			
Air speed		1 m/s	
Air temperature		70 degC	
Relative humidity		35%	
Treatment		Chemically treated gra	
Replicate number		1	
Date:		27-Mar-17	
Initial moisture content		6.3 dry basis	
t	m, Mass	Moisture c	dX/dt
h:min:s	g		1/h
11:41:04 AM	322.36	6.299	
11:51:04 AM	320.96	6.268	0.241
12:01:05 PM	318.81	6.219	0.344
12:11:05 PM	315.89	6.153	0.412
12:21:05 PM	312.75	6.082	0.451
12:31:05 PM	309.25	6.002	0.486
12:41:05 PM	305.59	5.920	0.499
12:51:06 PM	301.9	5.836	0.505
1:01:06 PM	298.15	5.751	0.512
1:11:06 PM	294.36	5.665	0.510
1:21:06 PM	290.64	5.581	0.512
1:31:07 PM	286.83	5.495	0.512
1:41:07 PM	283.1	5.410	0.501
1:51:07 PM	279.45	5.328	0.496
2:01:07 PM	275.8	5.245	0.491
2:11:08 PM	272.22	5.164	0.488
2:21:08 PM	268.61	5.082	0.486
2:31:08 PM	265.06	5.002	0.483
2:41:09 PM	261.5	4.921	0.474
2:51:09 PM	258.08	4.844	0.462
3:01:10 PM	254.7	4.767	0.452
3:11:10 PM	251.43	4.693	0.449
3:21:10 PM	248.09	4.618	0.447
3:31:10 PM	244.85	4.544	0.448
3:41:10 PM	241.5	4.468	0.445
3:51:11 PM	238.3	4.396	0.427
4:01:11 PM	235.22	4.326	0.418
4:11:11 PM	232.14	4.256	0.414
4:21:12 PM	229.13	4.188	0.410
4:31:12 PM	226.1	4.120	0.416
4:41:12 PM	223	4.049	0.422
4:51:12 PM	219.89	3.979	0.420
5:01:13 PM	216.81	3.909	0.423
5:11:13 PM	213.66	3.838	0.437
5:21:13 PM	210.38	3.764	0.439
5:31:14 PM	207.2	3.692	0.431
5:41:14 PM	204.03	3.620	0.413
5:51:14 PM	201.12	3.554	0.404
6:01:14 PM	198.09	3.485	0.404
6:11:14 PM	195.18	3.420	0.401
6:21:15 PM	192.19	3.352	0.412
6:31:15 PM	189.12	3.282	0.415
6:41:15 PM	186.08	3.213	0.410
6:51:15 PM	183.09	3.146	0.390
7:01:15 PM	180.34	3.083	0.387
7:11:16 PM	177.4	3.017	0.396
7:21:16 PM	174.51	2.951	0.376
7:31:17 PM	171.87	2.892	0.367
7:41:17 PM	169.1	2.829	0.365
7:51:18 PM	166.5	2.770	0.348
8:01:18 PM	163.98	2.713	0.345
8:11:18 PM	161.42	2.655	0.352
8:21:18 PM	158.8	2.596	0.348
8:31:19 PM	156.3	2.539	0.333
8:41:19 PM	153.9	2.485	0.331
8:51:19 PM	151.43	2.429	0.327
9:01:19 PM	149.08	2.376	0.319
9:11:20 PM	146.74	2.323	0.314
9:21:20 PM	144.46	2.271	0.304
9:31:20 PM	142.27	2.221	0.302
9:41:20 PM	140.02	2.171	0.303
9:51:20 PM	137.81	2.120	0.295
10:01:21 PM	135.67	2.072	0.281
10:11:21 PM	133.68	2.027	0.275
10:21:22 PM	131.62	1.980	0.284
10:31:22 PM	129.5	1.932	0.280
10:41:22 PM	127.5	1.887	0.274
10:51:23 PM	125.46	1.841	0.274
11:01:23 PM	123.47	1.796	0.262
11:11:23 PM	121.6	1.753	0.259
11:21:23 PM	119.65	1.709	0.255
11:31:23 PM	117.84	1.668	0.247
11:41:24 PM	116.01	1.627	0.247
11:51:24 PM	114.21	1.586	0.240
12:01:24 AM	112.48	1.547	0.228
12:11:24 AM	110.85	1.510	0.224
12:21:24 AM	109.18	1.472	0.224
12:31:25 AM	107.55	1.435	0.221
12:41:25 AM	105.92	1.398	0.220
12:51:25 AM	104.31	1.362	0.212
1:01:25 AM	102.8	1.328	0.213
1:11:26 AM	101.17	1.291	0.207
1:21:26 AM	99.75	1.259	0.199
1:31:27 AM	98.24	1.224	0.199
1:41:27 AM	96.82	1.192	0.190
1:51:28 AM	95.45	1.161	0.187
2:01:28 AM	94.07	1.130	0.187

2:11:29 AM	92.7	1.099	0.183
2:21:29 AM	91.38	1.069	0.183
2:31:29 AM	90	1.038	0.174
2:41:30 AM	88.82	1.011	0.158
2:51:30 AM	87.68	0.985	0.158
3:01:30 AM	86.5	0.959	0.160
3:11:31 AM	85.32	0.932	0.158
3:21:31 AM	84.18	0.906	0.151
3:31:32 AM	83.1	0.882	0.145
3:41:32 AM	82.05	0.858	0.148
3:51:32 AM	80.92	0.832	0.145
4:01:33 AM	79.92	0.810	0.140
4:11:33 AM	78.86	0.786	0.130
4:21:33 AM	78	0.766	0.115
4:31:34 AM	77.17	0.747	0.122
4:41:34 AM	76.2	0.725	0.125
4:51:34 AM	75.33	0.706	0.115
5:01:34 AM	74.5	0.687	0.114
5:11:34 AM	73.65	0.668	0.109
5:21:35 AM	72.9	0.651	0.105
5:31:35 AM	72.1	0.633	0.109
5:41:35 AM	71.3	0.614	0.091
5:51:35 AM	70.76	0.602	0.085
6:01:36 AM	70.05	0.586	0.096
6:11:36 AM	69.34	0.570	0.096
6:21:37 AM	68.64	0.554	0.092
6:31:37 AM	67.98	0.539	0.086
6:41:38 AM	67.37	0.525	0.082
6:51:38 AM	66.78	0.512	0.086
7:01:39 AM	66.1	0.497	0.086
7:11:39 AM	65.51	0.483	0.073
7:21:39 AM	65.03	0.472	0.071
7:31:39 AM	64.47	0.460	0.075
7:41:40 AM	63.93	0.448	0.073
7:51:40 AM	63.39	0.435	0.070
8:01:40 AM	62.9	0.424	0.066
8:11:41 AM	62.42	0.413	0.062
8:21:41 AM	61.99	0.404	0.062
8:31:42 AM	61.5	0.393	0.065
8:41:42 AM	61.04	0.382	0.052
8:51:42 AM	60.74	0.375	0.045
9:01:43 AM	60.38	0.367	0.052
9:11:43 AM	59.98	0.358	0.046
9:21:43 AM	59.7	0.352	0.046
9:31:43 AM	59.3	0.343	1.055
9:41:44 AM	58.97		

8.1.5. Raw data for sample blanched with oil at 60 °C, (replicate 1)

Raisin Drying data: Oil	blanched grapes at 6		
Air speed		1 m/s	
Air temperature		60 degC	
Relative humidity		35%	
Treatment		Oil blanched grapes	
Replicate number		1	
Date:		11-May-17	
Initial moisture content		4.6 dry basis	
t	m, Mass	Moisture co	dX/dt
h:min:s	g		1/h
12:54:50 PM	370.72	4.586	
1:04:50 PM	365.76	4.511	0.450
1:14:50 PM	360.77	4.436	0.455
1:24:50 PM	355.7	4.359	0.459
1:34:50 PM	350.62	4.283	0.459
1:44:51 PM	345.54	4.206	0.452
1:54:51 PM	340.62	4.132	0.449
2:04:52 PM	335.6	4.057	0.453
2:14:52 PM	330.59	3.981	0.439
2:24:52 PM	325.89	3.910	0.433
2:34:53 PM	321	3.837	0.399
2:44:53 PM	317.06	3.777	0.372
2:54:53 PM	312.76	3.712	0.388
3:04:53 PM	308.47	3.648	0.395
3:14:53 PM	304.03	3.581	0.388
3:24:53 PM	299.88	3.518	0.381
3:34:54 PM	295.6	3.454	0.382
3:44:54 PM	291.42	3.391	0.383
3:54:54 PM	287.13	3.326	0.379
4:04:55 PM	283.04	3.265	0.375
4:14:55 PM	278.83	3.201	0.381
4:24:55 PM	274.6	3.137	0.379
4:34:56 PM	270.44	3.075	0.370
4:44:56 PM	266.41	3.014	0.365
4:54:56 PM	262.37	2.953	0.365
5:04:56 PM	258.33	2.892	0.369
5:14:57 PM	254.2	2.830	0.368
5:24:57 PM	250.18	2.769	0.365
5:34:58 PM	246.13	2.708	0.363
5:44:58 PM	242.14	2.648	0.358
5:54:58 PM	238.2	2.589	0.345
6:04:58 PM	234.5	2.533	0.336
6:14:59 PM	230.77	2.477	0.336
6:24:59 PM	227.06	2.421	0.338
6:34:59 PM	223.3	2.364	0.341
6:44:59 PM	219.51	2.307	0.339
6:54:59 PM	215.81	2.252	0.334
7:05:00 PM	212.11	2.196	0.335
7:15:00 PM	208.4	2.140	0.332
7:25:01 PM	204.76	2.085	0.325
7:35:01 PM	201.2	2.032	0.316
7:45:02 PM	197.78	1.980	0.307
7:55:02 PM	194.41	1.929	0.306
8:05:02 PM	191	1.878	0.301
8:15:03 PM	187.76	1.829	0.291
8:25:03 PM	184.57	1.781	0.282
8:35:04 PM	181.53	1.735	0.283
8:45:04 PM	178.3	1.686	0.280
8:55:04 PM	175.34	1.642	0.274
9:05:05 PM	172.23	1.595	0.276
9:15:05 PM	169.24	1.550	0.267
9:25:05 PM	166.33	1.506	0.259
9:35:05 PM	163.5	1.463	0.258
9:45:06 PM	160.63	1.420	0.248
9:55:06 PM	158.02	1.381	0.232
10:05:07 PM	155.5	1.343	0.226
10:15:07 PM	153.01	1.305	0.223
10:25:08 PM	150.56	1.269	0.226
10:35:08 PM	148.01	1.230	0.219
10:45:08 PM	145.71	1.195	0.212
10:55:08 PM	143.32	1.159	0.208
11:05:09 PM	141.1	1.126	0.195
11:15:09 PM	139	1.094	0.191
11:25:09 PM	136.88	1.062	0.190
11:35:09 PM	134.8	1.031	0.182
11:45:10 PM	132.85	1.002	0.176
11:55:10 PM	130.91	0.972	0.167
12:05:10 AM	129.15	0.946	0.160
12:15:10 AM	127.36	0.919	0.156
12:25:10 AM	125.7	0.894	0.148
12:35:11 AM	124.09	0.870	0.146
12:45:11 AM	122.47	0.845	0.141
12:55:12 AM	120.98	0.823	0.140
1:05:12 AM	119.37	0.799	0.138
1:15:12 AM	117.93	0.777	0.122
1:25:12 AM	116.66	0.758	0.115
1:35:12 AM	115.39	0.739	0.116
1:45:13 AM	114.1	0.719	0.114
1:55:13 AM	112.87	0.701	0.105
2:05:13 AM	111.77	0.684	0.095
2:15:14 AM	110.76	0.669	0.098
2:25:14 AM	109.6	0.651	0.095
2:35:14 AM	108.65	0.637	0.089
2:45:15 AM	107.64	0.622	0.089
2:55:15 AM	106.69	0.608	0.078
3:05:15 AM	105.91	0.596	0.075
3:15:16 AM	105.02	0.582	0.081
3:25:16 AM	104.12	0.569	0.068
3:35:17 AM	103.51	0.560	0.058
3:45:17 AM	102.83	0.549	0.067
3:55:17 AM	102.03	0.537	0.068
4:05:18 AM	101.32	0.527	0.051
4:15:18 AM	100.9	0.520	0.049
4:25:18 AM	100.24	0.510	0.055
4:35:18 AM	99.68	0.502	0.056

4:45:18 AM	99.01	0.492	0.051
4:55:19 AM	98.56	0.485	0.046
5:05:19 AM	98	0.477	0.042
5:15:20 AM	97.62	0.471	0.041
5:25:20 AM	97.09	0.463	0.041
5:35:20 AM	96.72	0.457	0.037
5:45:21 AM	96.28	0.451	0.040
5:55:21 AM	95.84	0.444	0.039
6:05:22 AM	95.42	0.438	0.035
6:15:22 AM	95.07	0.432	0.029
6:25:22 AM	94.77	0.428	0.027
6:35:23 AM	94.47	0.423	0.026
6:45:23 AM	94.19	0.419	0.027
6:55:23 AM	93.88	0.415	0.031
7:05:23 AM	93.5	0.409	0.038
7:15:24 AM	93.05	0.402	0.027
7:25:24 AM	92.91	0.400	0.020
7:35:24 AM	92.6	0.395	0.024
7:45:25 AM	92.38	0.392	0.017
7:55:25 AM	92.22	0.389	0.024
8:05:25 AM	91.86	0.384	0.026
8:15:26 AM	91.65	0.381	0.019
8:25:26 AM	91.45	0.378	0.018
8:35:26 AM	91.25	0.375	0.019
8:45:26 AM	91.02	0.371	0.014
8:55:27 AM	90.93	0.370	0.015
9:05:27 AM	90.69	0.366	0.024
9:15:27 AM	90.4	0.362	0.014
9:25:27 AM	90.37	0.362	0.011
9:35:27 AM	90.16	0.358	0.020
9:45:27 AM	89.93	0.355	0.021
9:55:28 AM	89.7	0.352	0.013
10:05:28 AM	89.65	0.351	0.009
10:15:28 AM	89.5	0.349	0.011
10:25:29 AM	89.41	0.347	0.014
10:35:29 AM	89.19	0.344	0.014
10:45:30 AM	89.09	0.342	0.010
10:55:30 AM	88.96	0.340	0.009
11:05:30 AM	88.89	0.339	0.009
11:15:30 AM	88.75	0.337	0.014
11:25:31 AM	88.57	0.334	0.013
11:35:31 AM	88.47	0.333	0.006
11:45:31 AM	88.43	0.332	0.012
11:55:31 AM	88.2	0.329	0.012
12:05:31 PM	88.16	0.328	0.006
12:15:31 PM	88.06	0.327	0.011
12:25:32 PM	87.92	0.325	0.011
12:35:32 PM	87.81	0.323	0.010
12:45:32 PM	87.7	0.321	0.008
12:55:33 PM	87.64	0.320	0.009
1:05:33 PM	87.49	0.318	

8.1.6. Raw data for sample blanched with oil at 70 °C, (replicate 1)

Raisin Drying data: Oil blanched grapes at 70 degC			
Air speed		1 m/s	
Air temperature		70 degC	
Relative humidity		35%	
Treatment		Oil blanched grapes	
Replicate number		1	
Date:		6-Apr-17	
Initial moisture content		4.6 dry basis	
t	m, Mass	Moisture cc	dX/dt
h:min:s	g		1/h
3:44:55 PM	247.32	4.585	
3:54:55 PM	240.37	4.429	0.913
4:04:55 PM	233.85	4.281	0.865
4:14:56 PM	227.61	4.140	0.840
4:24:56 PM	221.45	4.001	0.807
4:34:56 PM	215.7	3.871	0.769
4:44:56 PM	210.1	3.745	0.755
4:54:57 PM	204.56	3.620	0.732
5:04:57 PM	199.3	3.501	0.711
5:14:58 PM	194.07	3.383	0.711
5:24:58 PM	188.81	3.264	0.691
5:34:58 PM	183.87	3.153	0.674
5:44:59 PM	178.86	3.039	0.642
5:54:59 PM	174.39	2.938	0.619
6:05:00 PM	169.73	2.833	0.616
6:15:00 PM	165.3	2.733	0.596
6:25:00 PM	160.94	2.635	0.596
6:35:01 PM	156.5	2.534	0.579
6:45:01 PM	152.4	2.442	0.564
6:55:02 PM	148.18	2.346	0.552
7:05:02 PM	144.25	2.258	0.527
7:15:02 PM	140.4	2.171	0.514
7:25:03 PM	136.66	2.086	0.512
7:35:03 PM	132.84	2.000	0.510
7:45:03 PM	129.13	1.916	0.483
7:55:03 PM	125.71	1.839	0.470
8:05:04 PM	122.2	1.760	0.457
8:15:04 PM	118.97	1.687	0.428
8:25:04 PM	115.89	1.617	0.404
8:35:04 PM	113.01	1.552	0.398
8:45:05 PM	110.02	1.485	0.404
8:55:05 PM	107.05	1.418	0.377
9:05:05 PM	104.46	1.359	0.350
9:15:06 PM	101.89	1.301	0.339

9:25:06 PM	99.45	1.246	0.333
9:35:07 PM	96.98	1.190	0.327
9:45:07 PM	94.63	1.137	0.295
9:55:07 PM	92.62	1.092	0.263
10:05:07 PM	90.75	1.049	0.236
10:15:07 PM	89.14	1.013	0.233
10:25:07 PM	87.31	0.972	0.227
10:35:07 PM	85.79	0.937	0.203
10:45:08 PM	84.31	0.904	0.196
10:55:08 PM	82.9	0.872	0.192
11:05:08 PM	81.47	0.840	0.176
11:15:09 PM	80.3	0.813	0.150
11:25:09 PM	79.25	0.790	0.150
11:35:10 PM	78.09	0.764	0.157
11:45:10 PM	76.94	0.738	0.142
11:55:10 PM	76	0.716	0.124
12:05:10 AM	75.11	0.696	0.123
12:15:11 AM	74.19	0.676	0.116
12:25:11 AM	73.4	0.658	0.103
12:35:12 AM	72.67	0.641	0.103
12:45:12 AM	71.88	0.623	0.100
12:55:12 AM	71.19	0.608	0.080
1:05:13 AM	70.7	0.597	0.074
1:15:13 AM	70.1	0.583	0.091
1:25:14 AM	69.36	0.566	0.082
1:35:14 AM	68.89	0.556	0.074
1:45:14 AM	68.27	0.542	0.072
1:55:15 AM	67.83	0.532	0.062
2:05:15 AM	67.35	0.521	0.058
2:15:15 AM	66.97	0.512	0.057
2:25:16 AM	66.51	0.502	0.056
2:35:16 AM	66.14	0.494	0.043
2:45:16 AM	65.87	0.488	0.052
2:55:17 AM	65.37	0.476	0.056
3:05:17 AM	65.04	0.469	0.043
3:15:17 AM	64.73	0.462	0.043
3:25:17 AM	64.4	0.454	0.045
3:35:18 AM	64.06	0.447	0.049
3:45:18 AM	63.68	0.438	0.047
3:55:19 AM	63.37	0.431	0.026
4:05:19 AM	63.29	0.429	0.031
4:15:19 AM	62.91	0.421	0.041
4:25:19 AM	62.68	0.416	0.028
4:35:20 AM	62.49	0.411	0.024
4:45:20 AM	62.33	0.408	0.031
4:55:21 AM	62.03	0.401	0.035
5:05:21 AM	61.82	0.396	0.035

5:15:21 AM	61.51	0.389	0.022
5:25:21 AM	61.5	0.389	0.015
5:35:21 AM	61.29	0.384	0.032
5:45:22 AM	61.03	0.378	0.026
5:55:22 AM	60.9	0.375	0.022
6:05:23 AM	60.71	0.371	0.014
6:15:23 AM	60.7	0.371	0.016
6:25:24 AM	60.48	0.366	0.021
6:35:24 AM	60.39	0.364	0.019
6:45:24 AM	60.2	0.360	0.019
6:55:24 AM	60.11	0.358	0.016
7:05:25 AM	59.97	0.354	0.016
7:15:25 AM	59.87	0.352	0.024
7:25:25 AM	59.61	0.346	0.019
7:35:26 AM	59.59	0.346	0.015
7:45:26 AM	59.39	0.341	0.017
7:55:27 AM	59.34	0.340	0.000
8:05:27 AM	59.39	0.341	0.007
8:15:27 AM	59.24	0.338	0.016
8:25:27 AM	59.16	0.336	0.017
8:35:28 AM	58.99	0.332	0.013
8:45:28 AM	58.97	0.332	0.007
8:55:29 AM	58.88	0.330	0.005
9:05:29 AM	58.9	0.330	0.008
9:15:29 AM	58.76	0.327	0.014
9:25:30 AM	58.69	0.325	-0.008
9:35:30 AM	58.88	0.330	0.020
9:45:30 AM	58.4	0.319	0.026
9:55:30 AM	58.49	0.321	0.007
10:05:30 AM	58.3	0.317	0.013
10:15:30 AM	58.3	0.317	0.003
10:25:31 AM	58.25	0.316	0.013
10:35:31 AM	58.11	0.312	0.009
10:45:32 AM	58.11	0.312	0.013
10:55:32 AM	57.92	0.308	0.022
11:05:32 AM	57.79	0.305	0.007
11:15:33 AM	57.81	0.306	0.012
11:25:33 AM	57.61	0.301	0.014
11:35:34 AM	57.6	0.301	0.008
11:45:34 AM	57.49	0.298	0.013
11:55:34 AM	57.41	0.297	0.012
12:05:34 PM	57.32	0.295	0.007
12:15:34 PM	57.3	0.294	0.005
12:25:34 PM	57.25	0.293	0.007
12:35:34 PM	57.19	0.292	0.007
12:45:35 PM	57.14	0.290	0.010
12:55:35 PM	57.04	0.288	0.005
1:05:35 PM	57.06	0.289	

8.1.7. Raw data for neelded sample at 60 °C , (replicate 1)

Raisin Drying data: Needled grapes at 60 degC			
Air speed		1 m/s	
Air temperature		60 degC	
Relative humidity		35%	
Treatment		Needled grapes	
Replicate number		1	
Date:		19-Apr-17	
Initial moisture content		4.6 dry basis	
t	m, Mass	Moisture c	dX/dt
h:min:s	g		1/h
11:13:45 AM	251.51	4.585	
11:23:45 AM	246.8	4.481	0.670
11:33:45 AM	241.45	4.362	0.706
11:43:46 AM	236.2	4.245	0.688
11:53:46 AM	231.12	4.132	0.668
12:03:46 PM	226.17	4.023	0.652
12:13:46 PM	221.33	3.915	0.624
12:23:46 PM	216.8	3.814	0.600
12:33:47 PM	212.33	3.715	0.575
12:43:47 PM	208.17	3.623	0.546
12:53:48 PM	204.14	3.533	0.536
1:03:48 PM	200.12	3.444	0.529
1:13:48 PM	196.2	3.357	0.522
1:23:48 PM	192.29	3.270	0.516
1:33:49 PM	188.46	3.185	0.503
1:43:49 PM	184.74	3.103	0.484
1:53:49 PM	181.2	3.024	0.466
2:03:49 PM	177.74	2.947	0.459
2:13:50 PM	174.31	2.871	0.454
2:23:50 PM	170.92	2.796	0.446
2:33:50 PM	167.62	2.722	0.442
2:43:51 PM	164.29	2.648	0.436
2:53:51 PM	161.08	2.577	0.422
3:03:51 PM	157.95	2.508	0.424
3:13:52 PM	154.71	2.436	0.413
3:23:52 PM	151.75	2.370	0.387
3:33:52 PM	148.9	2.307	0.385
3:43:53 PM	145.97	2.242	0.378
3:53:53 PM	143.22	2.180	0.371
4:03:53 PM	140.4	2.118	0.370
4:13:54 PM	137.66	2.057	0.355
4:23:54 PM	135.07	1.999	0.342
4:33:54 PM	132.52	1.943	0.333
4:43:54 PM	130.07	1.888	0.328
4:53:55 PM	127.6	1.834	0.332
5:03:55 PM	125.09	1.778	0.320
5:13:56 PM	122.8	1.727	0.303
5:23:56 PM	120.54	1.677	0.300
5:33:56 PM	118.3	1.627	0.292
5:43:56 PM	116.15	1.579	0.282
5:53:56 PM	114.06	1.533	0.272
6:03:56 PM	112.06	1.489	0.272
6:13:57 PM	109.98	1.442	0.270
6:23:57 PM	108	1.398	0.258
6:33:58 PM	106.11	1.356	0.245
6:43:58 PM	104.32	1.317	0.240
6:53:59 PM	102.51	1.276	0.235
7:03:59 PM	100.79	1.238	0.232
7:14:00 PM	99.03	1.199	0.222
7:24:00 PM	97.46	1.164	0.211
7:34:00 PM	95.87	1.129	0.205
7:44:01 PM	94.38	1.096	0.204
7:54:01 PM	92.81	1.061	0.195
8:04:02 PM	91.46	1.031	0.186
8:14:02 PM	90.02	0.999	0.187
8:24:03 PM	88.66	0.969	0.180
8:34:03 PM	87.32	0.939	0.171
8:44:03 PM	86.09	0.912	0.155
8:54:03 PM	85	0.888	0.149
9:04:04 PM	83.85	0.862	0.150
9:14:04 PM	82.75	0.838	0.143
9:24:04 PM	81.71	0.815	0.137
9:34:05 PM	80.7	0.792	0.135
9:44:05 PM	79.68	0.769	0.126
9:54:05 PM	78.81	0.750	0.125
10:04:06 PM	77.8	0.728	0.124
10:14:06 PM	76.95	0.709	0.109
10:24:06 PM	76.17	0.692	0.099
10:34:06 PM	75.47	0.676	0.109
10:44:07 PM	74.54	0.655	0.107
10:54:07 PM	73.86	0.640	0.101
11:04:08 PM	73.03	0.622	0.089
11:14:08 PM	72.52	0.610	0.075
11:24:08 PM	71.9	0.597	0.076
11:34:08 PM	71.38	0.585	0.080
11:44:09 PM	70.7	0.570	0.079
11:54:09 PM	70.2	0.559	0.074

12:04:10 AM	69.59	0.545	0.075
12:14:10 AM	69.07	0.534	0.072
12:24:11 AM	68.51	0.521	0.065
12:34:11 AM	68.1	0.512	0.057
12:44:11 AM	67.65	0.502	0.065
12:54:12 AM	67.12	0.491	0.057
1:04:12 AM	66.79	0.483	0.047
1:14:13 AM	66.41	0.475	0.051
1:24:13 AM	66.03	0.466	0.053
1:34:13 AM	65.62	0.457	0.046
1:44:14 AM	65.34	0.451	0.038
1:54:14 AM	65.05	0.445	0.041
2:04:14 AM	64.72	0.437	0.036
2:14:14 AM	64.51	0.433	0.033
2:24:14 AM	64.22	0.426	0.043
2:34:14 AM	63.87	0.418	0.040
2:44:15 AM	63.62	0.413	0.032
2:54:15 AM	63.39	0.408	0.028
3:04:16 AM	63.2	0.403	0.031
3:14:16 AM	62.93	0.397	0.033
3:24:16 AM	62.71	0.393	0.028
3:34:17 AM	62.51	0.388	0.020
3:44:17 AM	62.41	0.386	0.027
3:54:17 AM	62.1	0.379	0.038
4:04:18 AM	61.84	0.373	0.028
4:14:18 AM	61.68	0.370	0.021
4:24:18 AM	61.53	0.366	0.025
4:34:19 AM	61.3	0.361	0.029
4:44:19 AM	61.1	0.357	0.019
4:54:19 AM	61.02	0.355	0.020
5:04:20 AM	60.8	0.350	0.021
5:14:20 AM	60.7	0.348	0.016
5:24:21 AM	60.56	0.345	0.018
5:34:21 AM	60.43	0.342	0.026
5:44:21 AM	60.17	0.336	0.031
5:54:21 AM	59.97	0.332	0.011
6:04:21 AM	60.01	0.333	0.007
6:14:22 AM	59.87	0.330	0.027
6:24:22 AM	59.6	0.324	0.017
6:34:23 AM	59.62	0.324	0.013
6:44:23 AM	59.4	0.319	0.010
6:54:23 AM	59.47	0.321	0.010
7:04:23 AM	59.25	0.316	0.015
7:14:23 AM	59.24	0.316	0.011
7:24:24 AM	59.09	0.312	0.016
7:34:24 AM	59	0.310	0.011
7:44:25 AM	58.93	0.309	0.016

7:54:25 AM	58.76	0.305	0.011
8:04:25 AM	58.77	0.305	0.011
8:14:26 AM	58.6	0.301	0.012
8:24:26 AM	58.59	0.301	0.009
8:34:26 AM	58.47	0.298	0.013
8:44:26 AM	58.4	0.297	0.014
8:54:27 AM	58.26	0.294	0.011
9:04:27 AM	58.23	0.293	-0.001
9:14:27 AM	58.27	0.294	0.008
9:24:28 AM	58.11	0.290	0.011
9:34:28 AM	58.1	0.290	0.005
9:44:28 AM	58.04	0.289	0.006
9:54:28 AM	58.01	0.288	0.004
10:04:29 AM	57.98	0.288	0.006
10:14:29 AM	57.92	0.286	0.005
10:24:30 AM	57.91	0.286	0.004
10:34:30 AM	57.86	0.285	0.010
10:44:30 AM	57.76	0.283	0.005
10:54:30 AM	57.78	0.283	0.005
11:04:31 AM	57.69	0.281	0.010
11:14:31 AM	57.63	0.280	0.006
11:24:32 AM	57.6	0.279	0.003
11:34:32 AM	57.58	0.279	0.009
11:44:33 AM	57.47	0.276	0.013
11:54:33 AM	57.39	0.274	0.005
12:04:34 PM	57.4	0.275	0.003
12:14:34 PM	57.34	0.273	0.013
12:24:34 PM	57.2	0.270	0.001
12:34:34 PM	57.33	0.273	0.001
12:44:34 PM	57.19	0.270	0.013
12:54:35 PM	57.14	0.269	0.005
1:04:35 PM	57.12	0.268	0.009
1:14:35 PM	57.01	0.266	0.009
1:24:35 PM	56.99	0.266	0.007
1:34:36 PM	56.91	0.264	0.013
1:44:36 PM	56.8	0.261	0.011
1:54:36 PM	56.74	0.260	0.001
2:04:36 PM	56.78	0.261	-0.004
2:14:37 PM	56.8	0.261	0.008
2:24:37 PM	56.66	0.258	0.013
2:34:37 PM	56.61	0.257	0.008
2:44:38 PM	56.54	0.256	0.007
2:54:38 PM	56.5	0.255	

8.1.8. Raw data for neelded sample at 70 °C, (replicate 1)

Raisin Drying data: Needled grapes at 70 degC			
Air speed		1 m/s	
Air temperature		70 degC	
Relative humidity		35%	
Treatment		Needled grapes	
Replicate number		1	
Date:		5-Apr-17	
Initial moisture content		4.9 dry basis	
Time:			
Comment:			
t	m, Mass	Moisture co	dX/dt
h:min:s	g		1/h
11:16:09 AM	293.8	4.882	
11:16:10 AM	293.79	4.882	0.137
11:26:10 AM	291.52	4.837	0.324
11:36:11 AM	288.4	4.774	0.438
11:46:11 AM	284.22	4.691	0.545
11:56:11 AM	279.33	4.593	0.615
12:06:12 PM	273.98	4.486	0.638
12:16:12 PM	268.7	4.380	0.641
12:26:12 PM	263.3	4.272	0.638
12:36:12 PM	258.08	4.167	0.613
12:46:13 PM	253.09	4.067	0.593
12:56:13 PM	248.2	3.969	0.575
1:06:14 PM	243.51	3.875	0.541
1:16:14 PM	239.2	3.789	0.491
1:26:15 PM	235.34	3.712	0.459
1:36:15 PM	231.56	3.636	0.449
1:46:16 PM	227.87	3.562	0.442
1:56:16 PM	224.2	3.489	0.425
2:06:16 PM	220.8	3.421	0.397
2:16:16 PM	217.59	3.357	0.366
2:26:17 PM	214.7	3.299	0.336
2:36:17 PM	211.99	3.244	0.308
2:46:17 PM	209.57	3.196	0.294
2:56:18 PM	207.1	3.146	0.287
3:06:18 PM	204.79	3.100	0.299
3:16:19 PM	202.12	3.047	0.301
3:26:19 PM	199.78	3.000	0.284
3:36:19 PM	197.4	2.952	0.291
3:46:20 PM	194.93	2.903	0.294
3:56:20 PM	192.5	2.854	0.278
4:06:20 PM	190.3	2.810	0.268
4:16:20 PM	188.03	2.765	0.267
4:26:21 PM	185.85	2.721	0.264
4:36:21 PM	183.64	2.677	0.260
4:46:21 PM	181.52	2.634	0.254
4:56:22 PM	179.41	2.592	0.250
5:06:22 PM	177.35	2.551	0.240
5:16:23 PM	175.41	2.512	0.237
5:26:23 PM	173.4	2.472	0.235
5:36:23 PM	171.49	2.434	0.234
5:46:23 PM	169.5	2.394	0.244
5:56:23 PM	167.42	2.352	0.257
6:06:24 PM	165.22	2.308	0.264
6:16:24 PM	163.02	2.264	0.259
6:26:24 PM	160.9	2.221	0.253
6:36:24 PM	158.8	2.179	0.258
6:46:24 PM	156.6	2.135	0.264
6:56:24 PM	154.41	2.092	0.270
7:06:24 PM	152.11	2.045	0.265
7:16:24 PM	150	2.003	0.259
7:26:25 PM	147.8	1.959	0.268
7:36:25 PM	145.54	1.914	0.264
7:46:25 PM	143.41	1.871	0.250
7:56:26 PM	141.38	1.831	0.250
8:06:26 PM	139.25	1.788	0.259
8:16:27 PM	137.06	1.744	0.260
8:26:27 PM	134.92	1.701	0.247
8:36:28 PM	132.95	1.662	0.235
8:46:28 PM	131	1.623	0.232
8:56:28 PM	129.08	1.584	0.235
9:06:28 PM	127.08	1.544	0.233
9:16:29 PM	125.2	1.507	0.219
9:26:29 PM	123.43	1.471	0.211
9:36:29 PM	121.69	1.436	0.212
9:46:29 PM	119.9	1.401	0.212
9:56:29 PM	118.16	1.366	0.208
10:06:30 PM	116.43	1.331	0.196
10:16:30 PM	114.9	1.300	0.193
10:26:30 PM	113.21	1.267	0.201
10:36:31 PM	111.56	1.234	0.193
10:46:31 PM	109.99	1.202	0.191

10:56:31 PM	108.38	1.170	0.192
11:06:31 PM	106.8	1.138	0.185
11:16:32 PM	105.3	1.108	0.175
11:26:32 PM	103.89	1.080	0.173
11:36:33 PM	102.42	1.051	0.168
11:46:33 PM	101.09	1.024	0.166
11:56:33 PM	99.66	0.995	0.172
12:06:34 AM	98.22	0.967	0.162
12:16:34 AM	96.96	0.941	0.151
12:26:34 AM	95.7	0.916	0.146
12:36:35 AM	94.53	0.893	0.138
12:46:35 AM	93.4	0.870	0.140
12:56:35 AM	92.2	0.846	0.133
1:06:36 AM	91.18	0.826	0.131
1:16:36 AM	90.02	0.802	0.131
1:26:36 AM	89	0.782	0.121
1:36:37 AM	88	0.762	0.120
1:46:37 AM	87	0.742	0.116
1:56:37 AM	86.07	0.723	0.117
2:06:37 AM	85.05	0.703	0.118
2:16:37 AM	84.1	0.684	0.116
2:26:38 AM	83.12	0.664	0.108
2:36:38 AM	82.3	0.648	0.109
2:46:39 AM	81.3	0.628	0.104
2:56:39 AM	80.57	0.613	0.099
3:06:40 AM	79.66	0.595	0.100
3:16:40 AM	78.9	0.580	0.091
3:26:41 AM	78.14	0.564	0.090
3:36:41 AM	77.4	0.550	0.092
3:46:42 AM	76.61	0.534	0.091
3:56:42 AM	75.89	0.519	0.086
4:06:43 AM	75.17	0.505	0.085
4:16:43 AM	74.48	0.491	0.082
4:26:44 AM	73.8	0.478	0.083
4:36:44 AM	73.1	0.464	0.076
4:46:44 AM	72.53	0.452	0.072
4:56:45 AM	71.9	0.440	0.068
5:06:45 AM	71.39	0.429	0.067
5:16:46 AM	70.79	0.417	0.066

5:26:46 AM	70.29	0.407	0.065
5:36:47 AM	69.71	0.396	0.065
5:46:47 AM	69.2	0.385	0.059
5:56:48 AM	68.72	0.376	0.060
6:06:48 AM	68.2	0.365	0.058
6:16:49 AM	67.76	0.357	0.049
6:26:49 AM	67.39	0.349	0.051
6:36:49 AM	66.91	0.340	0.047
6:46:49 AM	66.6	0.333	0.048
6:56:49 AM	66.11	0.324	0.050
7:06:49 AM	65.77	0.317	0.046
7:16:50 AM	65.35	0.308	0.046
7:26:50 AM	65	0.301	0.045
7:36:50 AM	64.6	0.293	0.041
7:46:51 AM	64.31	0.288	0.037
7:56:51 AM	63.99	0.281	0.037
8:06:51 AM	63.7	0.275	0.037
8:16:52 AM	63.37	0.269	0.038
8:26:52 AM	63.06	0.263	0.036
8:36:52 AM	62.77	0.257	0.029
8:46:53 AM	62.57	0.253	0.032
8:56:53 AM	62.23	0.246	0.028
9:06:53 AM	62.1	0.243	0.020
9:16:54 AM	61.89	0.239	0.026
9:26:54 AM	61.67	0.235	0.025
9:36:54 AM	61.48	0.231	0.026
9:46:54 AM	61.23	0.226	0.029
9:56:55 AM	61	0.221	0.029
10:06:55 AM	60.74	0.216	0.020
10:16:56 AM	60.67	0.215	0.043
10:26:56 AM	60.02	0.202	0.045
10:36:56 AM	59.92	0.200	0.017
10:46:56 AM	59.73	0.196	0.023
10:56:56 AM	59.53	0.192	0.024
11:06:56 AM	59.33	0.188	0.016
11:16:56 AM	59.26	0.186	0.022
11:26:56 AM	58.97	0.181	

8.1.9. Raw data for halved sample at 60 °C, (replicate 1)

Raisin Drying data: Halved grapes at 60 degC			
Air speed		1 m/s	
Air temperature		60 degC	
Relative humidity		35%	
Treatment		halved grapes	
Replicate number		1	
Date:		3-Apr-17	
Initial moisture content		4.9 dry basis	
Time:			
Comment:			
t	m, Mass	Moisture co	dX/dt
h:min:s	g		1/h
4:45:02 PM	181.29	4.882	
4:55:02 PM	175.03	4.679	1.175
5:05:03 PM	169.22	4.491	1.070
5:15:03 PM	164.04	4.323	0.984
5:25:03 PM	159.11	4.163	0.920
5:35:04 PM	154.59	4.016	0.856
5:45:04 PM	150.32	3.877	0.804
5:55:04 PM	146.33	3.748	0.761
6:05:05 PM	142.5	3.624	0.723
6:15:05 PM	138.9	3.507	0.695
6:25:05 PM	135.36	3.392	0.673
6:35:06 PM	131.99	3.283	0.654
6:45:06 PM	128.64	3.174	0.640
6:55:06 PM	125.42	3.070	0.605
7:05:07 PM	122.42	2.972	0.583
7:15:07 PM	119.43	2.875	0.568
7:25:07 PM	116.58	2.783	0.545
7:35:07 PM	113.83	2.693	0.539
7:45:08 PM	111.04	2.603	0.516
7:55:08 PM	108.53	2.521	0.499
8:05:09 PM	105.91	2.436	0.490
8:15:09 PM	103.5	2.358	0.473
8:25:09 PM	101.05	2.279	0.460
8:35:09 PM	98.77	2.205	0.445
8:45:10 PM	96.48	2.131	0.442
8:55:10 PM	94.23	2.057	0.426
9:05:10 PM	92.1	1.988	0.409
9:15:10 PM	90.03	1.921	0.389
9:25:11 PM	88.1	1.859	0.392
9:35:11 PM	86	1.790	0.380
9:45:11 PM	84.2	1.732	0.346
9:55:12 PM	82.45	1.675	0.339
10:05:12 PM	80.72	1.619	0.336
10:15:12 PM	79	1.563	0.317
10:25:13 PM	77.46	1.513	0.311
10:35:13 PM	75.81	1.460	0.311
10:45:13 PM	74.26	1.410	0.285
10:55:13 PM	72.88	1.365	0.275
11:05:13 PM	71.43	1.318	0.269
11:15:13 PM	70.12	1.275	0.262
11:25:14 PM	68.74	1.230	0.252
11:35:14 PM	67.53	1.191	0.247
11:45:14 PM	66.2	1.148	0.242
11:55:14 PM	65.04	1.110	0.224
12:05:15 AM	63.9	1.073	0.217
12:15:15 AM	62.81	1.038	0.214
12:25:15 AM	61.7	1.002	0.208
12:35:15 AM	60.67	0.969	0.190
12:45:15 AM	59.75	0.939	0.176
12:55:15 AM	58.86	0.910	0.183
1:05:15 AM	57.87	0.878	0.162
1:15:16 AM	57.2	0.856	0.154
1:25:16 AM	56.29	0.826	0.156
1:35:16 AM	55.6	0.804	0.134
1:45:16 AM	54.91	0.782	0.136
1:55:17 AM	54.2	0.759	0.133
2:05:17 AM	53.54	0.737	0.128
2:15:18 AM	52.89	0.716	0.121
2:25:18 AM	52.3	0.697	0.111
2:35:18 AM	51.75	0.679	0.098
2:45:18 AM	51.29	0.664	0.097
2:55:19 AM	50.75	0.647	0.104
3:05:19 AM	50.22	0.629	0.088
3:15:19 AM	49.85	0.617	0.083
3:25:20 AM	49.37	0.602	0.092

3:35:20 AM	48.91	0.587	0.076
3:45:20 AM	48.59	0.577	0.069
3:55:21 AM	48.2	0.564	0.065
4:05:21 AM	47.92	0.555	0.059
4:15:21 AM	47.59	0.544	0.060
4:25:21 AM	47.3	0.535	0.065
4:35:21 AM	46.92	0.522	0.055
4:45:22 AM	46.74	0.517	0.051
4:55:22 AM	46.4	0.506	0.058
5:05:22 AM	46.14	0.497	0.045
5:15:22 AM	45.94	0.491	0.038
5:25:23 AM	45.75	0.484	0.049
5:35:23 AM	45.44	0.474	0.048
5:45:24 AM	45.26	0.469	0.032
5:55:24 AM	45.11	0.464	0.026
6:05:24 AM	44.99	0.460	0.028
6:15:25 AM	44.82	0.454	0.038
6:25:25 AM	44.6	0.447	0.034
6:35:26 AM	44.47	0.443	0.035
6:45:26 AM	44.24	0.435	0.027
6:55:26 AM	44.19	0.434	0.023
7:05:27 AM	44	0.428	0.024
7:15:27 AM	43.94	0.426	0.020
7:25:28 AM	43.79	0.421	0.023
7:35:28 AM	43.7	0.418	0.023
7:45:28 AM	43.55	0.413	0.034
7:55:29 AM	43.35	0.407	0.034
8:05:29 AM	43.2	0.402	0.024
8:15:29 AM	43.1	0.398	0.017
8:25:29 AM	43.03	0.396	0.013
8:35:30 AM	42.97	0.394	0.015
8:45:30 AM	42.88	0.391	0.017
8:55:30 AM	42.8	0.389	0.018
9:05:31 AM	42.69	0.385	0.000
9:15:31 AM	42.8	0.389	-0.004
9:25:32 AM	42.73	0.386	0.010
9:35:32 AM	42.7	0.385	0.016
9:45:33 AM	42.57	0.381	0.023
9:55:33 AM	42.46	0.378	0.023
10:05:33 AM	42.33	0.373	

8.1.10. Raw data for halved sample at 70 °C, (replicate 1)

Raisin Drying data: Halved grapes at 70 degC			
Air speed		1 m/s	
Air temperature		70 degC	
Relative humidity		35%	
Treatment		halved grapes	
Replicate number		1	
Date:		31-Mar-17	
Initial moisture content		4.7 dry basis	
t	m, Mass	Moisture c	dX/dt
h:min:s	g		1/h
10:59:27 AM	167.56	4.682	
11:09:28 AM	160.51	4.443	1.357
11:19:28 AM	154.22	4.229	1.226
11:29:29 AM	148.46	4.034	1.119
11:39:29 AM	143.22	3.856	1.034
11:49:29 AM	138.3	3.690	0.959
11:59:29 AM	133.79	3.537	0.897
12:09:29 PM	129.48	3.391	0.853
12:19:30 PM	125.4	3.252	0.803
12:29:30 PM	121.59	3.123	0.768
12:39:30 PM	117.85	2.996	0.739
12:49:30 PM	114.33	2.877	0.717
12:59:31 PM	110.8	2.757	0.708
1:09:31 PM	107.37	2.641	0.701
1:19:32 PM	103.91	2.524	0.679
1:29:32 PM	100.7	2.415	0.644
1:39:32 PM	97.58	2.309	0.651
1:49:32 PM	94.3	2.198	0.646
1:59:33 PM	91.23	2.094	0.617
2:09:33 PM	88.23	1.992	0.603
2:19:33 PM	85.3	1.892	0.583
2:29:33 PM	82.5	1.798	0.570
2:39:33 PM	79.7	1.703	0.560
2:49:33 PM	77	1.611	0.530
2:59:34 PM	74.49	1.526	0.507
3:09:34 PM	72.02	1.442	0.498
3:19:34 PM	69.59	1.360	0.480
3:29:35 PM	67.3	1.282	0.449
3:39:35 PM	65.18	1.210	0.427
3:49:35 PM	63.1	1.140	0.402
3:59:36 PM	61.23	1.076	0.600
10:33:32 AM	57.2	0.940	0.634
10:43:33 AM	55	0.865	0.397
10:53:33 AM	53.3	0.807	0.307
11:03:33 AM	51.98	0.763	0.254
11:13:34 AM	50.8	0.723	0.212
11:23:34 AM	49.9	0.692	0.193
11:33:34 AM	48.9	0.658	0.192
11:43:34 AM	48.01	0.628	0.183
11:53:34 AM	47.1	0.597	0.171
12:03:35 PM	46.33	0.571	0.163
12:13:35 PM	45.5	0.543	0.154
12:23:36 PM	44.82	0.520	0.143
12:33:36 PM	44.09	0.495	0.130
12:43:36 PM	43.54	0.476	0.109
12:53:36 PM	43.02	0.459	0.101
1:03:37 PM	42.55	0.443	0.094
1:13:37 PM	42.1	0.428	0.086
1:23:37 PM	41.7	0.414	0.085
1:33:37 PM	41.26	0.399	0.077
1:43:37 PM	40.94	0.388	0.066
1:53:38 PM	40.61	0.377	0.051
2:03:38 PM	40.44	0.371	0.053
2:13:38 PM	40.09	0.359	0.062
2:23:39 PM	39.83	0.351	0.047
2:33:39 PM	39.63	0.344	0.044
2:43:39 PM	39.4	0.336	0.051
2:53:40 PM	39.13	0.327	0.049
3:03:40 PM	38.92	0.320	0.045
3:13:40 PM	38.69	0.312	0.053
3:23:41 PM	38.4	0.302	0.042
3:33:41 PM	38.28	0.298	0.019
3:43:42 PM	38.21	0.296	

8.1.11. Raw data for control sample at 60 °C (replicate 2)

Raisin Drying data: Control grapes at			
Air speed		1 m/s	
Air temperature		60 degC	
Relative humidity		0.35	
Treatment		Control	
Replicate number		2	
Date:		15-Mar-17	
Initial moisture conten	5.0 dry basis		
t	m, Mass		
h:min:s	g	Xw	dX/dt
0.449363426	247.95	4.988024	
10:57:06 AM	247.25	4.9711189	0.17316
11:07:06 AM	245.56	4.9303051	0.18402
11:17:06 AM	244.71	4.9097775	-0.2753
11:27:06 AM	249.36	5.0220756	-0.2572
11:37:07 AM	248.26	4.9955105	0.1833
11:47:07 AM	246.83	4.9609758	0.20286
11:57:07 AM	245.46	4.9278901	0.19924
12:07:07 PM	244.08	4.894563	0.20503
12:17:07 PM	242.63	4.8595453	0.19127
12:27:07 PM	241.44	4.8308066	0.18475
12:37:08 PM	240.08	4.7979625	0.20866
12:47:08 PM	238.56	4.7612543	0.21735
12:57:08 PM	237.08	4.7255121	0.20793
1:07:09 PM	235.69	4.6919434	0.19489
1:17:09 PM	234.39	4.6605482	0.1891
1:27:09 PM	233.08	4.6289116	0.19417
1:37:09 PM	231.71	4.5958259	0.18185
1:47:10 PM	230.57	4.5682947	0.14273
1:57:10 PM	229.74	4.5482501	0.1449
2:07:10 PM	228.57	4.5199945	0.18402
2:17:11 PM	227.2	4.4869088	0.15867
2:27:11 PM	226.38	4.4671057	0.13186
2:37:11 PM	225.38	4.4429556	0.13476
2:47:12 PM	224.52	4.4221865	0.16881
2:57:12 PM	223.05	4.3866858	0.19634
3:07:12 PM	221.81	4.3567396	0.17098
3:17:12 PM	220.69	4.3296915	0.142
3:27:12 PM	219.85	4.3094054	0.15432
3:37:13 PM	218.56	4.2782517	0.1833
3:47:13 PM	217.32	4.2483056	0.1775
3:57:13 PM	216.11	4.2190839	0.16881
4:07:13 PM	214.99	4.1920358	0.16519
4:17:14 PM	213.83	4.1640216	0.16664
4:27:14 PM	212.69	4.1364905	0.18185
4:37:15 PM	211.32	4.1034048	0.18547
4:47:15 PM	210.13	4.0746662	0.18113
4:57:15 PM	208.82	4.0430295	0.15432
5:07:16 PM	208	4.0232264	0.13983
5:17:16 PM	206.89	3.9964197	0.14997
5:27:16 PM	205.93	3.9732356	0.18113
5:37:16 PM	204.39	3.9360444	0.22242
5:47:17 PM	202.86	3.8990947	0.1891
5:57:17 PM	201.78	3.8730126	0.16881
6:07:17 PM	200.53	3.8428249	0.19127
6:17:17 PM	199.14	3.8092563	0.1833
6:27:18 PM	198	3.7817251	0.20359
6:37:18 PM	196.33	3.7413944	0.2188
6:47:18 PM	194.98	3.7087917	0.20648
6:57:18 PM	193.48	3.6725665	0.21228
7:07:18 PM	192.05	3.6380319	0.20286
7:17:18 PM	190.68	3.6049462	0.20721
7:27:18 PM	189.19	3.5689625	0.21083
7:37:19 PM	187.77	3.5346693	0.19417
7:47:19 PM	186.51	3.5042402	0.17533
7:57:19 PM	185.35	3.476226	0.1775
8:07:19 PM	184.06	3.4450723	0.18765
8:17:19 PM	182.76	3.4136772	0.17461
8:27:20 PM	181.65	3.3868705	0.1449
8:37:20 PM	180.76	3.3653769	0.17533
8:47:20 PM	179.23	3.3284272	0.19127
8:57:21 PM	178.12	3.3016206	0.17461
9:07:21 PM	176.82	3.2702254	0.17026
9:17:21 PM	175.77	3.2448678	0.14852
9:27:21 PM	174.77	3.2207177	0.15504
9:37:21 PM	173.63	3.1931865	0.16301
9:47:21 PM	172.52	3.1663799	0.16591
9:57:22 PM	171.34	3.1378827	0.16156
10:07:22 PM	170.29	3.1125251	0.14707
10:17:22 PM	169.31	3.088858	0.16084
10:27:23 PM	168.07	3.0589118	0.15287
10:37:23 PM	167.2	3.0379012	0.15359
10:47:24 PM	165.95	3.0077136	0.1478
10:57:24 PM	165.16	2.988635	0.14128
11:07:24 PM	164	2.9606208	0.14997
11:17:24 PM	163.09	2.9386442	0.13548
11:27:25 PM	162.13	2.9154601	0.14997
11:37:25 PM	161.02	2.8886534	0.13186
11:47:25 PM	160.31	2.8715068	0.13331
11:57:26 PM	159.18	2.8442172	0.14925
12:07:26 AM	158.25	2.8217576	0.13041
12:17:26 AM	157.38	2.800747	0.12824
12:27:27 AM	156.48	2.7790118	0.12751
12:37:27 AM	155.62	2.7582427	0.12317
12:47:28 AM	154.78	2.7379566	0.13258
12:57:28 AM	153.79	2.714048	0.13403
1:07:28 AM	152.93	2.6932789	0.13403
1:17:29 AM	151.94	2.6693703	0.14273
1:27:29 AM	150.96	2.6457031	0.13258

1:37:29 AM	150.11	2.6251755	0.11157
1:47:30 AM	149.42	2.608512	0.11012
1:57:30 AM	148.59	2.5884673	0.12317
2:07:31 AM	147.72	2.5674567	0.11737
2:17:31 AM	146.97	2.5493441	0.10288
2:27:31 AM	146.3	2.5331636	0.12099
2:37:32 AM	145.3	2.5090134	0.11665
2:47:32 AM	144.69	2.4942819	0.10433
2:57:32 AM	143.86	2.4742372	0.13476
3:07:32 AM	142.83	2.4493626	0.1065
3:17:33 AM	142.39	2.4387366	0.11012
3:27:33 AM	141.31	2.4126544	0.12606
3:37:33 AM	140.65	2.3967153	0.09998
3:47:33 AM	139.93	2.3793272	0.10868
3:57:33 AM	139.15	2.3604902	0.1036
4:07:33 AM	138.5	2.3447926	0.11157
4:17:33 AM	137.61	2.323299	0.11592
4:27:34 AM	136.9	2.3061524	0.1065
4:37:34 AM	136.14	2.2877983	0.12389
4:47:34 AM	135.19	2.2648556	0.1036
4:57:34 AM	134.71	2.2532636	0.09419
5:07:35 AM	133.89	2.2334605	0.10216
5:17:35 AM	133.3	2.2192119	0.08477
5:27:35 AM	132.72	2.2052048	0.08839
5:37:35 AM	132.08	2.1897488	0.11375
5:47:35 AM	131.15	2.1672891	0.12969
5:57:35 AM	130.29	2.14652	0.07752
6:07:36 AM	130.08	2.1414485	0.07462
6:17:36 AM	129.26	2.1216454	0.10433
6:27:36 AM	128.64	2.1066723	0.08984
6:37:36 AM	128.02	2.0916992	0.08042
6:47:36 AM	127.53	2.0798657	0.08042
6:57:37 AM	126.91	2.0648926	0.08404
7:07:37 AM	126.37	2.0518515	0.09346
7:17:37 AM	125.62	2.0337389	0.1123
7:27:37 AM	124.82	2.0144188	0.09129
7:37:37 AM	124.36	2.0033098	0.06158
7:47:37 AM	123.97	1.9938912	0.09129
7:57:37 AM	123.1	1.9728806	0.08766
8:07:38 AM	122.76	1.9646696	0.07317
8:17:38 AM	122.09	1.948489	0.0797
8:27:39 AM	121.66	1.9381044	0.0768
8:37:39 AM	121.03	1.9228899	0.0768
8:47:40 AM	120.6	1.9125053	0.0681
8:57:40 AM	120.09	1.9001887	0.07535

9:07:40 AM	119.56	1.8873892	0.09056
9:17:41 AM	118.84	1.8700011	0.09781
9:27:41 AM	118.21	1.8547865	0.08839
9:37:41 AM	117.62	1.8405379	0.07245
9:47:41 AM	117.21	1.8306364	0.08622
9:57:42 AM	116.43	1.8117993	0.09129
10:07:42 AM	115.95	1.8002072	0.09636
10:17:42 AM	115.1	1.7796796	0.09781
10:27:43 AM	114.6	1.7676045	0.0768
10:37:43 AM	114.04	1.7540805	0.08332
10:47:44 AM	113.45	1.7398319	0.07028
10:57:44 AM	113.07	1.7306548	0.07028
11:07:44 AM	112.48	1.7164063	0.09056
11:17:44 AM	111.82	1.7004672	0.08259
11:27:45 AM	111.34	1.6888751	0.0739
11:37:45 AM	110.8	1.6758341	0.08187
11:47:46 AM	110.21	1.6615855	0.09129
11:57:46 AM	109.54	1.6454049	0.09274
12:07:46 PM	108.93	1.6306733	0.07825
12:17:47 PM	108.46	1.6193228	0.08911
12:27:47 PM	107.7	1.6009687	0.1036
12:37:48 PM	107.03	1.5847881	0.08259
12:47:48 PM	106.56	1.5734375	0.08911
12:57:48 PM	105.8	1.5550834	0.08114
1:07:48 PM	105.44	1.5463894	0.06521
1:17:49 PM	104.9	1.5333483	0.08911
1:27:49 PM	104.21	1.5166847	0.09781
1:37:49 PM	103.55	1.5007456	0.08694
1:47:49 PM	103.01	1.4877046	0.06593
1:57:50 PM	102.64	1.478769	0.07752
2:07:50 PM	101.94	1.4618639	0.08694
2:17:51 PM	101.44	1.4497889	0.0739
2:27:51 PM	100.92	1.4372308	0.06738
2:37:51 PM	100.51	1.4273292	0.0797
2:47:51 PM	99.82	1.4106657	0.08549
2:57:51 PM	99.33	1.3988321	0.08187
3:07:52 PM	98.69	1.383376	0.08114
3:17:52 PM	98.21	1.371784	0.071
3:27:53 PM	97.71	1.3597089	0.071
3:37:53 PM	97.23	1.3481168	0.07173
3:47:53 PM	96.72	1.3358003	0.0681
3:57:54 PM	96.29	1.3254157	0.07462
4:07:54 PM	95.69	1.3109256	0.07897
4:17:54 PM	95.2	1.2990921	0.05434
4:27:55 PM	94.94	1.292813	6.89728

8.1.12. Raw data for control sample at 70 °C (replicate 2)

Raisin Drying data:			
Control grapes at 70 degC			
Air speed		1 m/s	
Air temperature		70 degC	
Relative humidity		0.35	
Treatment		Control	
Replicate number		2	
Date:		15-May-17	
Initial moisture cor		4.6 dry basis	
t	m, Mass		
h:min:s	g	Xw	dX/dt
11:42:07 AM	307.04	4.58659218	
11:42:34 AM	306.92	4.58440878	0.00764
11:42:35 AM	306.9	4.58404488	0.05349
11:52:36 AM	305.94	4.56657768	0.13428
12:02:36 PM	304.44	4.53928518	0.19869
12:12:36 PM	302.3	4.50034789	0.24454
12:22:36 PM	299.96	4.45777159	0.2762
12:32:36 PM	297.24	4.4082812	0.30841
12:42:37 PM	294.31	4.35496985	0.31168
12:52:37 PM	291.53	4.30438776	0.30076
1:02:38 PM	288.8	4.25471542	0.2893
1:12:38 PM	286.23	4.20795427	0.28657
1:22:39 PM	283.55	4.15919168	0.29148
1:32:39 PM	280.89	4.11079298	0.2893
1:42:39 PM	278.25	4.06275819	0.2822
1:52:40 PM	275.72	4.01672484	0.28657
2:02:40 PM	273	3.96723445	0.29585
2:12:41 PM	270.3	3.91810795	0.28384
2:22:41 PM	267.8	3.87262046	0.27838
2:32:42 PM	265.2	3.82531346	0.28712
2:42:42 PM	262.54	3.77691477	0.2833
2:52:43 PM	260.01	3.73088142	0.28057
3:02:43 PM	257.4	3.68339248	0.28493
3:12:43 PM	254.79	3.63590353	0.27893
3:22:43 PM	252.29	3.59041604	0.27784
3:32:43 PM	249.7	3.54329099	0.2822
3:42:44 PM	247.12	3.4963479	0.27675
3:52:44 PM	244.63	3.45104236	0.2822
4:02:44 PM	241.95	3.40227976	0.28166
4:12:45 PM	239.47	3.35715617	0.28111
4:22:45 PM	236.8	3.30857552	0.27838
4:32:45 PM	234.37	3.26436168	0.2691
4:42:45 PM	231.87	3.21887418	0.2691
4:52:45 PM	229.44	3.17466034	0.26583
5:02:46 PM	227	3.13026454	0.26419
5:12:46 PM	224.6	3.08659655	0.2631
5:22:46 PM	222.18	3.04256465	0.25655
5:32:47 PM	219.9	3.00108006	0.24454
5:42:47 PM	217.7	2.96105106	0.24672
5:52:48 PM	215.38	2.91883866	0.24618
6:02:48 PM	213.19	2.87899162	0.24945
6:12:49 PM	210.81	2.83568752	0.25055
6:22:49 PM	208.6	2.79547658	0.25164
6:32:50 PM	206.2	2.75180858	0.25109
6:42:50 PM	204	2.71177959	0.24563
6:52:51 PM	201.7	2.66993109	0.25109
7:02:51 PM	199.4	2.6280826	0.24727
7:12:52 PM	197.17	2.58750775	0.24399
7:22:52 PM	194.93	2.54675096	0.2429
7:32:52 PM	192.72	2.50654001	0.24181
7:42:53 PM	190.5	2.46614711	0.23963
7:52:53 PM	188.33	2.42666397	0.23362
8:02:53 PM	186.22	2.38827252	0.22762
8:12:53 PM	184.16	2.35079083	0.22762
8:22:53 PM	182.05	2.31239938	0.23253
8:32:54 PM	179.9	2.27328014	0.22817
8:42:54 PM	177.87	2.23634429	0.22871
8:52:54 PM	175.71	2.19704309	0.23199
9:02:54 PM	173.62	2.15901555	0.2238
9:12:54 PM	171.61	2.1224436	0.21834
9:22:54 PM	169.62	2.08623556	0.21506
9:32:54 PM	167.67	2.05075531	0.21452
9:42:55 PM	165.69	2.01472921	0.21124
9:52:55 PM	163.8	1.98034067	0.20851
10:02:56 PM	161.87	1.94522432	0.21288
10:12:56 PM	159.9	1.90938018	0.21288
10:22:56 PM	157.97	1.87426383	0.20906
10:32:56 PM	156.07	1.83969333	0.20524
10:42:56 PM	154.21	1.80585064	0.19705
10:52:56 PM	152.46	1.77400939	0.19705
11:02:57 PM	150.6	1.7401667	0.19814
11:12:57 PM	148.83	1.70796155	0.19159
11:22:57 PM	147.09	1.67630225	0.18723
11:32:58 PM	145.4	1.64555271	0.1845
11:42:58 PM	143.71	1.61480316	0.18559
11:52:58 PM	142	1.58368971	0.17522
12:02:59 AM	140.5	1.55639722	0.17031
12:12:59 AM	138.88	1.52692132	0.18013
12:23:00 AM	137.2	1.49635372	0.17904

12:33:00 AM	135.6	1.46724173	0.16539
12:43:00 AM	134.17	1.44122288	0.16703
12:53:01 AM	132.54	1.41156503	0.16485
1:03:01 AM	131.15	1.38627398	0.15939
1:13:02 AM	129.62	1.35843564	0.16539
1:23:02 AM	128.12	1.33114314	0.15393
1:33:02 AM	126.8	1.30712574	0.14956
1:43:02 AM	125.38	1.28128885	0.14793
1:53:03 AM	124.09	1.2578173	0.14629
2:03:03 AM	122.7	1.23252625	0.15666
2:13:04 AM	121.22	1.20559765	0.14847
2:23:04 AM	119.98	1.18303586	0.13592
2:33:05 AM	118.73	1.16029211	0.13537
2:43:05 AM	117.5	1.13791226	0.13755
2:53:05 AM	116.21	1.11444071	0.13646
3:03:06 AM	115	1.09242477	0.12718
3:13:06 AM	113.88	1.07204637	0.13046
3:23:06 AM	112.61	1.04893872	0.1321
3:33:06 AM	111.46	1.02801447	0.12609
3:43:06 AM	110.3	1.00690828	0.12555
3:53:06 AM	109.16	0.98616598	0.119
4:03:06 AM	108.12	0.96724318	0.11736
4:13:07 AM	107.01	0.94704673	0.11135
4:23:07 AM	106.08	0.93012539	0.10972
4:33:07 AM	105	0.91047479	0.1179
4:43:07 AM	103.92	0.89082419	0.11299
4:53:08 AM	102.93	0.87281114	0.10862
5:03:08 AM	101.93	0.85461614	0.10535
5:13:08 AM	101	0.8376948	0.10098
5:23:09 AM	100.08	0.8209554	0.09825
5:33:09 AM	99.2	0.8049438	0.10153
5:43:09 AM	98.22	0.7871127	0.09825
5:53:10 AM	97.4	0.7721928	0.09389
6:03:10 AM	96.5	0.7558173	0.09334
6:13:10 AM	95.69	0.74107936	0.09225
6:23:10 AM	94.81	0.72506776	0.09279
6:33:11 AM	93.99	0.71014786	0.09061
6:43:11 AM	93.15	0.69486406	0.08624
6:53:12 AM	92.41	0.68139976	0.08352
7:03:12 AM	91.62	0.66702571	0.08788
7:13:12 AM	90.8	0.65210582	0.08843
7:23:13 AM	90	0.63754982	0.08188
7:33:13 AM	89.3	0.62481332	0.07751
7:43:13 AM	88.58	0.61171292	0.07915
7:53:14 AM	87.85	0.59843057	0.08024
8:03:14 AM	87.11	0.58496627	0.07806
8:13:14 AM	86.42	0.57241173	0.07642
8:23:15 AM	85.71	0.55949328	0.07751
8:33:15 AM	85	0.54657483	0.06605
8:43:16 AM	84.5	0.53747733	0.06168
8:53:16 AM	83.87	0.52601448	0.08188
9:03:16 AM	83	0.51018483	0.07478
9:13:17 AM	82.5	0.50108733	0.0655
9:23:17 AM	81.8	0.48835083	0.06496
9:33:17 AM	81.31	0.47943529	0.06168
9:43:17 AM	80.67	0.46779049	0.06823
9:53:17 AM	80.06	0.45669154	0.06714
10:03:18 AM	79.44	0.44541064	0.06714
10:13:18 AM	78.83	0.43431169	0.06769
10:23:18 AM	78.2	0.42284884	0.06168
10:33:18 AM	77.7	0.41375134	0.04967
10:43:18 AM	77.29	0.40629139	0.05186
10:53:19 AM	76.75	0.39646609	0.06004
11:03:19 AM	76.19	0.3862769	0.06277
11:13:19 AM	75.6	0.37554185	0.06114
11:23:19 AM	75.07	0.3658985	0.06004
11:33:20 AM	74.5	0.35552735	0.04803
11:43:20 AM	74.19	0.3498869	0.04803
11:53:20 AM	73.62	0.33951575	0.04967
12:03:20 PM	73.28	0.33332945	0.04421
12:13:21 PM	72.81	0.3247778	0.05186
12:23:21 PM	72.33	0.3160442	0.0464
12:33:21 PM	71.96	0.30931205	0.03985
12:43:22 PM	71.6	0.30276186	0.04694
12:53:22 PM	71.1	0.29366436	0.04749
1:03:22 PM	70.73	0.28693221	0.04858
1:13:22 PM	70.21	0.27747081	0.04803
1:23:22 PM	69.85	0.27092061	0.03766
1:33:23 PM	69.52	0.26491626	0.03876
1:43:23 PM	69.14	0.25800216	0.03657
1:53:24 PM	68.85	0.25272561	0.02948
2:03:24 PM	68.6	0.24817686	0.03111
2:13:25 PM	68.28	0.24235446	0.01638
2:23:25 PM	68.3	0.24271836	

8.1.13. Raw data for chemically treated sample at 60 °C, (replicate 2)

				9:51:11 PM	116.23	3.300469748	0.203128099
Raisin Drying data:				10:01:11 PM	115.36	3.268280049	0.184258275
Chemically treated grapes at 60 degC				10:11:12 PM	114.57	3.239050322	0.202018109
Air speed		1 m/s		10:21:12 PM	113.54	3.200940679	0.185368265
Air temperature		60 degC		10:31:12 PM	112.9	3.177260901	0.180928307
Relative humidity		0.35		10:41:12 PM	111.91	3.140631244	0.190918213
Treatment		Chemically treated grape		10:51:12 PM	111.18	3.113621497	0.167608431
Replicate number		2		11:01:12 PM	110.4	3.084761767	0.175378358
Date:		17-May-17		11:11:13 PM	109.6	3.055162044	0.19979813
Initial moisture content		5.0 dry basis		11:21:13 PM	108.6	3.01816239	0.186478255
				11:31:14 PM	107.92	2.993002625	0.166498442
t	m, Mass			11:41:14 PM	107.1	2.962662909	0.206458068
h:min:s	g	Xw	dX/dt	11:51:14 PM	106.06	2.92418327	0.183148286
3:41:00 PM	161.84	4.988023952		12:01:15 AM	105.45	2.901613481	0.158728514
3:51:00 PM	160.21	4.927714517	0.36296660	12:11:15 AM	104.63	2.871273765	0.175378358
4:01:00 PM	158.57	4.867035085	0.34520676	12:21:16 AM	103.87	2.843154028	0.165388452
4:11:00 PM	157.1	4.812645594	0.36296660	12:31:16 AM	103.14	2.816144281	0.157618525
4:21:00 PM	155.3	4.746046217	0.38516639	12:41:16 AM	102.45	2.79061452	0.164278462
4:31:01 PM	153.63	4.684256795	0.35741665	12:51:17 AM	101.66	2.761384793	0.177598338
4:41:01 PM	152.08	4.626907332	0.32966691	1:01:17 AM	100.85	2.731415074	0.153178566
4:51:01 PM	150.66	4.574367824	0.36518658	1:11:18 AM	100.28	2.710325271	0.167608431
5:01:02 PM	148.79	4.505178472	0.36518658	1:21:18 AM	99.34	2.675545597	0.180928307
5:11:02 PM	147.37	4.452638963	0.31412700	1:31:18 AM	98.65	2.650015836	0.173158379
5:21:02 PM	145.96	4.400469452	0.31856701	1:41:18 AM	97.78	2.617826137	0.160948494
5:31:02 PM	144.5	4.346449957	0.30524714	1:51:19 AM	97.2	2.596366338	0.14207867
5:41:03 PM	143.21	4.298720404	0.28637733	2:01:19 AM	96.5	2.57046658	0.165388452
5:51:03 PM	141.92	4.250990851	0.29747721	2:11:19 AM	95.71	2.541236854	0.147628618
6:01:03 PM	140.53	4.199561332	0.28193736	2:21:20 AM	95.17	2.521257041	0.138748701
6:11:04 PM	139.38	4.15701173	0.27305744	2:31:20 AM	94.46	2.494987287	0.149848597
6:21:04 PM	138.07	4.108542184	0.27194745	2:41:20 AM	93.82	2.471307509	0.139858691
6:31:04 PM	136.93	4.066362579	0.2564070	2:51:20 AM	93.2	2.448367723	0.146518629
6:41:04 PM	135.76	4.023072984	0.26861748	3:01:20 AM	92.5	2.422467966	0.157618525
6:51:05 PM	134.51	3.976823417	0.26528751	3:11:20 AM	91.78	2.395828215	0.144298649
7:01:05 PM	133.37	3.934643812	0.24197773	3:21:21 AM	91.2	2.374368416	0.130978774
7:11:05 PM	132.33	3.896164172	0.24530770	3:31:21 AM	90.6	2.352168624	0.146518629
7:21:06 PM	131.16	3.852874577	0.25196764	3:41:22 AM	89.88	2.325528873	0.127648805
7:31:06 PM	130.06	3.812174958	0.24530770	3:51:22 AM	89.45	2.309619022	0.127648805
7:41:06 PM	128.95	3.771105342	0.23975775	4:01:22 AM	88.73	2.282979271	0.146518629
7:51:06 PM	127.9	3.732255706	0.23753777	4:11:23 AM	88.13	2.260779479	0.144298649
8:01:07 PM	126.81	3.691926084	0.21977794	4:21:23 AM	87.43	2.234879722	0.139858691
8:11:07 PM	125.92	3.658996392	0.21866795	4:31:23 AM	86.87	2.214159915	0.139858691
8:21:07 PM	124.84	3.619036766	0.23309781	4:41:24 AM	86.17	2.188260158	0.148738608
8:31:08 PM	123.82	3.581297119	0.21311800	4:51:24 AM	85.53	2.16458038	0.118768888
8:41:08 PM	122.92	3.547997431	0.21089802	5:01:25 AM	85.1	2.148670528	0.122098857
8:51:08 PM	121.92	3.510997777	0.22643788	5:11:25 AM	84.43	2.12388076	0.129868784
9:01:09 PM	120.88	3.472518137	0.21533798	5:21:26 AM	83.93	2.105380934	0.128758795
9:11:09 PM	119.98	3.439218449	0.21311800	5:31:26 AM	83.27	2.080961162	0.135418732
9:21:10 PM	118.96	3.401478802	0.21422799	5:41:26 AM	82.71	2.060241356	0.147628618
9:31:10 PM	118.05	3.367809117	0.19646816	5:51:27 AM	81.94	2.031751623	0.133198753
9:41:10 PM	117.19	3.335989415	0.20201810	6:01:27 AM	81.51	2.015841772	0.133198753

6:11:27 AM	80.74	1.987352038	0.126538816
6:21:28 AM	80.37	1.973662167	0.102119044
6:31:28 AM	79.82	1.953312357	0.125428826
6:41:28 AM	79.24	1.931852558	0.133198753
6:51:28 AM	78.62	1.908912773	0.110998961
7:01:29 AM	78.24	1.894852904	0.107668992
7:11:29 AM	77.65	1.873023109	0.134308743
7:21:29 AM	77.03	1.850083323	0.106559003
7:31:29 AM	76.69	1.837503441	0.104339023
7:41:30 AM	76.09	1.815303649	0.124318836
7:51:30 AM	75.57	1.796063829	0.115438919
8:01:31 AM	75.05	1.776824009	0.126538816
8:11:31 AM	74.43	1.753884224	0.115438919
8:21:31 AM	74.01	1.738344369	0.091019148
8:31:32 AM	73.61	1.723544508	0.110998961
8:41:32 AM	73.01	1.701344715	0.120988868
8:51:32 AM	72.52	1.683214885	0.098789075
9:01:33 AM	72.12	1.668415024	0.103229034
9:11:33 AM	71.59	1.648805207	0.107668992
9:21:33 AM	71.15	1.63252536	0.094349117
9:31:33 AM	70.74	1.617355502	0.083249221
9:41:34 AM	70.4	1.604775619	0.092129138
9:51:34 AM	69.91	1.586645789	0.095459107
10:01:35 AM	69.54	1.572955917	0.096569096
10:11:35 AM	69.04	1.55445609	0.104339023
10:21:36 AM	68.6	1.538176243	0.11432893
10:31:36 AM	68.01	1.516346447	0.094349117
10:41:36 AM	67.75	1.506726537	0.091019148
10:51:37 AM	67.19	1.486006731	0.101009055
11:01:37 AM	66.84	1.473056852	0.092129138
11:11:38 AM	66.36	1.455297018	0.108778982
11:21:38 AM	65.86	1.436797192	0.078809262
11:31:38 AM	65.65	1.429027264	0.093239127
11:41:39 AM	65.02	1.405717482	0.108778982
11:51:39 AM	64.67	1.392767604	0.110998961
12:01:40 PM	64.02	1.368717829	0.08435921
12:11:40 PM	63.91	1.364647867	0.05660947
12:21:40 PM	63.51	1.349848005	0.110998961
12:31:40 PM	62.91	1.327648213	0.105449013
12:41:41 PM	62.56	1.314698334	0.099899065
12:51:41 PM	62.01	1.294348525	0.089909158
1:01:42 PM	61.75	1.284728615	0.066599377
1:11:42 PM	61.41	1.272148733	0.077699273
1:21:43 PM	61.05	1.258828857	0.08657919
1:31:43 PM	60.63	1.243289003	0.106559003
1:41:43 PM	60.09	1.22330919	0.026639751
1:51:44 PM	60.39	1.234409086	0.065489387
2:01:44 PM	59.5	1.201479394	3.703227258
Data End			

8.1.14. Raw data for chemically treated sample at 70 °C, (replicate 2)

Raisin Drying data:			
Chemically treated grapes at 70 degC			
Air speed		1 m/s	
Air temperature		70 degC	
Relative humidity		0.35	
Treatment		Chemically treated grapes	
Replicate number		2	
Date:		16-May-17	
Initial moisture content		4.6 dry basis	
Data Start			
t	m, Mass		
h:min:s	g	Xw	dX/dt
2:40:35 PM	554.52	4.586592179	
2:41:04 PM	554.31	4.584476503	0.007555984
2:41:06 PM	554.27	4.584073518	0.138123384
2:51:06 PM	549.74	4.538435375	0.331858808
3:01:06 PM	543.29	4.473453915	0.41950822
3:11:06 PM	535.86	4.398599302	0.462728448
3:21:07 PM	527.98	4.319211099	0.479049373
3:31:07 PM	520.01	4.238916178	0.476026979
3:41:07 PM	512.23	4.160535439	0.468168756
3:51:07 PM	504.52	4.082859926	0.465750841
4:01:08 PM	496.82	4.005285159	0.458194857
4:11:08 PM	489.36	3.930128307	0.44308289
4:21:08 PM	482.16	3.857590862	0.440060496
4:31:09 PM	474.8	3.783441475	0.443687368
4:41:09 PM	467.48	3.709695073	0.432202273
4:51:10 PM	460.5	3.63937405	0.407418646
5:01:10 PM	454	3.573888857	0.392911157
5:11:10 PM	447.5	3.508403664	0.408023125
5:21:10 PM	440.5	3.437881149	0.414370151
5:31:11 PM	433.79	3.370280281	0.408325364
5:41:11 PM	426.99	3.301772694	0.411045518
5:51:12 PM	420.19	3.233265108	0.406209689
6:01:12 PM	413.55	3.166369465	0.401676099
6:11:12 PM	406.9	3.099373075	0.399258184
6:21:12 PM	400.34	3.033283403	0.393817875
6:31:12 PM	393.87	2.96810045	0.389888764
6:41:13 PM	387.44	2.903320482	0.386261892
6:51:13 PM	381.09	2.839346486	0.381426062
7:01:14 PM	374.82	2.776178461	0.382937259
7:11:14 PM	368.42	2.711700733	0.378101429
7:21:15 PM	362.31	2.650144652	0.370847685
7:31:15 PM	356.15	2.588084838	0.366314094
7:41:15 PM	350.19	2.528039954	0.363291701
7:51:15 PM	344.13	2.466987605	0.356340196
8:01:16 PM	338.4	2.409259888	0.346366297
8:11:16 PM	332.67	2.351532172	0.343948382
8:21:16 PM	327.02	2.294610428	0.34032151
8:31:16 PM	321.41	2.238091669	0.330045372
8:41:16 PM	316.1	2.184595304	0.326720739
8:51:17 PM	310.6	2.129184756	0.324605064
9:01:17 PM	305.36	2.076393616	0.316746841
9:11:17 PM	300.12	2.023602475	0.316142362
9:21:18 PM	294.9	1.971012828	0.315840123
9:31:18 PM	289.67	1.918322435	0.308284139
9:41:18 PM	284.7	1.868251449	0.307981899
9:51:19 PM	279.48	1.815661801	0.301634873
10:01:19 PM	274.72	1.767706491	0.291056496
10:11:19 PM	269.85	1.718642969	0.290754256
10:21:20 PM	265.1	1.670788405	0.285616187
10:31:20 PM	260.4	1.623437574	0.278966922
10:41:20 PM	255.87	1.577799432	0.270806459
10:51:20 PM	251.44	1.533168754	0.269597502
11:01:21 PM	246.95	1.487933598	0.262343757
11:11:21 PM	242.76	1.445720835	0.252369859
11:21:21 PM	238.6	1.403810311	0.247836268
11:31:21 PM	234.56	1.363108745	0.240884763
11:41:21 PM	230.63	1.32351539	0.239071327
11:51:21 PM	226.65	1.283418303	0.23332878
12:01:22 AM	222.91	1.24573913	0.221239206
12:11:22 AM	219.33	1.209671901	0.217914573
12:21:22 AM	215.7	1.173100939	0.215194418
12:31:23 AM	212.21	1.137940428	0.206731717
12:41:23 AM	208.86	1.104190367	0.205824999
12:51:23 AM	205.4	1.069332095	0.199175733
1:01:24 AM	202.27	1.037798456	0.19101527
1:11:24 AM	199.08	1.005660339	0.18648168
1:21:25 AM	196.1	0.975637896	0.175601063
1:31:25 AM	193.27	0.947126651	0.170765234
1:41:25 AM	190.45	0.918716152	0.159582378
1:51:25 AM	187.99	0.893932525	0.152630873
2:01:25 AM	185.4	0.867839194	0.15383983
2:11:25 AM	182.9	0.842652582	0.151119676
2:21:26 AM	180.4	0.817465969	0.143865931
2:31:26 AM	178.14	0.794697271	0.138425623
2:41:27 AM	175.82	0.771324094	0.130869639
2:51:27 AM	173.81	0.751074058	0.124522613
3:01:27 AM	171.7	0.729816557	0.123918134

3:11:27 AM	169.71	0.709768013	0.112735278
3:21:28 AM	167.97	0.692238131	0.11182856
3:31:28 AM	166.01	0.672491826	0.107899449
3:41:29 AM	164.4	0.656271648	0.101552422
3:51:29 AM	162.65	0.638641019	0.095507635
4:01:29 AM	161.24	0.62443577	0.089160609
4:11:29 AM	159.7	0.608920816	0.089160609
4:21:29 AM	158.29	0.594715567	0.087347173
4:31:29 AM	156.81	0.579805092	0.07948895
4:41:29 AM	155.66	0.56821925	0.074350881
4:51:30 AM	154.35	0.555021465	0.072537444
5:01:30 AM	153.26	0.544040102	0.069212812
5:11:30 AM	152.06	0.531950528	0.070724008
5:21:30 AM	150.92	0.520465432	0.059843392
5:31:31 AM	150.08	0.512002731	0.056820998
5:41:31 AM	149.04	0.5015251	0.06044787
5:51:32 AM	148.08	0.491853441	0.052891887
6:01:32 AM	147.29	0.483894471	0.051985169
6:11:32 AM	146.36	0.474525051	0.048056057
6:21:33 AM	145.7	0.467875785	0.045335903
6:31:33 AM	144.86	0.459413083	0.044429185
6:41:34 AM	144.23	0.453066057	0.040802312
6:51:34 AM	143.51	0.445812313	0.040197834
7:01:34 AM	142.9	0.439666779	0.036570962
7:11:34 AM	142.3	0.433621992	0.03717544
7:21:35 AM	141.67	0.427274966	0.033850807
7:31:35 AM	141.18	0.42233839	0.032037371
7:41:35 AM	140.61	0.416595842	0.029619456
7:51:35 AM	140.2	0.412465237	0.026294824
8:01:36 AM	139.74	0.407830901	0.028410499
8:11:36 AM	139.26	0.402995071	0.029014978
8:21:37 AM	138.78	0.398159241	0.025085866
8:31:37 AM	138.43	0.394633116	0.023574669
8:41:37 AM	138	0.390301018	0.02327243
8:51:37 AM	137.66	0.386875639	0.022063473
9:01:38 AM	137.27	0.382946527	0.022970191
9:11:38 AM	136.9	0.379218909	0.022063473
9:21:38 AM	136.54	0.375592037	0.021156755
9:31:39 AM	136.2	0.372166657	0.019041079
9:41:39 AM	135.91	0.36924501	

8.1.15. Raw data for sample blanched with oil at 60 °C, (replicate 2)

Raisin Drying data: Oil blanched			
		grapes at 60 deg	
Air speed		1 m/s	
Air temperature		60 degC	
Relative humidity		35%	
Treatment		Oil blanched grape	
Replicate number		2	
Date:		12-Apr-17	
Initial moisture cont	4.6 dry basis		
t	m, Mass		
h:min:s	g	Xw	dX/dt
11:39:14 AM	234.64	4.585164	0.16638
11:39:17 AM	232.37	4.5311309	0.39561
11:49:17 AM	229.1	4.4532947	0.45488
11:59:18 AM	226	4.379505	0.44845
12:09:18 PM	222.82	4.3038111	0.42917
12:19:18 PM	219.99	4.2364483	0.41703
12:29:19 PM	216.98	4.1648009	0.39561
12:39:19 PM	214.45	4.104579	0.37419
12:49:19 PM	211.74	4.0400726	0.37776
12:59:19 PM	209.16	3.9786605	0.36347
1:09:20 PM	206.65	3.9189147	0.35062
1:19:20 PM	204.25	3.8617872	0.36919
1:29:20 PM	201.48	3.7958525	0.35133
1:39:20 PM	199.33	3.7446758	0.34705
1:49:21 PM	196.62	3.6801694	0.34848
1:59:21 PM	194.45	3.6285166	0.32277
2:09:22 PM	192.1	3.5725793	0.33205
2:19:22 PM	189.8	3.5178321	0.28564
2:29:23 PM	188.1	3.4773668	0.27207
2:39:23 PM	185.99	3.4271422	0.30563
2:49:23 PM	183.82	3.3754895	0.32063
2:59:24 PM	181.5	3.3202662	0.32848
3:09:24 PM	179.22	3.2659951	0.32348
3:19:25 PM	176.97	3.2124381	0.30563
3:29:25 PM	174.94	3.1641177	0.29921
3:39:25 PM	172.78	3.112703	0.30635
3:49:26 PM	170.65	3.0620024	0.29992
3:59:26 PM	168.58	3.0127299	0.29206
4:09:27 PM	166.56	2.9646476	0.29778
4:19:27 PM	164.41	2.9134709	0.28707
4:29:27 PM	162.54	2.8689591	0.27921
4:39:27 PM	160.5	2.8204007	0.3042
4:49:27 PM	158.28	2.7675578	0.28064
4:59:28 PM	156.57	2.7268544	0.26564
5:09:28 PM	154.56	2.6790102	0.28778
5:19:28 PM	152.54	2.6309279	0.40418
5:29:28 PM	148.9	2.5442845	0.46916
5:39:52 PM	145.97	2.4745414	0.40561
5:49:53 PM	143.22	2.4090828	0.39775
5:59:53 PM	140.4	2.341958	0.39704
6:09:53 PM	137.66	2.2767374	0.38061
6:19:54 PM	135.07	2.2150874	0.36704
6:29:54 PM	132.52	2.1543894	0.35705
6:39:54 PM	130.07	2.0960718	0.35133
6:49:54 PM	127.6	2.0372781	0.35562
6:59:55 PM	125.09	1.9775322	0.34276
7:09:55 PM	122.8	1.9230231	0.32491
7:19:56 PM	120.54	1.869228	0.32134
7:29:56 PM	118.3	1.8159091	0.31349
7:39:56 PM	116.15	1.7647323	0.30278
7:49:56 PM	114.06	1.7149838	0.29206
7:59:56 PM	112.06	1.6673776	0.29135
8:09:56 PM	109.98	1.6178671	0.28992
8:19:57 PM	108	1.5707369	0.27635
8:29:57 PM	106.11	1.525749	0.26279
8:39:58 PM	104.32	1.4831414	0.25707
8:49:58 PM	102.51	1.4400578	0.25208
8:59:59 PM	100.79	1.3991164	0.2485
9:09:59 PM	99.03	1.3572229	0.23779
9:19:00 PM	97.46	1.319852	0.22565
9:29:00 PM	95.87	1.2820051	0.21994
9:39:00 PM	94.38	1.2465384	0.21851
9:49:01 PM	92.81	1.2091675	0.20852
9:59:01 PM	91.46	1.1770333	0.19923
10:09:02 PM	90.02	1.1427568	0.19995
10:19:02 PM	88.66	1.1103846	0.19281
10:29:03 PM	87.32	1.0784884	0.18352
10:39:03 PM	86.09	1.0492106	0.16567
10:49:03 PM	85	1.0232652	0.15996
10:59:03 PM	83.85	0.9958916	0.16067
11:09:04 PM	82.75	0.9697081	0.15282
11:19:04 PM	81.71	0.9449529	0.14639
11:29:04 PM	80.7	0.9209118	0.14496
11:39:05 PM	79.68	0.8966326	0.13496
11:49:05 PM	78.81	0.8759239	0.13425
11:59:05 PM	77.8	0.8518827	0.13282
12:09:06 AM	76.95	0.8316501	0.1164

12:19:06 AM	76.17	0.8130836	0.10569
12:29:06 AM	75.47	0.7964214	0.1164
12:39:06 AM	74.54	0.7742845	0.11497
12:49:07 AM	73.86	0.7580984	0.10783
12:59:07 AM	73.03	0.7383418	0.09569
1:09:08 AM	72.52	0.7262022	0.08069
1:19:08 AM	71.9	0.7114443	0.08141
1:29:08 AM	71.38	0.6990667	0.08569
1:39:08 AM	70.7	0.6828806	0.08426
1:49:09 AM	70.2	0.670979	0.07926
1:59:09 AM	69.59	0.6564591	0.08069
2:09:10 AM	69.07	0.6440815	0.07712
2:19:10 AM	68.51	0.6307517	0.06927
2:29:11 AM	68.1	0.6209924	0.06141
2:39:11 AM	67.65	0.610281	0.06998
2:49:11 AM	67.12	0.5976654	0.06141
2:59:12 AM	66.79	0.5898104	0.0507
3:09:12 AM	66.41	0.5807652	0.05427
3:19:13 AM	66.03	0.57172	0.05641
3:29:13 AM	65.62	0.5619607	0.04927
3:39:13 AM	65.34	0.5552958	0.0407
3:49:14 AM	65.05	0.5483929	0.04427
3:59:14 AM	64.72	0.5405379	0.03856
4:09:14 AM	64.51	0.5355392	0.0357
4:19:14 AM	64.22	0.5286363	0.0457
4:29:14 AM	63.87	0.5203053	0.04285
4:39:14 AM	63.62	0.5143545	0.03499
4:49:15 AM	63.38	0.5086417	0.02928
4:59:15 AM	63.21	0.5045952	0.03213
4:09:16 AM	62.93	0.4979303	0.03499
4:19:16 AM	62.72	0.4929317	0.02999
4:29:16 AM	62.51	0.487933	0.02142
4:39:17 AM	62.42	0.4857907	0.02856
4:49:17 AM	62.11	0.4784118	0.0407
4:59:17 AM	61.85	0.4722229	0.02999
5:09:18 AM	61.69	0.4684145	0.02285
5:19:18 AM	61.53	0.464606	0.02714
5:29:18 AM	61.31	0.4593693	0.02999
5:39:19 AM	61.11	0.4546086	0.02071
5:49:19 AM	61.02	0.4524664	0.02142
5:59:19 AM	60.81	0.4474677	0.02142
6:09:20 AM	60.72	0.4453254	0.01714
6:19:20 AM	60.57	0.441755	0.01999
6:29:21 AM	60.44	0.4386606	0.02785
6:39:21 AM	60.18	0.4324717	0.03285
6:49:21 AM	59.98	0.4277111	0.01214
6:59:21 AM	60.01	0.4284252	0.00786
6:09:21 AM	59.87	0.4250928	0.02928
6:19:22 AM	59.6	0.4186659	4.27528

8.1.16. Raw data for sample blanched with oil at 70 °C, (replicate 2)

Raisin Drying data: Oil blanched			
		grapes at 70 deg	
Air speed		1 m/s	
Air temperature		70 degC	
Relative humidity		35%	
Treatment		Oil blanched grape	
Replicate number		2	
Date:		10-Apr-17	
Initial moisture cont		4.6 dry basis	
Data Start			
t	m, Mass		
h:min:s	g	Xw	dX/dt
4:26:33 PM	266.5	4.5865922	
4:26:35 PM	266.5	4.5865922	0.13332
4:36:36 PM	264.38	4.542151	0.34211
4:46:36 PM	261.06	4.4725544	0.46978
4:56:36 PM	256.91	4.3855587	0.54713
5:06:37 PM	252.36	4.2901779	0.59681
5:16:37 PM	247.42	4.1866215	0.61379
5:26:37 PM	242.6	4.0855807	0.60499
5:36:37 PM	237.8	3.9849592	0.59807
5:46:37 PM	233.09	3.8862243	0.58926
5:56:37 PM	228.43	3.7885375	0.58298
6:06:38 PM	223.82	3.6918989	0.56537
6:16:38 PM	219.44	3.6000818	0.5465
6:26:38 PM	215.13	3.509732	0.52449
6:36:38 PM	211.1	3.4252518	0.50688
6:46:39 PM	207.07	3.3407716	0.49493
6:56:39 PM	203.23	3.2602744	0.46978
7:06:39 PM	199.6	3.1841794	0.45154
7:16:39 PM	196.05	3.1097613	0.44525
7:26:40 PM	192.52	3.0357626	0.43079
7:36:40 PM	189.2	2.966166	0.43582
7:46:40 PM	185.59	2.8904902	0.44022
7:56:40 PM	182.2	2.8194262	0.42764
8:06:41 PM	178.79	2.747943	0.41506
8:16:41 PM	175.6	2.6810716	0.40626
8:26:41 PM	172.33	2.6125232	0.40374
8:36:41 PM	169.18	2.5464903	0.39746
8:46:42 PM	166.01	2.4800382	0.38676
8:56:42 PM	163.03	2.4175689	0.38048
9:06:42 PM	159.96	2.3532131	0.37607
9:16:42 PM	157.05	2.2922113	0.36853
9:26:42 PM	154.1	2.2303709	0.36601
9:36:42 PM	151.23	2.1702076	0.35658
9:46:42 PM	148.43	2.1115117	0.3528
9:56:43 PM	145.62	2.0526062	0.35406
10:06:43 PM	142.8	1.993491	0.34714
10:16:43 PM	140.1	1.9368914	0.33645
10:26:43 PM	137.45	1.8813399	0.3245
10:36:44 PM	134.94	1.8287233	0.31507
10:46:44 PM	132.44	1.7763162	0.31884
10:56:45 PM	129.87	1.7224417	0.31884
11:06:45 PM	127.37	1.6700347	0.31067
11:16:45 PM	124.93	1.6188854	0.30375
11:26:45 PM	122.54	1.5687843	0.30501
11:36:46 PM	120.08	1.5172157	0.30438
11:46:46 PM	117.7	1.4673242	0.2918
11:56:46 PM	115.44	1.4199482	0.28048
12:06:46 AM	113.24	1.37383	0.27168
12:16:47 AM	111.12	1.3293888	0.26665
12:26:47 AM	109	1.2849476	0.2591
12:36:48 AM	107	1.243022	0.2547
12:46:48 AM	104.95	1.2000482	0.24527
12:56:48 AM	103.1	1.161267	0.23646
1:06:48 AM	101.19	1.121228	0.23898
1:16:48 AM	99.3	1.0816083	0.22891
1:26:49 AM	97.55	1.0449233	0.21445
1:36:49 AM	95.89	1.010125	0.21193
1:46:50 AM	94.18	0.9742786	0.20753
1:56:50 AM	92.59	0.9409477	0.19747
2:06:51 AM	91.04	0.9084554	0.19307
2:16:51 AM	89.52	0.8765919	0.18867
2:26:51 AM	88.04	0.8455669	0.18112
2:36:51 AM	86.64	0.8162189	0.17735
2:46:52 AM	85.22	0.7864517	0.17169
2:56:52 AM	83.91	0.7589904	0.15533
3:06:52 AM	82.75	0.7346736	0.15156
3:16:53 AM	81.5	0.70847	0.14842
3:26:53 AM	80.39	0.6852013	0.14276
3:36:53 AM	79.23	0.6608844	0.13144
3:46:54 AM	78.3	0.641389	0.12955
3:56:54 AM	77.17	0.617701	0.12829
4:06:54 AM	76.26	0.5986248	0.1176
4:16:54 AM	75.3	0.5785005	0.11697
4:26:55 AM	74.4	0.559634	0.10691
4:36:55 AM	73.6	0.5428637	0.09622
4:46:56 AM	72.87	0.5275609	0.09433
4:56:56 AM	72.1	0.5114195	0.10125
5:06:57 AM	71.26	0.4938107	0.09433
5:16:57 AM	70.6	0.4799753	0.08238
5:26:57 AM	69.95	0.4663494	0.08176
5:36:58 AM	69.3	0.4527236	0.07295
5:46:58 AM	68.79	0.4420326	0.07169
5:56:59 AM	68.16	0.428826	0.07484
6:06:59 AM	67.6	0.4170868	0.06981
6:16:59 AM	67.05	0.4055572	0.06792
6:27:00 AM	66.52	0.3944469	0.05974
6:37:00 AM	66.1	0.3856426	0.05471

6:47:00 AM	65.65	0.3762093	0.06729
6:57:00 AM	65.03	0.3632123	0.05346
7:07:01 AM	64.8	0.3583909	0.04151
7:17:01 AM	64.37	0.3493769	0.04968
7:27:01 AM	64.01	0.3418303	0.04905
7:37:01 AM	63.59	0.3330259	0.05094
7:47:02 AM	63.2	0.3248504	0.04025
7:57:02 AM	62.95	0.3196097	0.04151
8:07:03 AM	62.54	0.3110149	0.04088
8:17:03 AM	62.3	0.3059838	0.03836
8:27:03 AM	61.93	0.2982276	0.03773
8:37:03 AM	61.7	0.2934061	0.02767
8:47:04 AM	61.49	0.289004	0.0327
8:57:04 AM	61.18	0.2825055	0.03082
9:07:04 AM	61	0.2787322	0.02201
9:17:05 AM	60.83	0.2751685	0.0195
9:27:05 AM	60.69	0.2722337	0.02516
9:37:05 AM	60.43	0.2667834	0.03396
9:47:06 AM	60.15	0.2609138	0.03144
9:57:06 AM	59.93	0.2563019	0.02516
10:07:07 AM	59.75	0.2525286	0.02075
10:17:07 AM	59.6	0.2493842	0.01824
10:27:07 AM	59.46	0.2464494	0.02264
10:37:07 AM	59.24	0.2418376	0.02264
10:47:08 AM	59.1	0.2389028	0.02138
10:57:08 AM	58.9	0.2347102	0.02327
11:07:09 AM	58.73	0.2311466	0.01761
11:17:09 AM	58.62	0.2288407	0.01572
11:27:09 AM	58.48	0.2259059	0.01635
11:37:10 AM	58.36	0.2233903	0.01761
11:47:10 AM	58.2	0.2200363	0.02327
11:57:10 AM	57.99	0.2156341	0.01824
12:07:11 PM	57.91	0.213957	0.01069
12:17:11 PM	57.82	0.2120704	0.01509
12:27:11 PM	57.67	0.208926	0.01887
12:37:11 PM	57.52	0.2057815	0.01698
12:47:11 PM	57.4	0.203266	0.01509
12:57:11 PM	57.28	0.2007505	0.00755
1:07:12 PM	57.28	0.2007505	0.01069
1:17:12 PM	57.11	0.1971868	0.01698
1:27:12 PM	57.01	0.1950905	0.01321
1:37:12 PM	56.9	0.1927846	0.01069
1:47:13 PM	56.84	0.1915268	0.00629
1:57:13 PM	56.8	0.1906883	0.0088
2:07:13 PM	56.7	0.188592	0.01509
2:17:14 PM	56.56	0.1856572	

8.1.17. Raw data for neelded sample at 60 °C , (replicate 2)

Raisin Drying data:			
Needled grapes at 60 degC			
Air speed		1 m/s	
Air temperature		60 degC	
Relative humidity		0.35	
Treatment		Needled grapes	
Replicate number		2	
Date:		18-May-15	
Initial moisture conten		4.6 dry basis	
t	m, Mass		
h:min:s	g	Xw	dX/dt
2:17:13 PM	250.11	4.586592179	
2:27:13 PM	246.812	4.512926268	0.58131
2:37:13 PM	241.435	4.392822689	0.7091
2:47:13 PM	236.23	4.276560995	0.68986
2:57:13 PM	231.14	4.162868003	0.66742
3:07:13 PM	226.27	4.05408905	0.65066
3:17:14 PM	221.43	3.945980193	0.62922
3:27:14 PM	216.88	3.844348933	0.60778
3:37:14 PM	212.36	3.74338777	0.57226
3:47:14 PM	208.34	3.653594876	0.53809
3:57:14 PM	204.33	3.564025348	0.53675
4:07:14 PM	200.33	3.474679186	0.53675
4:17:15 PM	196.32	3.385109658	0.52804
4:27:15 PM	192.45	3.298667246	0.52066
4:37:15 PM	188.55	3.211554737	12.5744
4:47:16 PM	4.7992	-0.89280247	0.48984
4:57:16 PM	181.24	3.048274625	-11.59
5:07:17 PM	177.766	2.970677483	0.46136
5:17:17 PM	174.355	2.894487543	0.4688
5:27:17 PM	170.77	2.814411045	0.4627
5:37:18 PM	167.45	2.74025373	0.43516
5:47:18 PM	164.276	2.66935755	0.42839
5:57:19 PM	161.057	2.597456225	0.42404
6:07:19 PM	157.948	2.528011921	0.42377
6:17:19 PM	154.733	2.456199942	0.41425
6:27:20 PM	151.766	2.389927426	0.39824
6:37:20 PM	148.79	2.323453881	0.39777
6:47:20 PM	145.83	2.257337721	0.37164
6:57:20 PM	143.244	2.199575427	0.36165
7:07:20 PM	140.433	2.136787411	0.37639
7:17:20 PM	137.627	2.074111078	0.35823
7:27:20 PM	135.087	2.017376265	0.34215
7:37:21 PM	132.521	1.960060702	0.32748
7:47:21 PM	130.2	1.908217591	0.32754
7:57:21 PM	127.633	1.850879691	0.34262
8:07:22 PM	125.087	1.794010859	0.32453
8:17:22 PM	122.79	1.742703825	0.31005
8:27:22 PM	120.46	1.690659685	0.30154
8:37:22 PM	118.29	1.642189392	0.28995

8:47:23 PM	116.133	1.594009474	0.28365
8:57:23 PM	114.057	1.547638815	0.26958
9:07:23 PM	112.11	1.504149571	0.2734
9:17:24 PM	109.977	1.45650573	0.27461
9:27:24 PM	108.012	1.412614427	0.25832
9:37:24 PM	106.122	1.370398366	0.24646
9:47:25 PM	104.334	1.330460631	0.2413
9:57:25 PM	102.521	1.289964483	0.23842
10:07:26 PM	100.776	1.250987219	0.23447
10:17:26 PM	99.022	1.211808927	0.22254
10:27:26 PM	97.455	1.176807568	0.21148
10:37:26 PM	95.866	1.141314805	0.20632
10:47:27 PM	94.376	1.108033359	0.20492
10:57:27 PM	92.808	1.073009663	0.19574
11:07:28 PM	91.455	1.042788324	0.18702
11:17:28 PM	90.017	1.010668379	0.18763
11:27:28 PM	88.655	0.98024601	0.18086
11:37:28 PM	87.318	0.950382055	0.17201
11:47:28 PM	86.088	0.92290811	0.15459
11:57:28 PM	85.011	0.898851656	0.15037
12:07:28 AM	83.844	0.872784913	0.15178
12:17:29 AM	82.746	0.848259392	0.14226
12:27:29 AM	81.721	0.825364437	0.13636
12:37:29 AM	80.711	0.802804531	0.13697
12:47:30 AM	79.677	0.779708548	0.12745
12:57:30 AM	78.809	0.760320431	0.12491
1:07:31 AM	77.813	0.738073237	0.12497
1:17:31 AM	76.944	0.718662783	0.11103
1:27:32 AM	76.156	0.701061589	0.10185
1:37:32 AM	75.424	0.684711241	0.10876
1:47:32 AM	74.533	0.664809383	0.10366
1:57:33 AM	73.877	0.650156613	0.09938
2:07:33 AM	73.05	0.631684294	0.09361
2:17:34 AM	72.48	0.618952465	0.08443
2:27:34 AM	71.79	0.603540252	0.07974
2:37:34 AM	71.29	0.592371982	0.07438
2:47:34 AM	70.68	0.578746692	0.07371
2:57:34 AM	70.19	0.567801787	0.08041
3:07:34 AM	69.48	0.551942843	0.07237
3:17:35 AM	69.11	0.543678323	0.06634
3:27:35 AM	68.49	0.529829668	0.06634
3:37:35 AM	68.12	0.521565148	0.05495
3:47:35 AM	67.67	0.511513705	0.06835
3:57:35 AM	67.1	0.498781877	0.05964
4:07:36 AM	66.78	0.491634184	0.04691
4:17:36 AM	66.4	0.483146298	0.04959
4:27:36 AM	66.04	0.475105144	0.0516
4:37:37 AM	65.63	0.465947162	0.04758
4:47:37 AM	65.33	0.4592462	0.0382
4:57:38 AM	65.06	0.453215334	0.03954

5:07:38 AM	64.74	0.446067641	0.03552
5:17:38 AM	64.53	0.441376967	0.03417
5:27:39 AM	64.23	0.434676005	0.04289
5:37:39 AM	63.89	0.427081581	0.04155
5:47:39 AM	63.61	0.42082735	0.03283
5:57:39 AM	63.4	0.416136676	0.0268
6:07:39 AM	63.21	0.411892734	0.03082
6:17:40 AM	62.94	0.405861868	0.03216
6:27:40 AM	62.73	0.401171194	0.03015
6:37:40 AM	62.49	0.395810424	0.02278
6:47:41 AM	62.39	0.39357677	0.0268
6:57:41 AM	62.09	0.386875808	0.03619
7:07:41 AM	61.85	0.381515038	0.0268
7:17:42 AM	61.69	0.377941192	0.02144
7:27:42 AM	61.53	0.374367345	0.02546
7:37:42 AM	61.31	0.369453306	0.02948
7:47:43 AM	61.09	0.364539268	0.0201
7:57:43 AM	61.01	0.362752344	0.0201
8:07:43 AM	60.79	0.357838305	0.02144
8:17:43 AM	60.69	0.355604651	0.01474
8:27:44 AM	60.57	0.352924266	0.01675
8:37:44 AM	60.44	0.350020516	0.0268
8:47:44 AM	60.17	0.34398965	0.03082
8:57:45 AM	59.98	0.339745707	0.00938
9:07:45 AM	60.03	0.340862534	0.0067
9:17:45 AM	59.88	0.337512053	0.02948
9:27:45 AM	59.59	0.331034457	0.01675
9:37:46 AM	59.63	0.331927918	0.0067
9:47:46 AM	59.49	0.328800803	0.01809
9:57:46 AM	59.36	0.325897052	0.01675
10:07:46 AM	59.24	0.323216667	0.01541
10:17:47 AM	59.13	0.320759648	0.01005
10:27:47 AM	59.09	0.319866186	0.00804
10:37:47 AM	59.01	0.318079263	0.01072
10:47:48 AM	58.93	0.31629234	0.01675
10:57:48 AM	58.76	0.312495128	0.01072
11:07:48 AM	58.77	0.312718493	0.01072
11:17:49 AM	58.6	0.308921281	0.01206
11:27:49 AM	58.59	0.308697916	0.00871
11:37:49 AM	58.47	0.306017531	0.01273
11:47:49 AM	58.4	0.304453973	0.01407
11:57:50 AM	58.26	0.301326858	0.01139
12:07:50 PM	58.23	0.300656761	-0.0007
12:17:50 PM	58.27	0.301550223	0.00804
12:27:50 PM	58.11	0.297976376	0.01206
12:37:50 PM	58.09	0.297529646	0.00469
12:47:51 PM	58.04	0.296412819	0.00536
12:57:51 PM	58.01	0.295742722	0.00402
1:07:51 PM	57.98	0.295072626	0.00469
1:17:51 PM	57.94	0.294179165	0.00402
1:27:52 PM	57.92	0.293732434	0.00603
1:37:52 PM	57.85	0.292168876	0.01072
1:47:52 PM	57.76	0.290158587	0.00737
1:57:52 PM	57.74	0.289711856	3.87048

8.1.18. Raw data for halved sample at 60 °C, (replicate 2)

Raisin Drying data: Halved grapes at 60 degC			
Air speed		1 m/s	
Air temperature		60 degC	
Relative humidity		35%	
Treatment		halved grapes	
Replicate number		2	
Date:		20-Apr-17	
Initial moisture content		4.6 dry basis	
t	m, Mass		
h:min:s	g	Xw	dX/dt
3:22:22 PM	164.02	4.58659218	
3:22:42 PM	163.96	4.58454855	0.56404077
3:32:42 PM	158.5	4.39857859	1.196543
3:42:43 PM	152.25	4.18570089	1.23843733
3:52:43 PM	146.38	3.98576615	1.15975773
4:02:44 PM	140.9	3.79911497	1.07086001
4:12:44 PM	135.9	3.62881281	0.99422403
4:22:45 PM	131.17	3.46770696	0.92678437
4:32:45 PM	126.83	3.31988468	0.8501484
4:42:46 PM	122.85	3.18432416	0.79190506
4:52:46 PM	119.08	3.05591633	0.75818523
5:02:46 PM	115.43	2.93159575	0.72344359
5:12:47 PM	112	2.81476847	0.6692875
5:22:47 PM	108.88	2.70849992	0.63250224
5:32:47 PM	105.81	2.60393439	0.61717504
5:42:47 PM	102.84	2.5027749	0.5742589
5:52:48 PM	100.19	2.41251476	0.55586626
6:02:48 PM	97.4	2.31748615	0.53951725
6:12:48 PM	94.91	2.23267567	0.50681924
6:22:48 PM	92.44	2.1485464	0.49455748
6:32:49 PM	90.07	2.06782318	0.48331754
6:42:49 PM	87.71	1.98744056	0.46696853
6:52:50 PM	85.5	1.912167	0.43222689
7:02:50 PM	83.48	1.84336493	0.41894332
7:12:51 PM	81.4	1.77251923	0.42098695
7:22:51 PM	79.36	1.70303594	0.41894332
7:32:51 PM	77.3	1.63287145	0.393398
7:42:51 PM	75.51	1.57190328	0.35763454
7:52:51 PM	73.8	1.51365994	0.36069998
8:02:52 PM	71.98	1.45166995	0.36069998
8:12:52 PM	70.27	1.39342661	0.33515466
8:22:52 PM	68.7	1.33995173	0.33413285
8:32:53 PM	67	1.28204899	0.32187109
8:42:53 PM	65.55	1.23266137	0.30654389
8:52:53 PM	64	1.1798677	0.2993912
9:02:54 PM	62.62	1.1328643	0.26873681
9:12:54 PM	61.37	1.09028876	0.26056231
9:22:54 PM	60.07	1.04601019	0.26464956
9:32:54 PM	58.78	1.00207224	0.26567138
9:42:55 PM	57.47	0.95745307	0.25238781
9:52:55 PM	56.31	0.91794297	0.2125371
10:02:56 PM	55.39	0.88660737	0.21049347
10:12:56 PM	54.25	0.84777848	0.21764617
10:22:56 PM	53.26	0.81405865	0.19925353
10:32:56 PM	52.3	0.78136063	0.18699178
10:42:57 PM	51.43	0.75172806	0.17473002
10:52:57 PM	50.59	0.72311729	0.17575183
11:02:57 PM	49.71	0.69314411	0.16859914
11:12:58 PM	48.94	0.66691758	0.15531557
11:22:58 PM	48.19	0.64137225	0.15940283
11:32:59 PM	47.38	0.6137833	0.15225013
11:42:59 PM	46.7	0.59062221	0.13487931
11:52:59 PM	46.06	0.56882353	0.12057393
12:02:59 AM	45.52	0.5504309	0.11853031
12:13:00 AM	44.9	0.52931343	0.12159574
12:23:00 AM	44.33	0.50989898	0.10729036
12:33:00 AM	43.85	0.49354998	0.11444305
12:43:00 AM	43.21	0.4717513	0.10933399
12:53:01 AM	42.78	0.45710531	0.0786796
1:03:01 AM	42.44	0.44552477	0.07970141
1:13:01 AM	42	0.43053818	0.07970141
1:23:02 AM	41.66	0.41895763	0.08174504
1:33:02 AM	41.2	0.40328983	0.0868541
1:43:03 AM	40.81	0.39000626	0.07152691
1:53:03 AM	40.5	0.37944753	0.06233059
2:03:04 AM	40.2	0.3692294	0.07459235
2:13:04 AM	39.77	0.35458341	0.0633524
2:23:04 AM	39.58	0.34811193	0.03371983
2:33:05 AM	39.44	0.34334347	0.03474164
2:43:05 AM	39.24	0.33653138	0.04598158
2:53:05 AM	38.99	0.32801627	0.06437422
3:03:05 AM	38.61	0.31507331	0.05722153
3:13:06 AM	38.43	0.30894243	0.04291615
3:23:06 AM	38.19	0.30076793	0.03678527
3:33:06 AM	38.07	0.29668067	0.04189433
3:43:06 AM	37.78	0.28680315	0.04291615
3:53:07 AM	37.65	0.28237529	0.03269802
4:03:07 AM	37.46	0.27590381	0.03576345
4:13:07 AM	37.3	0.27045414	0.02758895
4:23:07 AM	37.19	0.26670749	0.02043626
4:33:07 AM	37.1	0.26364205	0.02963258
4:43:08 AM	36.9	0.25682997	0.02145807
4:53:08 AM	36.89	0.25648936	0.01634901
5:03:08 AM	36.74	0.2513803	0.03985071
5:13:09 AM	36.5	0.2432058	0.03269802
5:23:09 AM	36.42	0.24048096	0.0081745
5:33:09 AM	36.42	0.24048096	0.02247989
5:43:09 AM	36.2	0.23298767	0.03269802
5:53:09 AM	36.1	0.22958162	0.01226176
6:03:10 AM	36.08	0.22890041	0.01021813
6:13:10 AM	36	0.22617558	0.01532719
6:23:11 AM	35.93	0.22379135	0.00919632
6:33:11 AM	35.91	0.22311014	0.01532719
6:43:11 AM	35.78	0.21868228	0.0235017
6:53:11 AM	35.68	0.21527624	0.0081745
7:03:12 AM	35.7	0.21595745	0.01021813
7:13:12 AM	35.58	0.2118702	0.01634901
7:23:13 AM	35.54	0.21050778	0.0081745
7:33:13 AM	35.5	0.20914536	0.00306544
7:43:13 AM	35.51	0.20948597	0.00919632
7:53:14 AM	35.41	0.20607992	0.01123994
8:03:14 AM	35.4	0.20573932	0.00715269
8:13:14 AM	35.34	0.20369569	0.01430538
8:23:15 AM	35.26	0.20097086	0.01328357
8:33:15 AM	35.21	0.19926784	0.00204363
8:43:15 AM	35.24	0.20028965	0.00306544
8:53:16 AM	35.18	0.19824602	0.02145807
9:03:16 AM	35.03	0.19313696	0.00510906
9:13:16 AM	35.13	0.196543	-0.0030654
9:23:17 AM	35.06	0.19415877	0.01737082
9:33:17 AM	34.96	0.19075273	0.01737082
9:43:18 AM	34.89	0.1883685	0.01737082
9:53:18 AM	34.79	0.18496246	0.01328357
10:03:18 AM	34.76	0.18394064	-0.0112399
10:13:19 AM	34.9	0.1887091	3.55182193

Appendix 8.2. Graphs of second replication

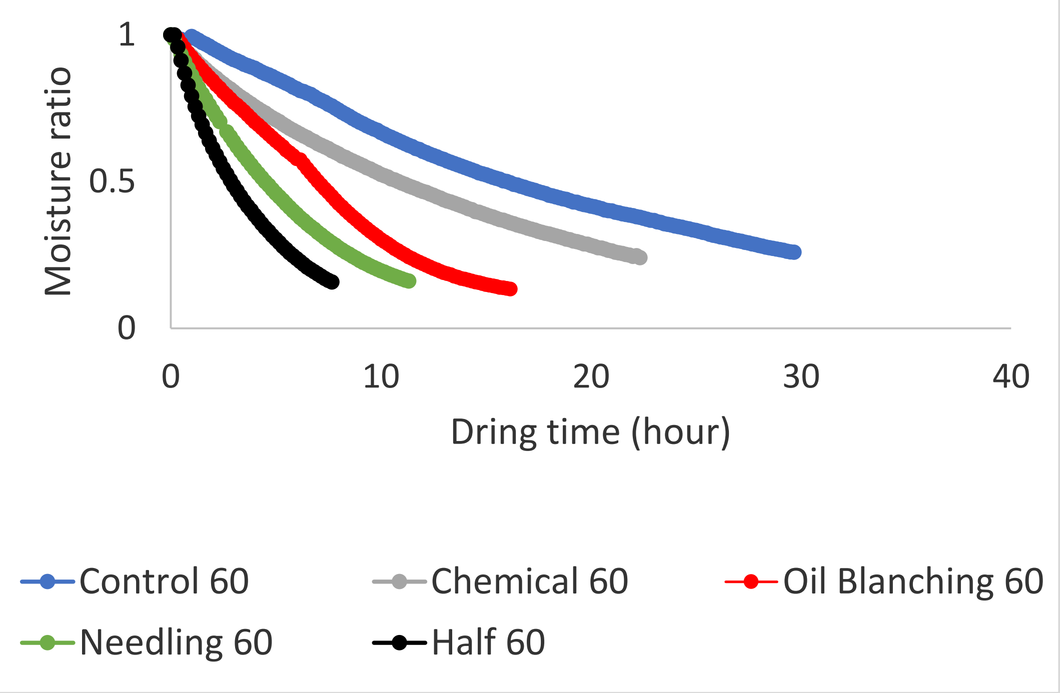

Figure 8.1. Moisture ratio changes of 2nd replication during drying at 60 °C

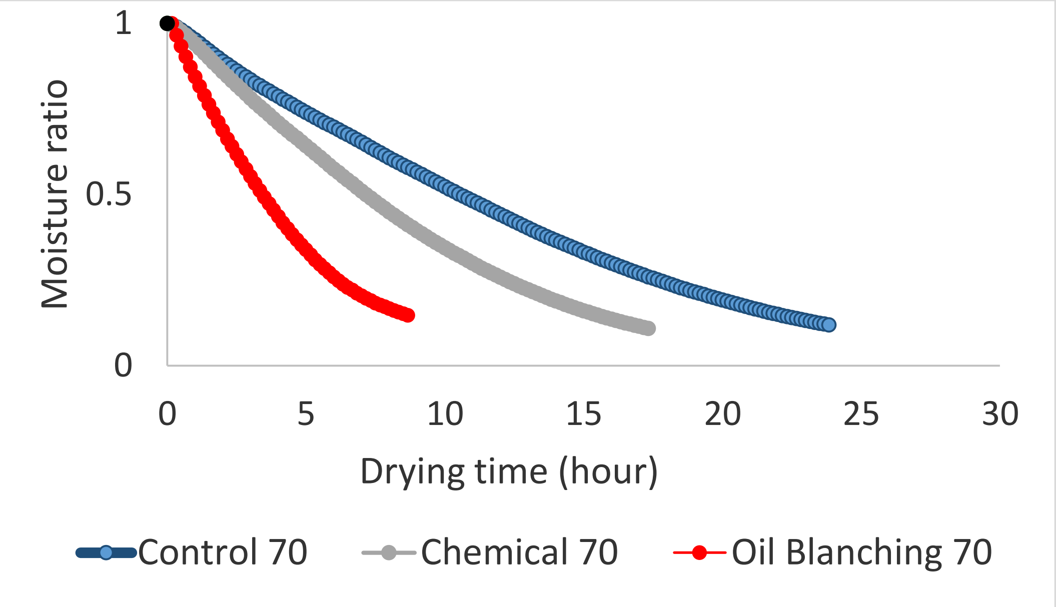

Figure 8.2. Moisture ratio changes of 2nd replication during drying at 70 °C