Effect of pretreatments and drying methods on the quality of dried mango (Mangifera Indica L.) slices

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Abstract: The present study was conducted to assess the effect of some pretreatments and drying methods on the qualities of dried mango slices. Four pretreatments (lemon juice, salt solution dips, hot water blanching and control) and four drying methods (solar, tray, freeze and fluidized bed drying) were considered and arranged in factorial experimental design. The proximate composition, physicochemical properties, antioxidants and colour were evaluated. The result showed that the pretreatments and drying methods showed significant effects on the proximate composition, physicochemical properties, and color, antioxidants of the dried mango slices. The nutrient analysis showed that mango slices had respective ranges for moisture, protein, fat, fibre, ash and carbohydrate contents (5.63–9.91%, 2.49–2.71%, 2.89–3.16%, 6.51–6.56%, 2.66–2.73% and 75.51–79.35%). The pH, TSS, TA, and hardness of the dried mango slices, respectively were 3.17–3.68, 69.36–86.29ºBrix, 2.20–2.54 g/100 g and 7.27–15.63 N. The ascorbic acid and phenol contents were affected by drying methods and had respective values of 33.18–41.24 mg/100 g and 131.13–251.12 mg/100 g; these indicate all dried mango slices were good source of nutrition and antioxidants. These findings suggest the freeze and fluidized bed driers after subjected to the pretreatments as the best method for the drying of mango in terms of ascorbic acid and colour preservation. In conclusion, these results indicate

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PUBLIC INTEREST STATEMENT

The fruit king, mango fruit is one of the most common nutritionally rich fruits with a unique flavour, scent, taste and health-promoting qualities, that makes it plentiful among new functional foods, also labelled as “super fruits”. It is rich in pre-biotic dietary fiber, vitamins, minerals, and polyphenolic and flavonoid antioxidant compounds. It has been found to protect against colon, breast, leukaemia and prostate cancers according to the new research report. However, exporting from farm to other countries are a formidable challenge because of the perishable nature of fresh mangoes. Drying mangoes is an ideal value-added opportunity for processors in many developing countries, as processing requirements are relatively non-capital intensive. These results would add to the scientific database for the use of drying technology to use these super fruits in Ethiopia.
that drying technology has an enormous potential to reduce the postharvest of mango in Ethiopia that is estimated between 25-40%.

Subjects: Carbohydrates; Food Analysis; Fruit & Vegetables; Food Engineering; Preservation; Processing

Keywords: Mango drying; physicochemical properties; pretreatments; antioxidants

1. Introduction

Mango is a fleshy stone fruit from the panes Mangifera (Blaise et al., 2009; Shah et al., 2010), tropical fruit of highly seasonal and one of the most popular fruits of the planet (Abano, 2015; Girma et al., 2016; Honja, 2014; Sehrawat et al., 2018). It is currently fifth among the key fruit crops worldwide (Shi et al., 2015) and one of the second most likely fruit cultivation grown in Ethiopia (Fita, 2014; Honja, 2014; Lalisa and Daniel, 2017; Neguse et al., 2019). According to Ethiopia Fresh Fruits Market update report, production of mango increased by 45% from 2013/14 to 2017/18. Considering the substantial quantity of mango fruit the processing industry in Ethiopia is incredibly weak (Dessalegn et al., 2014; Fita, 2014; Hagos et al., 2019; Honja, 2014). In Ethiopia, the mangoes are for fresh consumption and even that is to a limited extent. Thus, the market of fresh mango in Ethiopia faced a loss in quality and limited shelf life. The loss is estimated to be between 25 to 40% (Hailu & Worku, 2017; Kasso & Bekele, 2018). This is mostly because of improper processing and preservation facilities. Hence the degree of deterioration is severing and this could limit their access to lucrative markets to accommodate produce (Hagos et al., 2019). This can be used as a good indication for all the institutions concerned to develop efficient and effective policies and strategies to resolve existing challenges. Different strategies must be used to eat this balanced fruit all year (Caparino et al., 2012; Link et al., 2018; Neguse et al., 2019).

One way to tackle post-harvest losses is drying (Abe-Inge et al., 2018; Farhana et al., 2018; Omolola et al., 2015; Rwubatse et al., 2014; Surendar et al., 2018). The shelf life of dried products is almost unlimited and the cost of transportation, handling and storage are considerably lower than that of other methods of preservation (Mohamed et al., 2017; Wakjira, 2010; Q. Wang et al., 2019). Even if drying is attractive technology, in Ethiopia it's unknown because research and technology are not extensive (Yusufe et al., 2017). Consumers buy fresh fruits as processing is not undertaken (Mezgebe et al., 2016). Therefore, it is important to enhance and promote improved post-harvest management, value-added products and active research programs (Kumar & Shukla, 2017; Shimelis Admassu, 2015). During these last few years, there has been a considerable increase in demand for mango products and the most popular mango products are dried mango slices (Ismail & Nagy, 2012) with great potential in addressing food security and nutrition concerns around the world. Drying of mangoes is a promising preservation technique (Akoy, 2014).

Many researchers (Akoy, 2014; Adepoju & Osunde, 2017; Albernaz et al., 2017; Izli et al., 2017, 2018; Mohamed et al., 2017; Mwamba et al., 2017; Sehrawat et al., 2018; Singh et al., 2014; Link et al., 2018; Zhao et al., 2015) reported different types of drying methods, which are normally used in the drying of fruits. However, drying methods can alter the physicochemical properties and nutritive qualities of the dried products despite the improved shelf-life. Pretreatments are usually done before the fruit is dried so that adverse changes occur during drying and subsequent storage are reduced (Adepoju & Osunde, 2017; Delfiya et al., 2018). Different pretreatment methods have been developed for fruit drying (Abano et al., 2013; FAQ, 1995; Karim et al., 2008; Pott et al., 2005). However, necessary information on the combination of different pretreatments before different drying methods and the effects on the nutritional, physicochemical, color, vitamin C and phenol contents of dried mango slices in Ethiopia was lacking. Thus, this research was initiated to assess the effect of selected pretreatments (lemon juice, salt solution dips, hot water blanching and control) and drying methods (solar, tray, freeze and fluidized bed drying) on quality parameters of dried mango slices.
2. Materials and methods

Fresh, healthy and disease-free mango fruits of the Keitt cultivar used in this experiment was collected in plastic bags from Asossa, Benishangul Gumuz Regional State, Ethiopia.

2.1. Experimental plan

The experiment was set in a 4 × 4 factorial arrangement involving four pretreatments, that were lemon juice, salt solution, hot water blanching and control (untreated) prior to drying and four drying methods (solar, tray, freeze and fluidized bed drying), arranged in a completely randomized design (CRD) as indicated in Table 1.

2.2. Sample preparation

The mangoes were cleaned, peeled and the flesh sliced manually in the direction parallel to their fibres to a thickness of approximately 5 mm (Adepoju & Osunde, 2017) with a sharp stainless steel knife (Inox stainless, Brazil). These slice materials were categorized into 200 g each and treated with each pretreatments before drying.

2.2.1. Lemon juice dips

The slices were subjected to the pretreatment of equal parts of lemon juice and distilled water mixed solution 0.5 v/v (Abano and Sam-Amoah, 2011; Abano et al., 2013) in the container (Op plastics, Ethiopia) ensuring full coverage of the slices and allowed for 10 minutes. The pretreated slices were removed from the solution and spread evenly over a perforated tray, allowing the excess solution to drip for 20 minutes (Nyangena et al., 2019).

2.2.2. Hot water blanching

One minute hot water blanching was done by subjecting the sliced mangoes at 90 °C (Doymaz, 2010; Galoburda et al., 2012; H. Wang et al., 2018) in a water bath (BM 30, Turkey) ensuring full coverage of the slices by water.

2.2.3. Salt solution dips

The samples of sliced mangoes were soaked in the solution prepared by 0.011 g/mL (Abano and Sam-Amoah, 2011; Abano et al., 2013) for 10 minutes in the container (Op plastics, Ethiopia) ensuring full coverage of the slices. The pretreated slices have been removed from the solution and spread evenly over a perforated tray, allowing the excess solution to drip for 20 minutes (Nyangena et al., 2019).

2.2.4. Control

One sample was untreated and served as the control.

2.3. Drying methods

Solar drying of mango slices was carried out in a solar dryer (YYF-2-7112P1, China). Different sides of the slices were turned to increase drying efficiency regularly. A digital hygrometer (PWT-105, Dereje & Abera, Cogent Food & Agriculture (2020), 6: 1747961 https://doi.org/10.1080/23311932.2020.1747961

| Table 1. Experimental layout |
|-----------------------------|----------------|----------------|----------------|----------------|
| Drying Methods              | Lemon juice   | Hot water blanching | Salt solution | Control       |
| Solar                       | SL            | SB              | SS            | SC            |
| Tray                        | TL            | TB              | TS            | TC            |
| Freeze                      | FL            | FB              | FS            | FC            |
| Fluidized bed               | FBL           | FBB             | FBS           | FBC           |

Where S, T, F and FB represented solar, tray, freeze, and fluidized bed of drying methods, respectively and L, B, S, and C represented lemon juice, hot water blanching, salt solution dips and control of pretreatments, respectively.
China) was used to measure the temperature and relative humidity at the entrance of the collector and the drying chamber.

Tray drying of mango slices was carried out in a computer-controlled tray drying (SBANC, Madrid, Spain). The drying temperature was maintained at 70°C.

A laboratory-scale freeze dryer (Lablyo plus, Germany) was used to dry mango slices according to Marques et al. (2011), Kaewdam et al. (2013), and Izli et al. (2017). The drying was with total pressure and the temperature inside the vacuum chamber of 52 pa and —52°C respectively. The prepared slices were arranged in a single layer on the trays and placed inside the freeze dryer chamber. Thermocouple probes were used to control and monitor the product temperature on each tray during drying.

A batch type laboratory-scale fluidized bed dryer (TG 200, Germany) was used to dry the prepared mango slices. An air temperature of 50°C and an airflow of 1.5 m/s was set digitally (Quintana-Zaragoza et al., 2017).

All the samples were dried until the moisture content of the samples dropped below 10% on a wet basis (Mercer, 2012).

2.4. Data collection
Proximate values for moisture, fat, protein, ash, and crude fibre of dried fruit samples were determined according to Association of Official Analytical Chemists (AOAC) (2005); carbohydrate content was calculated by difference. The pH of the samples was measured by dipping the electrode of a digital pH meter (Inolab, pH7110, England) into the juice of the samples after proper calibration of the meter with the standard solution. The titratable acidity was determined by titrating the aliquot with 0.1 N NaOH solution using titration kit (Jencons digitrate pro, England) to the first appearance of pink endpoint, where phenolphthalein (3–5 drops) was used as an indicator. Using a refractometer (0–100 °Brix, Bellingham Stanley Ltd., England), total soluble solids were determined directly in each sample and expressed as °Brix by placing one to two drops of clear juice. The hardness was determined by a texture analyzer (Ametek, Germany) according to Kaewdam et al. (2013). The colour L*, a* and b* of the fresh and dried mangoes were measured by a colorimeter (NR110, 3 NH technology co., Ltd) per CIE L*a*b* colour space system and the ΔE values were calculated according to Hwa et al. (2013) and Nyangena et al. (2019). Total phenolic content was determined by spectrophotometer using Folin-Ciocalteu method following the procedure of Sogi et al. (2012) and Vitamin C content was determined using the 2, 6-dichloro-indophenol titration as per the procedure described by Marques et al. (2011) and Naidu et al. (2015).

2.5. Statistical analysis
Statistical analysis was carried out using the software package SAS (SAS Institute, Inc., Cary, North Carolina, USA) by using analysis of variance (ANOVA). Fisher’s Least Significance Difference (LSD) test at the significance level 5% (P < 0.05) was used to determine significant differences among samples.

3. Results and discussion

3.1. Physicochemical properties of fresh mango
The physicochemical properties of fresh mango fruit of Keitt variety were evaluated and the results indicated in Table 2. The average initial moisture content was 80.03% on a wet basis. These findings were consistent with previous studies by Ubwa et al. (2014), and Abbasi et al. (2015), who reported the initial moisture content of in the range of 77.85 to 82.22% and 80.69 to 89.47%, respectively. The physical properties of mango fruit such as weight of whole and weight of the inedible portion were to be 319.3 and 60.53 g, respectively. The data obtained were comparatively higher than that of Ubwa et al. (2014), who reported 264.82 g and 33.57 of the whole weight and inedible portion for the mango fruits. The total soluble solid content, pH and titratable acidity
contents were 11.59 °Brix, 3.86 and 1.92 g/100 g, respectively. The values of pH and TA were quite comparable with the results of Hailu and Worku (2017), who reported 3.54 and 1.67 g/100 g, respectively for mango. The results of total soluble solids and pH were lower than Teshome (2010), who reported 16.34 °Brix and 4.10, respectively for mango. The value of total soluble solids was in close agreement with a range of 10.1 to 17.1 °Brix given by Mugodo (2017) for mango.

Regarding the colour values, the value obtained in this study was higher than those reported by (Sanjinez-argandoña et al., 2017) and are parallel to those obtained by Zou et al. (2013), who reported 52.23, 2.71 and 46.7 and 60.8, 13.7 and 55.8 7 for L*, a* and b*, respectively, for mango. The total vitamin C content in the fresh mango samples was, on average, 49.53 mg/100 g. The same result was reported by Teshome (2010) 47.77 mg/100 g for the same variety. The finding of this study was not in agreement with values reported by Yebio et al. (2015), Bekele and Geleta (2015), and Kebena (2017) of 17, 1104 and 14.65 mg/100 mL, respectively for fresh mango. This variation resulted from differences in the maturity stage, regional fruit varieties, different measurement and squeezing techniques (Kebena, 2017). Ascorbic acid in fruits can also be affected by other factors such as climatic condition, temperature, sunlight and amount of nitrogen’s in the plant (Bekele & Geleta, 2015; Kebena, 2017).

3.2. Effect pretreatments and drying methods on proximate composition of dried mango

The results for nutritional contents of dried mango samples were determined and the outcomes are presented in Table 3. The entire dryer produced mango slices with moisture contents of lower 9.91% wet basis, that is adequate to suppress bacterial, yeast and mould growth (Nyangena et al., 2019). The results were reliable with the values of below 10.61 and 6.31% observed by Adepoju and Osunde (2017) and Singh et al. (2014) for dried mango fruits, respectively. The mean values of final moisture contents for the samples ranged from 5.63 to 9.91% for the drying methods and 7.85 to 8.13% for the pretreatments (Table 3). In this study, fluidized bed drying resulted in lowering the moisture contents of the dried slices and this low moisture content reduces perishability and increases the value and shelf life of the food (Agoreyo et al., 2011). The fluidized bed drying has the lowest moisture content due to the homogenous fluidization of particles in a flow of gas causing high heat transfer and mass transfer coefficients (Calderón-Santoyo et al., 2013; Senadeera et al., 2003).

In terms of pretreatment, the order of moisture content of the slices was lemon juice 7.85% < salt solution 8.01% < hot water blanching 8.05% < control 8.13%. This was in agreement with the work of Abano et al. (2013) and this may be caused by the lemon juice leaching effect affecting the fruit tissue, which promotes water removal during drying. Slices subjected to a salt solution have lower moisture contents following lemon juice treated samples. This is because of the osmotic pressure in the osmotic solution which forced water out of the internal tissues even before drying (Tolera & Abera, 2017). Similarly, hot water blanched slices have lower moisture content compared to untreated (control) samples. It showed that blanching resulted in lowering the moisture contents of the samples. Prior studies explained that the blanching softens the texture and in turn,
Table 3. Proximate composition of dried mango as affected by drying methods and pretreatments

| Drying methods | Mc (%)    | Fat (%)    | Fibre (%)   | Protein (%)   | Ash (%)   | Carbohydrate (%) |
|---------------|-----------|------------|-------------|---------------|-----------|------------------|
| Solar         | 8.63 ± 0.21<sup>b</sup> | 2.89 ± 0.08<sup>b</sup> | 6.51 ± 0.09<sup>a</sup> | 2.50 ± 0.07<sup>bc</sup> | 2.66 ± 0.12<sup>a</sup> | 76.82 ± 0.28<sup>a</sup> |
| Tray          | 9.91 ± 0.05<sup>a</sup> | 2.92 ± 0.06<sup>b</sup> | 6.51 ± 0.09<sup>a</sup> | 2.49 ± 0.08<sup>c</sup> | 2.67 ± 0.13<sup>b</sup> | 75.51 ± 0.23<sup>c</sup> |
| Freeze        | 7.88 ± 0.04<sup>c</sup> | 3.15 ± 0.11<sup>a</sup> | 6.53 ± 0.10<sup>a</sup> | 2.71 ± 0.19<sup>a</sup> | 2.73 ± 0.10<sup>a</sup> | 77.01 ± 0.27<sup>b</sup> |
| Fluidized     | 5.63 ± 0.16<sup>d</sup> | 3.16 ± 0.11<sup>a</sup> | 6.56 ± 0.12<sup>a</sup> | 2.62 ± 0.16<sup>ab</sup> | 2.68 ± 0.12<sup>a</sup> | 79.35 ± 0.31<sup>a</sup> |

| Pretreatments | Mc (%)    | Fat (%)    | Fibre (%)   | Protein (%)   | Ash (%)   | Carbohydrate (%) |
|---------------|-----------|------------|-------------|---------------|-----------|------------------|
| Lemon juice   | 7.85 ± 1.65<sup>c</sup> | 3.01 ± 0.14<sup>a</sup> | 6.55 ± 0.10<sup>a</sup> | 2.57 ± 0.17<sup>a</sup> | 2.67 ± 0.10<sup>a</sup> | 77.34 ± 1.46<sup>a</sup> |
| Hot water blanching | 8.05 ± 1.65<sup>b</sup> | 3.07 ± 0.20<sup>a</sup> | 6.49 ± 0.09<sup>a</sup> | 2.58 ± 0.18<sup>a</sup> | 2.67 ± 0.15<sup>a</sup> | 77.14 ± 1.45<sup>ab</sup> |
| Salt solution | 8.01 ± 1.62<sup>b</sup> | 3.02 ± 0.16<sup>a</sup> | 6.55 ± 0.12<sup>a</sup> | 2.59 ± 0.14<sup>a</sup> | 2.69 ± 0.12<sup>a</sup> | 77.14 ± 1.47<sup>ab</sup> |
| Control       | 8.13 ± 1.58<sup>c</sup> | 3.03 ± 0.12<sup>a</sup> | 6.51 ± 0.08<sup>a</sup> | 2.58 ± 0.17<sup>a</sup> | 2.68 ± 0.11<sup>a</sup> | 77.06 ± 1.49<sup>c</sup> |
| LSD           | 0.04      | 0.06       | 0.09        | 0.13          | 0.11      | 0.24             |
| CV            | 0.57      | 2.58       | 1.37        | 5.90          | 5.03      | 0.37             |

Values were means ± SD and values in the same column with different superscript letters were significantly different from each other (P < 0.05).
makes the water removal process easier (Raja et al., 2017; Sengkhamporn et al., 2013). There was no significant difference between the hot water blanching and salt solution treated samples but these two were significantly (P < 0.05) different from lemon juice and control samples. The drying methods and pretreatments caused significant (P < 0.05) differences on moisture contents as shown in Table 3.

The effect of interactions of pretreatment and drying techniques on the final moisture content is presented in Table 4. Values of moisture contents were significantly (P < 0.05) different from each other except for those of tray dryer with different treatment combinations which did not show significant differences among them. The top four records belonged to samples dried by tray dryers after subjected to the four different pretreatments. The values of the moisture contents obtained in this study were close to those obtained in the studies carried out by Adepoju and Osunde (2017), Nixwell et al. (2013), Singh et al. (2014), and Zou et al. (2013) which ranged from 5.9 to 7.5%, 7.8 to 9.3%, 5.86 to 10.61% and 5.28 to 6.31%, respectively. However, these moisture values were lower than those obtained by Abano et al. (2013), which ranged from 11.91 to 20.09%. In this study, fluidized bed and freeze driers with the pretreatments resulted in the lowering the moisture contents of dried samples. The interaction of pretreatments and drying methods affected the moisture contents of the dried samples. Similar findings were reported in the drying of tomato (Mohseni & Ghavidel, 2011), banana (Abano and Sam, 2011; Adepoju & Osunde, 2015), mango (Abano et al., 2013; Adepoju & Osunde, 2017) and papaya leaf powder (Raja et al., 2017).

The mean values of fat contents were 2.89, 2.92, 3.15 and 3.16% for the samples dried by the solar, tray, freeze and fluidized bed drying methods. The first two values did not show a significant difference between them, as was the case in the latter two values again. However, a significant (P < 0.05) difference was observed between the first and the second groups. All the values of fat were statistically the same (P > 0.05) for all of the four treatments. These values are quite comparable with the results of Teshome (2010) who reported a range of 0.19 to 4.68% for fat contents of mango leather. Fat contributes to the total energy content of a food product and its value is required in estimating the caloric value of a food product (Abe-Inge et al., 2018). Samples dried with solar and tray drier after all the four treatments did not show significant (P > 0.05) differences among them but are statistically lower than the values of the samples dried by freezing and fluidizing regardless of the pretreatments (Table 4). The former had values ranging from 2.83 to 2.94% while the latter group showed values between 3.03 and 3.26%. Short drying time prevented the melting of the fat thereby increasing their values.

The mean value of fibre oscillated between 6.51 and 6.56% for the drying methods and from 6.49 to 6.55% for the pretreatments used. This value is in agreement with Teshome (2010) with a range of 4.59 to 7.97% for dried mango leather. The results of the analysis did not show significant (P > 0.05) difference among both the drying methods and pretreatments used as shown in Table 3. Fibre is significant for typical working of the gastrointestinal tract brings down the danger of cardiovascular and coronary heart illnesses just as keeps up the ordinary bodyweight (Raghavendra et al., 2006; Sogi et al., 2012). The fibre content values ranged from 6.45 to 6.64% with no significant difference except very few samples (Table 4). The data showed that the products have relatively high fibre contents, which are acceptable from the healthy diet point of view.

Protein content data of the samples as influenced by drying methods and pretreatments are presented in Table 3. The protein content of samples dried by solar and tray driers were 2.50 and 2.49% with no significant difference between them. On the other hand, samples dried by freezing and fluidizing had protein contents of 2.71 and 2.62%, again with no statistical (P > 0.05) difference between them. The two groups of data showed significant (P < 0.05) difference among them. On the other hand, protein content values of samples subjected to the pretreatments ranged from 2.57 to 2.59% with no statistical (P > 0.05) difference among them. Adepoju and Osunde (2017), reported for protein content within the range of 2.9 to 4.64% for the dried mango. In overall the values for protein contents were close to those obtained in the studies carried out by Nixwell et al.
Table 4. Proximate composition of dried mango as affected by interactions of pretreatments and drying methods

| Code  | Mc (%) | Fat (%) | Fibre (%) | Protein (%) | Ash (%) | Carbohydrate (%) |
|-------|--------|---------|-----------|-------------|---------|------------------|
| SL    | 8.31 ± 0.07f | 2.87 ± 0.04f | 6.56 ± 0.10ab | 2.48 ± 0.04c | 2.66 ± 0.09c | 77.12 ± 0.19bc |
| SB    | 8.72 ± 0.02d | 2.93 ± 0.06df | 6.52 ± 0.13df | 2.51 ± 0.12bc | 2.63 ± 0.20a  | 76.69 ± 0.41c  |
| SS    | 8.64 ± 0.02e | 2.83 ± 0.13c  | 6.49 ± 0.06e  | 2.53 ± 0.07bc | 2.70 ± 0.15a  | 76.80 ± 0.10cd |
| SC    | 8.83 ± 0.03c | 2.94 ± 0.06df | 6.45 ± 0.06b  | 2.49 ± 0.07bc | 2.63 ± 0.07a  | 76.66 ± 0.10c  |
| TL    | 9.83 ± 0.02b | 2.96 ± 0.06df | 6.49 ± 0.10ef | 2.47 ± 0.09c  | 2.65 ± 0.12c  | 75.61 ± 0.33d  |
| TB    | 9.94 ± 0.03a | 2.87 ± 0.10f  | 6.45 ± 0.06b  | 2.45 ± 0.04bc | 2.65 ± 0.22a  | 75.59 ± 0.26d  |
| TS    | 9.89 ± 0.03a | 2.94 ± 0.03ef | 6.50 ± 0.06ef | 2.56 ± 0.07bc | 2.67 ± 0.10a  | 75.43 ± 0.22d  |
| TC    | 9.95 ± 0.01a | 2.92 ± 0.04ef | 6.57 ± 0.09ab | 2.44 ± 0.09c  | 2.70 ± 0.10a  | 75.42 ± 0.14d  |
| FL    | 7.84 ± 0.01h  | 3.03 ± 0.01de | 6.50 ± 0.12ab | 2.73 ± 0.25ab | 2.69 ± 0.15a  | 77.20 ± 0.37bc |
| FB    | 7.89 ± 0.03g  | 3.26 ± 0.08a  | 6.52 ± 0.12ab | 2.67 ± 0.25ab | 2.70 ± 0.06a  | 76.96 ± 0.25bc |
| FS    | 7.87 ± 0.06g  | 3.12 ± 0.11cd | 6.58 ± 0.11ab | 2.65 ± 0.18bc | 2.74 ± 0.09a  | 77.04 ± 0.28bc |
| FC    | 7.90 ± 0.02g  | 3.20 ± 0.06de | 6.52 ± 0.12ab | 2.78 ± 0.17c  | 2.76 ± 0.12a  | 76.84 ± 0.19bc |
| FBL   | 5.43 ± 0.03l  | 3.20 ± 0.07de | 6.64 ± 0.05a  | 2.59 ± 0.15bc | 2.68 ± 0.11a  | 79.45 ± 0.33a  |
| FBB   | 5.72 ± 0.04j  | 3.22 ± 0.17bc | 6.48 ± 0.08de | 2.63 ± 0.25ab | 2.71 ± 0.13a  | 79.33 ± 0.41a  |
| FBS   | 5.64 ± 0.03k  | 3.16 ± 0.03cde | 6.61 ± 0.20bc | 2.63 ± 0.21bc | 2.67 ± 0.16a  | 79.29 ± 0.42a  |
| FBC   | 5.83 ± 0.03i  | 3.06 ± 0.03cde | 6.50 ± 0.05bc | 2.63 ± 0.07bc | 2.67 ± 0.17a  | 79.33 ± 0.21a  |
| LSD   | 0.05           | 0.13         | 0.17        | 0.25         | 0.22         | 0.47           |
| CV    | 0.38           | 2.58         | 1.37        | 5.90         | 5.03         | 0.37           |

Values are means ± SD and values in the same column with different superscript letters were significantly different from each other (P < 0.05). Note: SL, SB, SS, SC = Solar drying with lemon juice, hot water blanching, salt solution dip, and control sample, respectively. TL, TB, TS, TC = Tray drying with juice, hot water blanching, salt solution dip, and control sample, respectively. FL, FB, FS, FC = Freeze-drying with lemon juice, hot water blanching, salt solution dip, and control sample, respectively. FBL, FBB, FBS, FBC = Fluidized bed drying with lemon juice, hot water blanching, salt solution dip, and control sample, respectively.
and Mwamba et al. (2017) for dried mango ranged from 1.9 to 2.8% and 1.65 to 2.65%, respectively. From Table 4, protein content values ranged from 2.44 to 2.78% with no significant difference except for few. These results were parallel to those obtained by Teshome (2010) which ranged between 1.75 to 2.81% for dried mango leather. According to Tewodros et al. (2014), mango contains a little higher protein than that of other fruits except for the avocado.

The ash content of the dried mango slices ranged from 2.66 to 2.73% with no statistical (P > 0.05) difference among the samples subjected to different treatments. Adepoju and Osunde (2017), observed a similar trend in which both drying methods and pretreatments did not show the statistical difference on the dried mango. However, the ash content obtained in this study was higher than that of Teshome (2010) 1.41 to 2.29% for mango leather, and Mwamba et al. (2017) 1.59 to 2.21% and lower than that of Adepoju and Osunde (2017) 3.30 to 3.89% for dried mango. Samples with high percentages of ash contents are expected to have high concentrations of various mineral elements and this represents the minerals present in the product that helps identify the stability criteria of the product. The mineral content, safety and quality of a food product are indicated by its ash content (Abe-Inge et al., 2018; Agoreyo et al., 2011; Wijewardana et al., 2016).

As indicated in Table 3 the carbohydrate content of the dried mango slice ranged from 75.51% to 79.35% for samples dried by the tray and fluidized bed driers and 77.06% to 77.34% for control and samples subjected to lemon juice pretreatments, respectively. The difference may be due to their moisture contents difference that influenced the dry matter contents. The moisture content approximates indirectly the dry matter of the samples (Ojo et al., 2017). An analogous result of 84.4 to 85.7% and 69.48 to 72.33% were reported by Adepoju and Osunde (2017) and Nixwell et al. (2013) for the dried mango. The drying methods showed significant (P < 0.05) difference between them. On the other hand, there was no significant (P > 0.05) difference among samples pretreated with hot water blanching and salt solution and again between the lemon juice and control samples. Samples dried with tray and fluidized bed drier after all the four treatments did not show significant differences between each group (Table 4). The data showed that the highest values of carbohydrates content belonged to fluidized bed dryer with significant differences from the samples dried by the solar, tray and freeze driers after the four different pretreatments but did not show significant difference among each group. The result agreed with the values 66.88 to 78.14% reported by Teshome (2010) for dried mango leather. The data showed significant differences between the first and second groups. For the biosynthesis of amino acids with aromatic side chains and phenolic compounds, carbohydrates may serve as precursors (Melaku & Duguma, 2016).

3.3. Effects of pretreatments and drying methods on physicochemical properties of dried mango

The results of the pH, total soluble solids, titratable acidity and hardness value of the slices dried in different drying methods with different pretreatments are shown in Table 5. The pH was in the range of 3.68 to 3.17 for samples dried by the different methods which are in good agreement with reported values 3.09 to 4.11 by Mwamba et al. (2017) for dried mango. The data indicated that the pH of dried mango slices was reduced from the fresh value of 3.86 (Table 2). This could be associated with the concentration of organic acids due to the removal of water during drying. The freeze-dried mango slices had 3.17, the lowest, whilst the solar-dried sample had 3.68, the highest pH values, which could probably be due to the slow drying process which leads to the degradation of more organic acids. The lower pH could be an indication of shelf stability against microbial contamination (Abe-Inge et al., 2018).

In terms of pretreatment, the order of pH contents was lemon juice 3.33 < control 3.39 < salt solution 3.46 < hot water blanching 3.49. The samples subjected to lemon juice treatments records the lowest pH values but the hot water blanching resulted in the highest value of pH. This might be due to leaching of soluble acids into the water increased and the addition of the lemon juice to the slices reduced the pH due to its acidic nature, respectively. The pH of a product had a key role in the prevention of microbial spoilage (Owolade et al., 2017). All values of pH obtained in this study...
varied significantly (P < 0.05) due to the drying method and pretreatments used as shown in Table 5. Significant (P < 0.05) differences were observed in the pH values of the samples subjected to different treatment combinations (Table 6). It ranged from 2.95 of those treated with lemon juice and dried in freeze to 3.76 of those samples subjected to hot water blanching dried by solar dryers. The top four records belonged to samples dried by solar dryers after the four different pretreatments. The pH value plays a key role in the prevention of microbial spoilage (Owolade et al., 2017).

The titratable acidity as anhydrous citric acid equivalents in dried mango slice ranged from 2.20 to 2.54 g/100 g for samples dried by solar and fluidized bed driers with no significant difference among them. The results indicated an increase of acidity in dried samples as compared to the fresh 1.92 g/100 g. This gives a good indication that fermentation occurred in samples, the thing that raises the value (Gallali et al., 2000) and the conversion of carbohydrate to acid through an extended time of drying (Reshmi et al., 2018), who observed an increment of titratable acidity after drying. The titratable acidity is an estimate of the total acid concentration in a food sample (Nielsen, 2003). It is an important parameter for blending with pH-sensitive food like milk and other dairy products (Singh et al., 2014) since it influences the sensory quality (S. Y. Wang et al., 2002). The result agreed with the values of 1.86 to 2.63 g/100 g reported by Zou et al. (2013) and 1.65 to 2.65 g/100 g of Mwamba et al. (2017) for dried mango. It can be seen that combinations of the freeze-drying with lemon juice had high titratable acidity 2.75 g/100 g (Table 6). The combinations of freeze-drying and pretreatments resulted in lowering pH values. The combination of the solar drying with hot water blanching treatments scored the lower value of titratable acidity 2.13 g/100 g as compared to those of other treatments. There is an inverse relationship between titratable acidity and pH (Hailu & Worku, 2017). The interaction of drying methods and pretreatments significantly (P < 0.05) affected the titratable acidity of the dried samples.

The total soluble solids of the samples dried by solar and tray driers were 75.31 and 69.36 °Brix with a significant difference between them. On the other hand, the samples dried by freezing and fluidizing had 85.14 and 86.29 °Brix with no significant difference among them. The two groups of data showed a significant difference between them. The values of freeze and fluidized bed agreed with range 82.4 to 91.2 g/100 g reported by Zou et al. (2013) for dried mango. A value ranging from 22.36 to 52.02 °Brix was reported by Mwamba et al. (2017) for solar and oven-dried mango. Generally, as compared with fresh mango slices 11.59 °Brix, the total soluble solids of dried

| Table 5. Physicochemical properties of dried mango as affected by pretreatment and drying method |
|-----------------------------------------------|-------------------------------|-------------------------------|-------------------------------|
| Drying methods       | pH   (±SD) | TA (g/100 g) (±SD) | TSS (°Brix) (±SD) | Hardness (N) (±SD) |
|----------------------|---------|--------------------|-------------------|-------------------|
| Solar                | 3.68 ± 0.07a | 2.20 ± 0.14b     | 75.31 ± 0.30bc    | 8.26 ± 0.67c     |
| Tray                 | 3.33 ± 0.04c | 2.41 ± 0.13g     | 69.36 ± 0.30d     | 7.27 ± 0.62b     |
| Freeze               | 3.17 ± 0.15d | 2.54 ± 0.27a     | 85.14 ± 2.44a     | 10.20 ± 1.34a    |
| Fluidized            | 3.49 ± 0.05b | 2.26 ± 0.10b     | 86.29 ± 2.17b     | 15.63 ± 1.66a    |
| Pretreatments        |         |                    |                   |                   |
| Lemon juice          | 3.33 ± 0.25d | 2.40 ± 0.29a     | 79.05 ± 7.55c     | 10.35 ± 3.63b    |
| Hot water blanching  | 3.49 ± 0.19a | 2.27 ± 0.14a     | 78.93 ± 7.45a     | 9.50 ± 2.87a     |
| Salt solution        | 3.46 ± 0.18a | 2.35 ± 0.19a     | 79.17 ± 7.56a     | 11.52 ± 3.95a    |
| Control              | 3.39 ± 0.19c | 2.39 ± 0.20a     | 78.95 ± 7.51a     | 9.99 ± 3.58bc    |
| LSD                  | 0.03    | 0.14              | 1.59              | 0.68             |
| CV                   | 0.88    | 7.32              | 2.43              | 7.91             |

Values are means ± SD and values in the same column with different superscript letters were significantly different from each other (P < 0.05).
mango slices were found to be higher. The reason for the increment could be linked to the fact that pretreatment reduces the loss of quality of the dried slices by reducing the drying time and by inactivating the enzymes responsible for the loss of the components since it includes sugar, organic acids, amino acids, and mineral salts. Samples dried by freeze and fluidized bed driers after all the four treatments did not show significant difference among them but are statistically higher than the values of the samples dried by solar and tray regardless of the pretreatments (Table 6). The reduction in slice moisture usually involves a greater percentage of total soluble solids, as the main component of dry matter was total soluble solids. Similarly, the increment could be due to changes in the cell wall structure and the breakdown into simple sugars of complex carbohydrates (Hailu & Worku, 2017). A drying method that could avoid undesirable changes and maintain a high quality of the dried product should be recommendable (Li et al., 2018) since longer drying time causing loss of certain volatile oils, esters and readily oxidizable materials like ascorbic acid during the drying process. Total soluble solids, titratable acidity, pH and volatile aroma composition are all associated with flavour and are generally assessed as part of fruit value assessment as they are correlated with sweetness and sweetness (Hailu & Worku, 2017). The total soluble solids that indicate the maximum concentration of sugar are essential for the processing, storage and quality of the food produced (Abe-Inge et al., 2018).

Fluidized bed dried samples had the highest hardness 15.63 N and tray-dried samples had the lowest 7.23 N. This finding was lower than obtained by Zou et al. (2013), which ranged from 16.4 to 31.3N for the dried mango. After subjected to different treatments, the hardness of the samples was increased in contrast to the fresh samples 7.23 N. The hardness of the samples dried by fluidized bed and freeze-driers obtained in this study was larger than 2.82 to 8.29 N reported by (Kaewdam et al., 2013) for the dried mango. According to Contreras et al. (2005), the texture of dried products is

| Code  | pH     | TA (g/100 g) | TSS (Brix) | Hardness (N) |
|-------|--------|--------------|------------|--------------|
| SL    | 3.60 ± 0.02 cd | 2.19 ± 0.03 cd | 75.47 ± 0.23 b | 8.48 ± 0.49 ef |
| SB    | 3.76 ± 0.03 a | 2.13 ± 0.18 a | 75.17 ± 0.21 b | 7.71 ± 0.49 fn |
| SS    | 3.71 ± 0.04 b | 2.28 ± 0.23 bcd | 75.37 ± 0.55 b | 9.02 ± 0.42 c |
| SC    | 3.64 ± 0.02 c | 2.19 ± 0.02 cd | 75.23 ± 0.15 b | 7.81 ± 0.32 fh |
| TL    | 3.33 ± 0.04 gh | 2.42 ± 0.09 gh | 69.27 ± 0.61 c | 7.51 ± 0.47 gh |
| TB    | 3.37 ± 0.01 c | 2.32 ± 0.07 bcd | 69.37 ± 0.06 c | 6.94 ± 0.78 h |
| TS    | 3.33 ± 0.03 gh | 2.36 ± 0.15 gh | 69.50 ± 0.26 c | 7.58 ± 0.88 gh |
| TC    | 3.29 ± 0.04 k | 2.53 ± 0.15 gh | 69.30 ± 0.10 c | 7.07 ± 0.27 n |
| FL    | 2.95 ± 0.07 h | 2.75 ± 0.40 h | 85.23 ± 3.00 c | 9.67 ± 1.32 d |
| FB    | 3.31 ± 0.03 k | 2.38 ± 0.12 bcd | 85.27 ± 2.81 c | 9.45 ± 0.14 gh |
| FS    | 3.27 ± 0.01 i | 2.51 ± 0.24 gh | 85.13 ± 2.76 c | 12.18 ± 0.33 g |
| FC    | 3.16 ± 0.03 j | 2.52 ± 0.28 gh | 84.93 ± 2.84 c | 9.50 ± 0.31 k |
| FBL   | 3.44 ± 0.03 f | 2.20 ± 0.06 cd | 86.23 ± 2.69 g | 15.73 ± 1.08 f |
| FBB   | 3.55 ± 0.01 de | 2.23 ± 0.04 cd | 85.93 ± 2.54 g | 13.90 ± 0.87 c |
| FBS   | 3.52 ± 0.02 b | 2.36 ± 0.15 bcd | 86.67 ± 2.53 g | 17.31 ± 1.05 b |
| FBC   | 3.46 ± 0.02 j | 2.32 ± 0.07 bcd | 86.33 ± 2.51 g | 15.58 ± 1.81 b |
| LSD   | 0.05 | 0.29 | 3.19 | 1.36 |
| CV    | 0.88 | 7.32 | 2.43 | 7.91 |

Values are means ± SD and values in the same column with different superscript letters were significantly different from each other (P < 0.05). Note: SL, SB, SS, SC = Solar drying with lemon juice, hot water blanching, salt solution dip, and control sample, respectively. TL, TB, TS, TC = Tray drying with juice, hot water blanching, salt solution dip, and control sample, respectively. FL, FB, FS, FC = Freeze-drying with lemon juice, hot water blanching, salt solution dip, and control sample, respectively. FBL, FBB, FBS, FBC = Fluidized bed drying with lemon juice, hot water blanching, salt solution dip, and control sample, respectively.
dependent on the behaviour of the cellular matrix and soluble solid phase inside the tissue during interactions with water. The highest hardness value of 11.52 N was obtained from the samples subjected to salt solution pretreatments. This finding was the same as reported by Gras et al. (2003), who observed the sample treated with calcium chloride had increased the hardness and this was due to the interaction of calcium chloride with components of the plant cellular matrix. Zou et al. (2013) stated that hardness increased most likely due to a slight increase in the soluble solid phase but an overly high hardness value is undesirable for chips. One of the important textural properties of a dried food product is its hardness (H. Wang et al., 2018). As shown in Table 5, samples subjected to hot water blanching had significantly lower hardness values 9.50 N. H. Wang et al. (2018) reported the same finding for a dried apple slice in which hot water blanching resulted in lowering hardness. Blanching can lead to some soluble solid loss in fruits tissue (Arroqui et al., 2002) and according to Romano et al. (2011), this reduces the rigidity of the cell wall in the tissue, in turn, reduce the hardness of dried samples. Additionally, Lewicki (1998), indicated high-temperature blanching itself can relax and soften the tissue which can also contribute to hardness reduction of dried products.

The pretreatments and drying methods showed significance (P < 0.05) differences in the hardness values. It’s the main sensory quality attributes affecting food acceptance (Ikoko & Kuri, 2007) since it can be related to the force performed by mastication that takes part during eating. The samples dried by fluidized bed dryers after the four different pretreatments recorded high means of hardness values ranging from 13.9 to 17.31 N. This may be due to the lowest moisture contents of those samples. Konopacka et al. (2002), noticed that the moisture contents affected the texture. Tray drying with the pretreatments resulted in the reduction of hardness values. The interaction of drying methods and pretreatments significantly (P < 0.05) affected the hardness of the dried samples. The texture of dried products is dependent on the behaviour of the cellular matrix and soluble solid phase inside the tissue during interactions with water (Contreras et al., 2005).

3.4. Effect of pretreatments and drying methods on the colour of dried mango

The data showing the effect of pretreatments and drying methods on the colour parameters of dried mango slices are shown in Table 7. The L* values of dried mango slice of solar, tray, freeze and fluidized bed dried samples were 55.58, 55.28, 56.0 and 57.00, respectively which indicated that lightness of dried mango slice decreased from those of the fresh slices 58.76 (Table 2) after the drying process. L* is a crucial parameter for drying since it is typically the first quality attribute that consumers are measured for determination of brand acceptance (Salehi & Kashaninejad, 2018). The pretreatments and drying methods showed significance (P<0.05) differences in the hardness values. It's the main sensory quality attributes affecting food acceptance (Ikoko & Kuri, 2007).

| Drying methods |  |  |  |  |
|----------------|---|---|---|---|
| Solar          | 55.58 ± 1.58* | 12.62 ± 1.00* | 32.99 ± 1.84 * | 19.91 ± 1.98 * |
| Tray           | 55.28 ± 1.66* | 12.84 ± 1.36* | 33.04 ± 1.05 * | 20.02 ± 1.24 * |
| Freeze         | 56.02 ± 1.40** | 11.85 ± 0.86* | 48.58 ± 0.88* | 5.15 ± 1.01 * |
| Fluidized      | 57.00 ± 2.43* | 11.95 ± 0.56* | 45.48 ± 1.97* | 7.75 ± 2.07* |
| Pretreatments  |  |  |  |  |
| Lemon juice    | 56.83 ± 2.26* | 11.89 ± 0.81* | 41.32 ± 7.01* | 11.80 ± 6.63* |
| Hot water blanching | 55.99 ± 1.69* | 12.25 ± 0.93* | 40.92 ± 7.58* | 12.38 ± 7.24* |
| Salt solution  | 55.58 ± 1.39* | 12.25 ± 0.64* | 39.83 ± 7.67* | 13.42 ± 7.41* |
| Control        | 55.49 ± 1.96* | 12.77 ± 1.53* | 38.02 ± 7.49* | 15.21 ± 7.43* |
| LSD            | 1.40 | 0.50 | 0.33 | 0.52 |
| CV             | 3.00 | 4.88 | 0.99 | 4.78 |

Values are means ± SD and values in the same column with different superscript letters were significantly different from each other (P < 0.05).
This study was in line with Rajkumar et al. (2007) on dried tomato slice, Ali et al. (2016) on guava slice, Mugodo (2017) on dried mango slices and Izli (2017) on the dried date fruits in which they observed the decrease of this value after drying as compared to the fresh fruits. There was a significant (P < 0.05) differences in the L* values of dried mango among the driers. The solar, tray and freeze-dried samples had a lower value than fluidized dried products, which indicated that they resulted in less lightness with a significant difference between them. The result agreed with the report of Muñoz-lópez et al. (2018) in which tray-dried samples resulted in a lower value of L* as compared to other driers for the dried Mexican plum slice. They concluded that the decrease in L* values (lightness) have been correlated with the loss of water by evaporation, deformation of surface and generation of brown pigments. Similarly, it may be due to prolong drying time and the presence of oxygen (Ali et al., 2016). This finding was related to the findings reported by Coparinlo et al. (2012), Hwa et al. (2013), Nyangena et al. (2019), and Zou et al. (2013) who observed that the lightness of the dried mango was relatively lower than that of fresh mango.

The pretreatments applied before the drying, they did not show significant (P > 0.05) differences, again there was a slight decrease in the L* values as compared to the fresh samples 58.76 (Table 2). Similar observations were made by Mugodo (2017), who observed that lemon juice treatment did not have a significant (P > 0.05) effect on the lightness of the dried mango. Furthermore, Augusto et al. (2016) found that pretreatment did not significantly change the lightness of dried mango. Correspondingly, these results were in accord with recent studies by Nyangena et al. (2019) indicating that the lightness for samples pretreated with lemon juice had the slightest decrease for dried mango. From Table 8, the L* values, ranged from 54.30 to 59.94 with statistical (P < 0.05) difference among some of the samples.

Table 8. The colour of dried mango slices as affected by the interactions of pretreatments and drying methods

| Code | L*    | a*    | b*    | ΔE    |
|------|-------|-------|-------|-------|
| SL   | 55.59 ± 0.42bc | 12.73 ± 0.81bc | 35.12 ± 0.89abc | 17.51 ± 0.29b |
| SB   | 56.27 ± 0.40bc | 11.34 ± 0.28ab | 33.79 ± 0.12bc | 19.05 ± 0.17c |
| SS   | 55.23 ± 2.44bc | 12.75 ± 0.67bc | 32.59 ± 0.41bc | 20.48 ± 0.53bc |
| SC   | 55.24 ± 2.52bc | 13.67 ± 0.45bc | 30.47 ± 0.23bc | 22.59 ± 0.38bc |
| TL   | 55.97 ± 1.07bc | 11.32 ± 1.13bc | 34.31 ± 0.29bc | 18.62 ± 0.47bc |
| TB   | 55.23 ± 1.94bc | 13.53 ± 0.55bc | 33.56 ± 0.15bc | 19.52 ± 0.48bc |
| TS   | 55.65 ± 1.52bc | 12.43 ± 0.67clo | 32.60 ± 0.20bc | 20.33 ± 0.45bc |
| TC   | 54.30 ± 2.37c  | 14.07 ± 1.19bc | 31.69 ± 0.24bc | 21.59 ± 0.81bc |
| FL   | 55.84 ± 0.82bc | 11.83 ± 0.09clo | 49.48 ± 0.19bc | 4.36 ± 0.58bc |
| FB   | 55.17 ± 2.00bc | 12.51 ± 0.12clo | 48.74 ± 0.09bc | 5.45 ± 1.35bc |
| FS   | 56.08 ± 0.38bc | 12.49 ± 0.66clo | 48.66 ± 0.98bc | 4.85 ± 0.98bc |
| FC   | 57.01 ± 1.85bc | 12.59 ± 0.04clo | 47.44 ± 0.07bc | 5.93 ± 0.59bc |
| FBL  | 59.94 ± 2.57bc | 11.69 ± 0.18bc | 46.38 ± 0.21bc | 6.71 ± 0.87bc |
| FBB  | 57.30 ± 1.76bc | 11.64 ± 0.17bc | 47.57 ± 0.22bc | 5.52 ± 0.33bc |
| FBS  | 55.37 ± 1.27bc | 11.73 ± 0.21clo | 45.48 ± 0.27bc | 8.02 ± 0.35bc |
| FBC  | 55.40 ± 0.34bc | 12.72 ± 0.63clo | 42.49 ± 0.29bc | 10.73 ± 0.22bc |
| LSD  | 2.34     | 0.99     | 0.66    | 1.05   |
| CV   | 2.55     | 4.88     | 0.99    | 4.78   |

Values are means ± SD and values in the same column with different superscript letters were significantly different from each other (P < 0.05). Note: SL, SB, SS, SC = Solar drying with lemon juice, hot water blanching, salt solution dip, and control sample, respectively. TL, TB, TS, TC = Tray drying with juice, hot water blanching, salt solution dip, and control sample, respectively. FL, FB, FS, FC = Freeze-drying with lemon juice, hot water blanching, salt solution dip, and control sample, respectively. FBL, FBB, FBS, FBC = Fluidized bed drying with lemon juice, hot water blanching, salt solution dip, and control sample, respectively.
The values of $a^*$ colour coordinate of samples dried by solar and tray methods were 12.62 and 12.84 with no significant ($P > 0.05$) difference between them. On the other hand, samples dried by freeze and the fluidized bed had 11.85 and 11.95 with no statistical difference between them again. The two groups of data showed significant ($P < 0.05$) difference between the groups. Compared to the fresh samples 12.31 (Table 2), an increment was observed in the $a^*$ values for the solar and tray-dried samples. Zou et al. (2013), observed that there was a slight increase in the $a^*$ values for the mango chips compared to the fresh sample. This indicated that browning occurred, which is probably a result of the higher $a^*$ values of the dried samples (Izli et al., 2018; Krokida et al., 2000). During drying, both enzymatic and non-enzymatic reactions cause the browning of fruits and vegetables (Krokida et al., 2000). In contrast, freeze and fluidized bed driers caused a decrease in $a^*$ value, which suggested that the loss of red colour in the final product. Following the present results, Coklar et al. (2018), reported that the lowest redness was observed in freeze-dried fruit among other driers. Except for control samples, the value of $a^*$ was not increased. This was possibly due to the existence of salt, acid and blanching which causes the relative inactivation of enzymes responsible for the enzymatic browning. Most of the treatment combinations did not show significant differences in the $a^*$ values. However, the highest $a^*$ of dried mango value 14.07 was obtained at the treatment combination of tray dryer and that of control samples. The value of parameter $a^*$ which indicates sample redness in its positive form is also an important indicator of quality fruit (Zielinska et al., 2018).

A decrease in yellow colour was observed after drying than that of fresh samples 52.65 (Table 2). However, all the samples had a positive $b^*$ value. These positive values indicate their yellowness (Rumainum et al., 2018). The results of Izli (2017) and Zou et al. (2013) showed that drying methods reduced the $b^*$ value. Solar and tray dried samples exhibited the lowest value for $b^*$ with no significant difference and freeze and fluidized bed driers showed higher values with a significant difference between them. The yellowness ($b^*$) of dehydrated materials is strongly affected by temperature and air relative humidity (Krokida et al., 1998). The isomerization of carotenoids contributed in particular to the degradation of the yellow pigment β-carotene as well as oxidative phase (Corzo & Álvarez, 2014). A significant ($P < 0.05$) differences were observed on the values $b^*$ of the samples subjected to different pretreatments. Zou et al. (2013), observed a significant reduction of $b^*$ values for dried mango compared to the fresh samples, but the $b^*$ values of the samples subjected to osmotically treatments was significantly higher than that of control samples. The values of $b^*$ for samples dried by the tray and freeze driers with control and lemon juice treatments were 31.69 and 49.48 among the highest with significant differences. On the other hand, those samples dried with fluidized bed driers ranged between 42.49 and 47.52 are the next higher group showing significant differences among them. The solar-dried samples had values ranging from 30.47 to 35.12 again with significant differences among them. This can be attributed to better retention of carotenoids for samples (Nyangena et al., 2019), which is responsible for the typical yellow colour of the mangoes (Harnkarnsujarit & Charoenrein, 2011). High $b^*$ parameters give more yellow products that are recommended for dried products (Salehi & Kashaninejad, 2018). Colour has an important factor in the choice of food user even the differences depend on fruit chemical compositions, pretreatments and drying methods variation (Coklar et al., 2018).

As seen in Table 7, the different drying methods affected the colour parameters of the dried mango slices. Relatively high values of 19.91 and 20.02 total colour difference was recorded in samples dried by solar and tray as compared to those of freeze, and fluidized bed dries. The total colour difference value is quite useful for expressing the total amount of colour change due to process (Corzo & Álvarez, 2014; Pu & Sun, 2017; Zou et al., 2013). Similar studies have shown an increased $\Delta E$ with the solar dryer (Li et al., 2018; Nyangena et al., 2019), that’s due to the long-time exposure to oxygen and light (Li et al., 2018). A higher $\Delta E$ indicates a greater loss in colour of dried samples (Q. Wang et al., 2019). In the comparison of all drying treatments, the freeze and fluidized bed driers retain the colour damage as they gave minimum values 5.15 and 7.75. It may be associated with the removal of water by ice sublimation to prevent enzymatic browning.
reactions, resulting in relative to colour stability for freeze-drying techniques (Muñoz-lópez et al., 2018). Similarly, it may be because of the less oxygen presented in the drying chamber (Li et al., 2018). These results were in good agreement with work done by Ali et al. (2016) on guava fruit, İzlİ (2017) on date fruit and İzlİ et al. (2018) on pineapple slices in which they observed the freeze dryer retain the colour quality of the dried samples. Significant differences of ΔE observed among the four pretreatments where the minimum and maximum values were 11.80 and 15.21 for the samples subjected to no treatments (control) and that of lemon juice. This may be due to the infusion of acids to fruits that have been shown to impart stability to colour parameters (Nyangena et al., 2019). The dried product with minimum colour change is highly preferred by consumers (Aniesrani Delfiya et al., 2017). Hot water blanching treatments caused a reduction in the total colour change. This is due to the complete inactivation of enzymes which causes colour changes in samples (Aniesrani Delfiya et al., 2017; Gulzar et al., 2018; H. Wang et al., 2018). The data showed that mango slices treated with lemon juice, hot water blanching and salt solution pretreatments scored lower colour loss after drying, resulting in products with superior colour compared to that of the control samples. There was significant (P > 0.05) difference on the ΔE of dried mango due to the interactions between pretreatments and drying methods except for very few of the samples.

### 3.5. Effect of pretreatments and drying methods on vitamin C and phenol contents of dried mango

An analysis has been made on vitamin C as effected by pretreatments and drying methods and the findings are shown in Table 9. The ascorbic acid values obtained in the present study ranged from 33.18 to 41.24 mg/100 g for the samples dried by different drying methods. This finding was lower than the values obtained by Adepoju and Osunde (2017) and Singh et al., (2014) which ranged from 97.59 to 225.38 mg/100 g and 109.32 to 158.15 mg/100 g respectively, for dried mango. These values are in agreement with a range of 27.7 to 198.3 mg/100 g given by Nixwell et al. (2013) for dried mango. When comparing fresh fruit with the corresponding dried mango, it was observed that the operation condition led to a decrease in ascorbic acid contents. It might be due to its heat-labile nature that leads to degradation of ascorbic acid (Singh et al., 2014; Sogi et al., 2012; Wilson et al., 2014). Similarly, vitamin C losses also depend on the drying methods and raw material type as well as additional factors such as pretreatments (Wijewardana et al., 2016). The highest values of vitamin C 41.06 and 41.24 mg/100 g were recorded by freeze and fluidized bed dried samples with no significant differences between them. This high retention may be due to the quick-drying resulted in prevention of ascorbic acid loss (Wijewardana et al., 2016) and the use of vacuum in the process with the low temperature used (Marques et al., 2011). Conversely, freeze

| Drying methods | Vitamin C (mg/100 g) | Total phenol content (mg/100 g) |
|----------------|----------------------|---------------------------------|
| Solar          | 33.18 ± 1.46 c       | 251.12 ± 4.71 a                 |
| Tray           | 35.97 ± 1.01 b       | 178.05 ± 12.62 c                |
| Freeze         | 41.06 ± 1.59 a       | 131.13 ± 3.96 d                 |
| Fluidized      | 41.24 ± 0.80 a       | 220.00 ± 3.15 b                 |
| Pretreatments  |                      |                                 |
| Lemon juice    | 39.18 ± 3.84 d       | 195.62 ± 46.34 b                |
| Hot water blanching | 38.07 ± 3.72 d   | 203.90 ± 46.78 c                |
| Salt solution  | 37.42 ± 3.41 bc      | 190.58 ± 48.61 c                |
| Control        | 36.78 ± 3.74 c       | 190.20 ± 47.49 c                |
| LSD            | 0.69                 | 0.82                            |
| CV             | 2.20                 | 0.51                            |

Values are means ± SD and values in the same column with different superscript letters were significantly different from each other (P < 0.05).
dryer is a drying method with high production cost (H. Wang et al., 2018) and time-consumer (Nawirska et al., 2009). Sehrawat et al. (2018) and Marques et al. (2011) confirmed average retention of vitamin C 73 to 81% using the low-pressure superheated steam, vacuum drying method and 96.95% after freeze-drying of mango. Vitamin C retention is used as reference or benchmark of nutrient preservation in foodstuffs (Ali et al., 2016; Sogi et al., 2012; Tewari et al., 2016; Yan et al., 2010).

Solar dryer scored lower value 33.18 mg/100 g of ascorbic acid as compared to other driers. This is due to oxygen and light exposure to vitamin C, regardless of the process temperatures that promote degradation (Lopes et al., 2006). Additionally, the presence of oxygen in the drying media induces unsound changes in the value of dehydrated goods (Rajkumar et al., 2007). The main enzyme that causes the enzyme degradation of ascorbic acid was ascorbate oxidase (Marques et al., 2011). As indicated in Table 9, high vitamin C 39.18 mg/100 g was found in samples subjected to lemon juice exceeding 38.07 mg/100 g that of hot water blanching pretreatments. Martinez et al. (2005) reported high retention of vitamin C in blanched samples than that of unblanched dried sweet pepper. In line with this Galoburda et al. (2012), concluded that blanching is recommended to prevent the major loss of nutrients but the conditions of blanching are very important. About 79% of the vitamin C of dried carrot was retained in the vacuum microwave dryer after subjected to blanching (Lin et al., 1998). The ascorbic acid content of samples subjected to the salt solution 37.42 mg/100 g was higher than 36.78 mg/100 g of the control samples. This may be because of salt that deactivates the enzyme and rapid water loss. The data showed that vitamin C of dried samples were significantly affected by the drying methods and pretreatments used.

Most of the treatment combinations showed significant differences in the vitamin C content of dried mango. The highest value 43.09 mg/100 g was obtained from the treatment combination of lemon juice and freeze dryers whereas the lowest value 32.05 mg/100 g was obtained from the combination of solar dryers without pretreatments. This result was coherent with the findings of Teshome (2010), who reported with the range of 14.98 to 44.44 mg/100 g for dried mango leather. However, the results obtained from the present study for a solar-dried group ranging from 32.05 to 34.38 mg/100 g were lower than 109.89 to 126.89 mg/100 g reported by Adepoju and Osunde (2017) for dried mango. A 39.66% loss of vitamin C was reported by Teshome (2010) for Keitt mango leather. Similarly, Mohamed et al. (2017) reported a reduction in the ascorbic acid content with a range of 24.29 to 71.88% for dried mango. According to Maria et al. (2012), if ascorbic acid is well retained, other components are also well retained. It can be found that samples subjected to lemon juice treatments and dried by freeze dryer resulted in high 43.09 mg/100 g retentions of vitamin C than that of the other treatments. During the freeze-drying process, the temperature was very low and it caused no significant loss of vitamin C (Lin et al., 1998) and that of lemon juice was due to its vitamin C contents in nature. The finding of this study was in agreement with the report of Adepoju and Osunde (2017) who stated that both the pretreatments and drying methods affected the vitamin C contents. It was, therefore, important to maintain vitamin C, as it was an essential nutrient for our body’s specific metabolism and acts as a reagent for the preparation of many pharmaceutical and food industry products. This vitamin can prevent many diseases and plays a vital role in the building of tissues like skin, tendons, cartilages and blood vessels (Ali et al., 2016). The consumption of dried mango could provide a measure of Vitamin C needed by the body for its physiological functions.

Mango is a rich source of nutrients like ascorbic acid, β carotene and various polyphenolic compounds (Hwa et al., 2013; Pott et al., 2003; Sehrawat et al., 2018). Vitamin C is the main human food nutrient, which fruits and vegetable supply 90 per cent (Hernandez et al., 2006; Lee & Kader, 2000; Owolade et al., 2017). It promotes cell growth, proper calcium absorption, the normal growth of tissues and the repairation of injuries and strengthening capillary wall (Kebena, 2017). The recommended daily allowance for vitamin C ranges from 40 to 120 mg per day for infants below 6 months and lactating women (Yebio et al., 2015). If for someone the dried mango studied
in this experiment are the only sources of vitamin C, someone has to consume at least 120, 211 and 100 g of solar, tray and freeze and fluidized bed dried mango, respectively to cross the minimum amount in the recommended daily allowance range of vitamin C.

From Table 9, the total phenol contents of the samples dried by different drying methods are ranging from 131.13 to 251.12 mg/100 g with significant differences among them. Freeze-dryer resulted in lower phenolic contents 131.13 mg/100 g. Similar findings were reported for the low phenolic contents of samples dried by freeze dryers (Hossain et al., 2010; Raja et al., 2017; Shofian et al., 2011). It is perhaps because of the low temperature, that can cause ice crystals produced during the freeze-drying process within the tissue matrix to break up the cell walls and release oxidative and hydrolytic enzymes that harm the phenolic compounds (Chang et al., 2006; Hossain et al., 2010). The present finding was supported by Shofian et al. (2011) and Raja et al. (2017). Tray dried samples contain lower phenolic 178.05 mg/100 g than fluidized bed 220 mg/100 g and solar 251.12 mg/100 g dried samples. This may be due to the heat sensitivity of polyphenolics (Aziah et al., 2012) and prolonged heat causes irreversible chemical changes (Mejia et al., 2015) favouring binding polyphenols to other compounds or changes in the chemical structure (Qu et al., 2010).

Regarding the pretreatments, the hot water blanching resulted in the highest value 203.90 mg/100 g exceeding lemon juice 195.62 mg/100 g of phenolic contents. This was in line with the results of Khajehei et al. (2018), studies which showed the lemon juice treated yacon chips indicated high total phenol contents as compared to control samples. Phenols are active compounds of antioxidants and can possess more free radical-scavenging activity than vitamins C and E (Coklar et al., 2018). The measured levels of total phenolic content in the samples were incomparable with Yi et al. (2017) of 186.6 to 550.1 mg/100 g but lower than that of Singh et al. (2014) with range 963.2 to 1725.2 mg/100 g for dried mango. The pretreatments and drying methods showed significant differences in phenol contents.

Table 10 showed that the total phenolic contents of those samples dried with solar and fluidized bed driers after all the four treatments showed significant (P < 0.05) differences among them. The top four records belonged to samples dried by solar dryers after the four different pretreatments. This might be due to a process that is carried out at room temperature (Chan et al., 2009). Similarly, the data showed those samples dried by the tray and freeze driers after the four pretreatments showed significant differences among them but are statistically lower than the values of the samples dried by solar and fluidized bed driers. Similar observations are also made by Raja et al. (2017) for Carica papaya L. leaf powder in which freeze-dryer resulted in lowering phenolic content than shade and oven-drying. Variations in the horticultural practices, climatic, maturation, method of extraction and analytical protocol may be the cause of the difference in phenolic content (Coklar et al., 2018; Khajehei et al., 2018; Singh et al., 2014).

4. Conclusions
The results of the study showed that dried mango slices were good sources of nutrients and antioxidants. The results show that the dried mango fruit samples were higher in fibre and carbohydrate contents; this makes them a healthy, energy food which can be used as raw materials for further processing or consume directly with breakfast cereals and snacks. The present findings shows that freeze and fluidized bed drying methods produced better dried mango slices with high quality parameters. Pretreatments were found to be a suitable method for the colour and vitamin C preservation of dried mango fruits. The best colour and vitamin C parameters were observed with lemon juice and hot water blanching pretreated samples. In conclusion, the right selection of pretreatment during mango slices drying can be used as one of the techniques to control undesirable quality changes. It can further be concluded that the pretreatments and drying methods had the potential to extend the shelf life of dried mango slices. This data was therefore anticipated to effectively cover the existing information gap about drying technologies and could serve as a guide to the participation of additional individuals within the sub-sector if well-used. This cannot only enhance job opportunities and financial gain but in
addition, it will expand the food processing industry and reduce the appalling post-harvest losses in Ethiopian mango fruits.

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Table 10. The antioxidants of dried mango as affected by the interactions of pretreatments and drying methods

| Code  | Vitamin C (mg/100 g) | Total phenol content (mg/100 g) |
|-------|---------------------|---------------------------------|
| SL    | 34.38 ± 0.33a       | 251.75 ± 0.66b                 |
| SB    | 33.10 ± 1.22a       | 258.21 ± 0.43a                 |
| SS    | 33.21 ± 1.12a       | 246.84 ± 0.43a                 |
| SC    | 32.05 ± 2.20a       | 247.69 ± 0.43a                 |
| TL    | 36.94 ± 0.57a       | 177.33 ± 1.28a                 |
| TB    | 36.47 ± 0.69a       | 197.94 ± 0.63a                 |
| TS    | 35.45 ± 0.59a       | 169.53 ± 0.49a                 |
| TC    | 35.02 ± 0.95a       | 167.40 ± 0.40a                 |
| FL    | 43.09 ± 0.51a       | 133.87 ± 0.45a                 |
| FB    | 41.87 ± 0.16ab      | 135.73 ± 0.49a                 |
| FS    | 39.85 ± 0.35ab      | 126.76 ± 0.63ab                |
| FC    | 39.42 ± 0.12a       | 128.16 ± 0.66ab                |
| FBL   | 42.33 ± 0.61ab      | 219.53 ± 1.83ab                |
| FBB   | 40.85 ± 0.40a       | 223.72 ± 0.43a                 |
| FBS   | 41.15 ± 0.30abc     | 220.76 ± 1.80bc                |
| FBC   | 40.61 ± 0.53abc     | 215.99 ± 1.25cd                |
| LSD   | 1.38                | 1.50                            |
| CV    | 2.20                | 0.46                            |

Values are means ± SD and values in the same column with different superscript letters were significantly different from each other (P < 0.05). Note: SL, SB, SS, SC = Solar drying with lemon juice, hot water blanching, salt solution dip, and control sample, respectively. TL, TB, TS, TC = Tray drying with juice, hot water blanching, salt solution dip, and control sample, respectively. FL, FB, FS, FC = Freeze-drying with lemon juice, hot water blanching, salt solution dip, and control sample, respectively. FBL, FBB, FBS, FBC = Fluidized bed drying with lemon juice, hot water blanching, salt solution dip, and control sample, respectively.
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