COMPARISON OF DRYING AND JAM PROCESSING OF JUJUBE (*ZIZIPHUS JUJUBA* L.) FRUIT, AND STORAGE EFFECTS ON QUALITY PARAMETERS, SENSORIAL CHARACTERISTICS, AND ANTIOXIDANT POTENTIAL

Luziana Hoxha [*1], Renata Kongoli[2]
1: Food Research Center, Agricultural University of Tirana, Koder Kamez, 1029, Tirana, Albania
2: Department of Agrifood Technologies, Agricultural University of Tirana, Koder Kamez, 1029, Tirana, Albania

Abstract
Nowadays nutritional importance of jujube fruit is well known by food scientists, and it is why is getting attention on the application potential for the development of commercial food products. This fruit is well adapted and grown in Albania, but ways for its preservation are still limited. Therefore, the aim of this study was preservation of jujube (Ziziphus jujuba L.) by application of drying and jam making techniques, comparison of quality parameters, sensorial characteristics and antioxidant activity of products with fresh fruits, and changes during storage. The processing scheme of the selected variety, was investigated through evaluation of quality attributes (physico-chemical parameters, vitamin C, color, water activity, total content of polyphenols, flavonoids and antioxidant potential), and sensorial characteristics of products at the moment of processing, and after 3 and 6 months of storage at room temperature. Results of the study showed suitability of selected jujube variety for processing, based on quality attributes, a stable preserved product (with aw around 0.6), and with minimal changes on physico-chemical parameters during storage. From the comparison made between dried jujube and jam a thermal degradation for polyphenols, flavonoids and antioxidant activity were noted, as their content resulted higher in dried jujube, respectively till 365.7 mg gallic acid equivalent (GAE), 167.67mg catechin equivalent (CE), 169.57 mg acid ascorbic (AA), and for jujube jam till 116.29 mg GAE, 62.39 mg CE, 112.83 mg AA per 100 g of sample. The technological schemes designed here may be proposed to small scale processors, as new alternatives for utilization of such nutritious fruit, with a potential to be profitable for Albanian agri-food sector too. Future efforts may be focused on diversification of feasible technologies for preservation of jujube, even capable to operate in a larger scale, and development of new dietetic products.

Keywords: antioxidant activity, jujube, processing.

Introduction

Jujube is extensively cultivating in tropical and subtropical regions. It is an edible and delicious fruit, and a long history of usage as vital food and/or traditional medicine (Ahmed et al., 2020). The scientific evidence has shown that jujube fruits have a high nutritional value, due to the presence of large amount of nutrients and phytochemicals, such as: fibers, proteins, fat, carbohydrate, vitamins, minerals and phenolics (Chen et al., 2019; Hernández et al., 2016; Li et al., 2007; Hoxha et al., 2020). Different studies are undertaken for extending the shelf-life of jujube, by processing them as dried fruits, nectar, jam, fruit extracts, powdered tea, cloying with honey, preservation in sweet–sour infusion vinegar, conservation in sweet infusions like compote, jelly, chutney, and pickles (Shin et al., 1992; Krška & Mishra, 2009; Uddin & Hussain,

[*] Corresponding author email: lhoxha@ubt.edu.al

2012), as well other food products such as candied jujube, smoked, stoneless sugared, liquor, liquor-saturated, paste, juice, slices, beer, essence, and pigment (Bi et al., 2010; Liu, 2004; Ji, 2008). Different researchers have considered drying as important technique for jujube preservation, and some applications are freeze, vacuum, short and medium-wave infrared radiation, microwave, microwave vacuum freeze, microwave vacuum puffing, and vacuum freeze drying (Hao et al., 2019; Wang et al., 2016; Wojdył et al., 2016; Wojdyło et al., 2019). Jujube jam on the other hand is considered a promising food product, and different formulation are studied (Zhao et al., 2012; Guo & Cheng-Rui, 2013; Jiang & Yan, 2007; Uddin & Hussain, 2012; Dubey et al., 2014). Albanian jujube preservation is still limited, and the aim of study is that optimization of jam recipe and drying process, to provide products with improved sensorial characteristics, which might be proposed to small scale processors, as new alternatives for utilization jujube fruit, with a potential to be profitable for Albanian agri-food sector. Future research prospects might be on diversification of feasible technologies for preservation of jujube and to develop new dietetic products, with intend to support the advancement of jujube value chain, as well to respond to the needs of producers, markets, and consumers.

Materials and Methods

For this study were selected *Ziziphus jujuba* L. fruit, autochthonous variety from Durres region. Fruits were manually harvested in autumn 2020, picked up randomly, and immediately transported to the laboratory for further processing and analyzation. Fruits were pre-selected with uniform maturity, shape, size, color, and free from defects. For drying jujube fruits, a laboratory scale hot-air dehydrator was used, and the drying chamber consisted of a centrifugal air blower (horizontally across the ten trays), electrical heating elements, with adjustable temperature here applied 60°±0.1 C and air velocity 1±0.1 m/s, relative humidity approximately 40% (at the beginning) and 10% (at the end), (Zhu et al., 2014; Hoxha & Kongoli, 2016). Jujube fruits were set on thin layer and no pre-treatments were applied. End of drying was judged till no change between two consecutive measurements was observed, and the drying process last approximately 4 h. Flow diagram for both dried and jujube jam making was as following:

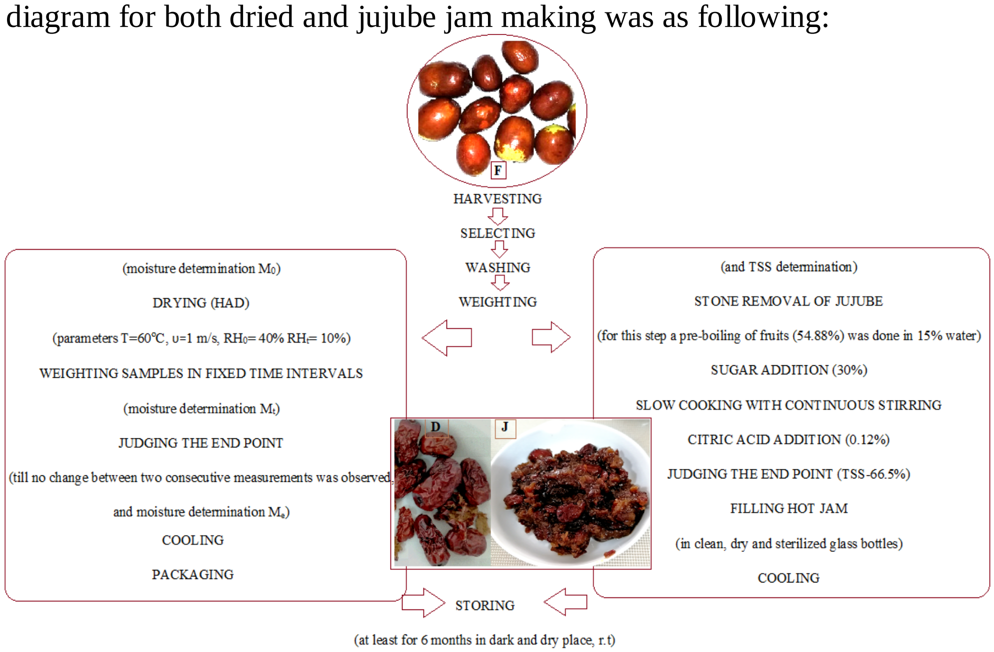

Fig. 1: Flow diagram for drying jujube and jam making

Prior processing jujube jam total soluble solids (TSS) of fruits was determined, and all ingredients were weighed separately, also no preservative were used. Each experiment for drying jujube and jam making was repeated three times and the average data were used for data analysis. Jujube jam (code J) and dried jujube (code D) were analyzed at the time of processing (J_0, D_0), and after 3 months (code J_3, D_3) and 6 months (code J_6, D_6) of storage at room temperature (r.t.), as control was used fresh jujube fruit (code F).
Length and width (mm) of fruit were measured using digital caliper gauge (± 0.01 mm). Moisture was measured at 105 °C with advanced moister analyzer (MB120 OHAUS), and the result were expresses as g/100 g fresh weight (FW) of sample; TSS were measured using ABBE refractometer and the results were expressed in °Brix; total titratable acidity (TA) was estimated by titration with 0.1 N NaOH and results expressed as g citric acid (CA)/100 g FW; pH measurements were done using pH meter (Lab 855), calibrated prior with standard buffer solution at pH 4 and 7; ash content was estimated as the difference in mass before and after incinerating at 525 °C in a muffle furnace, and the result were expresses as g/100 g FW. Vitamin C was determined according to Mussa & Sharaa (2014); color measurement parameters were carried out using a portable colorimeter (model NH310) with the CIE L*, a*, b*; water activity (a_w) was measured with handheld water activity meter (Rotronic). Extract preparation and determination of total polyphenols (TP), total flavonoids (TF) and antioxidant activity in terms of ABTS assay, were performed according to Hoxha et al., (2020). Sensorial characteristics of processed products (colour, flavour, sweetness, texture, taste and overall acceptability) were evaluated according to the method of Wills et al., (1990), on a nine-point hedonic scale (1= Dislike extremely, 2= Dislike very much, 3= Dislike moderately, 4= Dislike slightly, 5= Neither like nor dislike, 6= Like slightly, 7= Like moderately, 8= Like very much and 9= Like extremely). Parameters of jujube products are assessed at least in triplicates and presented as Mean ± standard deviation (SD), whereas the sensory properties results were expressed as the mean of ten replicates.

Results and discussions

Dried samples were weighted at fixed time intervals, and records from the different drying tests were expressed versus drying time, moisture ratio Ln (MR) calculated according to Zhang et al., (2006) and drying rate V (g/sec). Equilibrium moisture was achieved after 14400 sec, and jujube selected variety had a high drying rate compared to the study of Motevali et al., (2012). Jujube drying curves (Fig. 2) followed the general pattern for food products, but further studies are needed to predict the thin-layer drying model for moisture ratio of jujube.

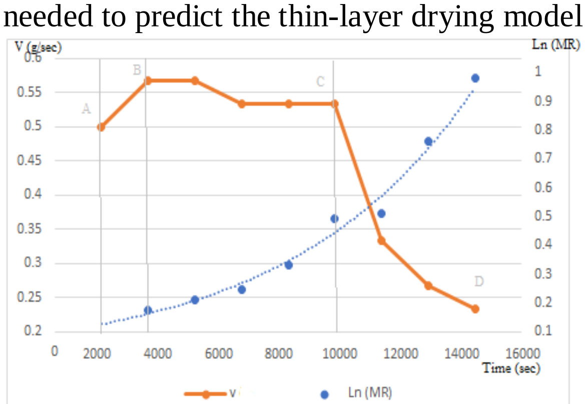

Fig. 2: Experimental values ln (MR) and drying rate versus drying time

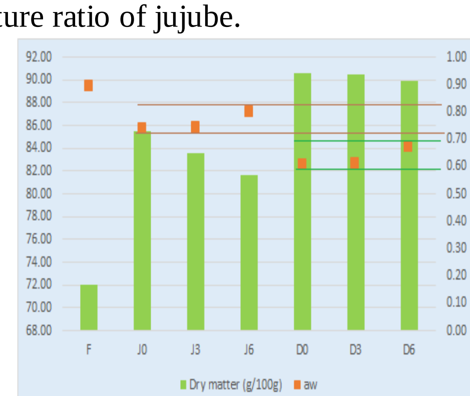

Fig. 3: Dry matter and a_w values of jujube products

Based on weight of fruits and stones in fresh and dried form, it is noted that weight reduction is around 75%, minimal changes occur in length, as its reduction is around 11%, compared with the width (44%), which affect a higher shape ratio for dried jujube (58%) compared to fresh fruit, but flesh/stone ratio is reduced around 65% in dried jujube, due to the loss of water. The amount of dry matter (DM) (Fig. 3) increased in samples J_0 (18.78%) and D_0 (25.82%) compared to F, and during storage vere noted a dicrease of DM for J_3 (2.3%), J_6 (4.5%), D_3 (02%), and D_6 (0.76%), which might be due to moisture absorption by sugar components of jam, also other concentrated component in dried jujube, the results seem to be higher compared to other studies (Hossain, 2011; Rahman, 2018). The a_w of jujube products was decreased by processing by 17 % (J_0) and 32% (D_0). a_w value till 0.6 (D_0) reached, may indicate that processed products are stable, even during storage, a slight increase (1%) of a_w values happened after 3 m, and a greater increase 7.6% (J_6 0.79) and 9.6% (D_6 0.66) occurred after 6 m, and such a_w values are favorable for mold and yeast growth, so future research may be focused on extending the shelf-life, especially for jam (a_w values 0.73 J_0 and 0.79 J_6). Total titratable acidity (TA) resulted 1.03 g (CA)/100 g FW (J_0) and 1.56 g (CA)/100g FW (D_0), which may serve as the measure of shelf-life of the product (Vidhya and Narain, 2011). During storage was increased 3.41 % (J_3) and 12.78% (J_6), which might be due to ascorbic acid degradation or hydrolysis of pectin (Sogi & Singh, 2001), also due to the formation of acidic compounds by degradation, or oxidation of reducing sugars present by the breakdown of peptic bodies (El-Warraki et al., 1976), or may indicate a microbial activity occurrence, but for this microbiological examination are needed and might be the prospect for future study, while in dried jujube a slight increase happened 1.28% (D_3), 2.69% (D_6). pH values resulted 4.32 (J_0) and 4.15 (D_0), and during storage a slight reduction was noted, also related with increasing trend of acidity. The TSS content of jujube jam varied from 66.26 to 67.12 ^{o}Brix, which was in standard range, and for dried jujube 57.87-58.73 ^{o}Brix, the range of TSS values might indicate low deterioration possibilities, as microorganisms cannot grow at high sugar concentration. During storage slight decreased of TSS were noted 0.8% (J_3), 1.28% (J_6), 0.92% (D_3) and 1.46% (D_6), which might be due to either conversion of sugar, or absorption of moisture during storage, and this is in agreement with findings of other studies (Garcia-Viguera et al., 1999; Hossain, 2011). Jujube jam showed higher TSS values, and TSS/TA ratios compared to dried jujube. TSS of the products is the index of sweetness, and in most cases is correlated with the maturity and ripeness of fruits (Jain & Agawal, 2005), also is indicative of a high acceptance of products (illustrated in Fig. 5b). The total sugar content was lower in jujube jam 41.01 g/100g FW (J_0) compared to dried jujube 47.09 g/100g FW (D_0), and decreased during storage respectively 1.06 % (J_3), 2.83 % (J_6), 0.2% (D_3), 0.57% (D_6), which might be explained with the increase of reducing sugars, which is in accordance with other studies (Rao & Ray,1980; Hossain, 2011). Total ash content resulted higher in dried jujube 2.56 g/100 g FW, compared to jam 0.9 g/100 g FW, slight reduction was noted during storage.

Color is one of the most principal characteristics of foods, being supposed as a key for their acceptance. Dried jujube and jam had significant differences in terms of L*, a*, and b* values (Fig. 4), where L* value indicates the lightness, 0–100 representing dark to light, a* value gives the degree of the green–red color, with a higher positive a* value indicating more red, b* value indicates the degree of the blue–yellow color, with a higher positive b* value indicating more yellow (Najjaa et al., 2020). The control (F) offered significantly highest L* value compared to J_0 (25.22) and D_0 (28.69), also same trend for a* value of J_0 (7.53) and D_0 (17.25), and b* value of J_0 (5.55), D_0 (4.02). During storage a decrease in lightness and redness was noted respectively L* and a* values of samples were: J_3 (26.53; 7.43), J_6 (29.58; 10.20), D_3 (25.06; 12.25), D_6 (22.58;

6.91), whereas blueness b* values increased J_3 (6.14), J_6 (10.73), and D_3 (5.66), D_6 (10.50). The differences in a* and b* values detected in F sample compared to dried jujube and jam, might due to various exposure to high temperatures, also this is an indicator for possible colored compounds generated from caramelization and Maillard reaction (principally depending on the level of sugars and proteins in the formulation), which may have occurred during processing (Purlis & Salvadori, 2007), as the amount of water reduced during drying and jam making, may provide good conditions for Maillard reaction.

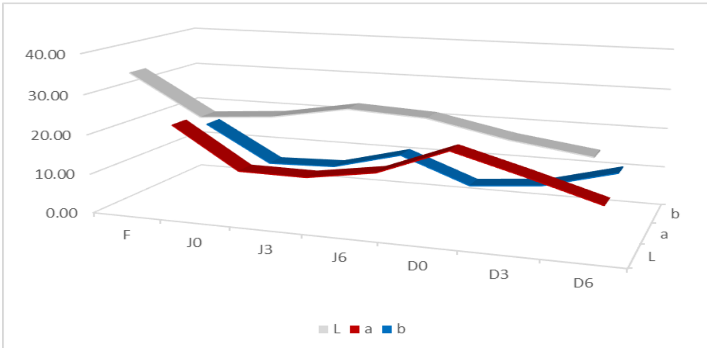

Fig. 4: Color parameters CIE L*, a*, b*

Ascorbic acid content of the jujube products was found very low with a reduction 97.69% (J_0) and 90.63% (D_0), respectively 2.64 and 10.72 mg/100 g FW, compared to fresh jujube (114.40 mg/100 g FW), which might happen due to both oxidative and non-oxidative changes, thermal degradation (Klopotek et al., 2005). Further degradation of vitamin C was noted during storage compared at the moment of processing till 19.36 % (J_3), 20.02 % (J_6), 7.61% (D_3), 19.66% (D_6), which was in accordance with other studies (Hossain, 2011; Rahman, 2017).

The content of total phenolic (TP), total flavonoid (TF), and antioxidant activity of jujube products are expressed as mean values in mg equivalents/100 g FW of sample. TP was decreased 50% in jujube jam (J_0 116.29 mg GAE/100 g FW) compared to F sample, whereas dried jujube resulted in greater amounts 58.1% for D_0 (365.7 g GAE/100 g FW). During storage TP content was further decreased J_3 (5.9%), J_6 (15.6%), D_3 (18.2%), and D_6 (25.5%) compared to the same product at the time of processing. Correlation factors of TP for jam and dried jujube at the moment of processing, and after 3 and 6 months of storage resulted respectively 0.9807 and 0.9429. Same trends were noted for total flavonoid content, where TF was decreased 42.5% in jujube jam (J_0 62.39 mg CE/100 g FW) compared to F sample, whereas dried jujube resulted in greater amounts 54.53% for D_0 (167.67 g CE/100 g FW). During storage TF content was further decreased J_3 (6.8%), J_6 (7%), D_3 (25.8%), and D_6 (31.3%) compared to the same product at the time of processing. Correlation factors of TF for J_0, J_3, J_6 and D_0, D_3, D_6 resulted respectively 0.9998 and 0.8763. The antioxidant activity was evaluated in terms of ABTS radical scavenging activity, and expressed as ascorbic acid equivalent (AAE) in mg/100 g FW of sample. From the results was noted a decrease by 12% J_0 (112.83 mg AAE/100 g FW) compared to F sample, whereas dried jujube resulted in greater amounts 32.73% D_0 (169.5 g AAE/100 g FW). During storage antioxidant activity was slightly decreased J_3 (1.51%), J_6 (2.26%), D_3 (1.1%), and D_6 (1.8%) compared to the same product at the time of processing. Correlation factors of antioxidant activity for J_0, J_3, J_6 and D_0, D_3, D_6 resulted respectively 0.9807 and 0.9429. Also, the correlation between TP, TF and antioxidant activity are shown in Fig. 6, where is noted that dried jujube has greater amount due to components concertation, whereas in jam is noted a significant decrease, which might be affected by high temperatures of treatment. Although comparison is difficult, the phenolic contents, flavonoid contents and antioxidant activity, due to external factors influence, this study selected jujube fruits and its developed products are good sources of antioxidant compounds, even when compared to other fruit species (Hoxha et al. 2020).

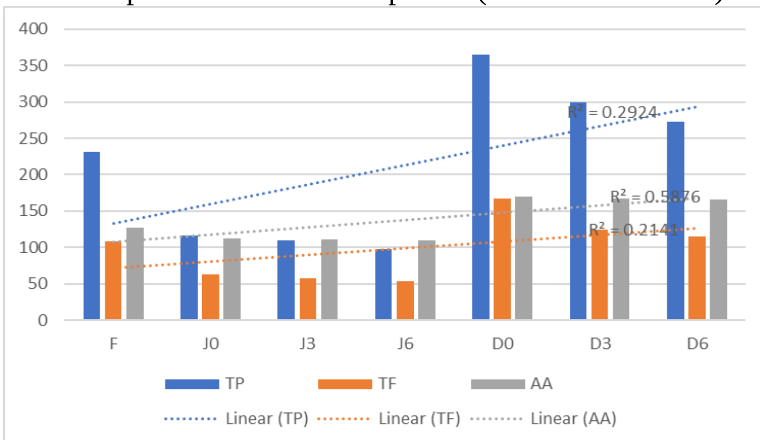

Fig. 6: Total polyphenolic and flavonoid and antioxidant activity of jujube samples

The sensory quality of dried jujube and jam was evaluated through colour, flavour, sweetness, texture, taste to determine the products acceptability score (Fig. 5a), reveals how organoleptic qualities of assessed products were affected by the processing. Processing jujube into dried and jam products was evident that provided products with improved sensory characteristic. Jujube jam (J_0) resulted to have higher mean scores (8.1), meaning higher consumer acceptability compared to dried jujube D_0 (7.6). During storage was observed a decrease in mean scores for the overall acceptability on a 9-point hedonic scale, respectively J_3 (7.94), J_6 (7.76), D_3 (7.4), D_6 (7.32).

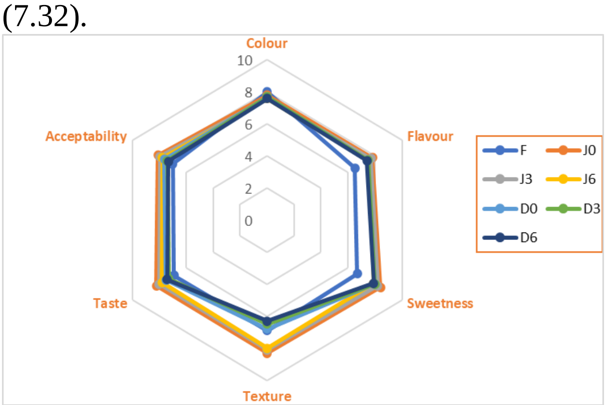

Fig. 5a: Rader diagram of selected sensory attributes

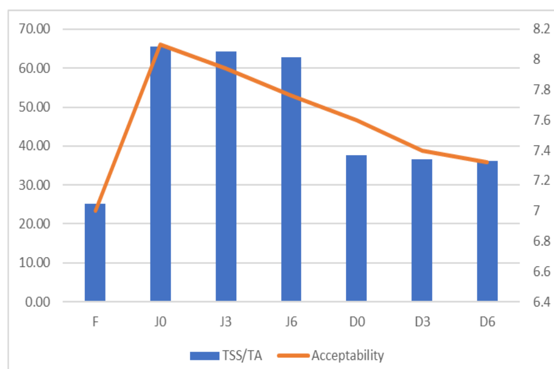

Fig. 5b: Correlation of overall acceptability and TSS/TA ratio

Conclusions

This study clearly shows the potential of Albanian selected variety to be diversified in jam and dried products, with improved sensorial characteristics and with good source of nutrients bioactive compounds. Based on quality parameters evaluated, generally a decreasing trend was observed during 6 months of storage (at r.t.), except titratable acidity and b* color parameter. Dried jujube showed greater amount of TP, TF and antioxidant activity compared to jam, and drying may be highly recommended, as dried jujube on the other hand could serve as good base for bioactive compounds extraction, or for development of functional food products. Jujube jam showed higher consumer acceptance, also might be a good option to be added to other food products. From study findings may be concluded that jam recipe and drying process may be proposed to be adapted by small scale processors, as new alternatives for utilization of such nutritious fruit. Future research prospects might be on further investigation for extending shelf-life of jujube products more than 6 months, and microbiological examinations for having a more complete panorama on quality and safety issues for jujube products. Further efforts might be on diversification of feasible technologies for preservation of jujube and development of new dietetic products, with intend to support the advancement of jujube value chain, as well to respond to the needs of producers, markets, and consumers.

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References

Ahmed, K., Karima R., N., Shishira, M., R., I., Baoa, T., Lua, Y., Chena, W. (2020) *Jujube fruit: A potential nutritious fruit for the development of functional food products.* Journal of Functional Foods 75: 104-205.

Bi, J., Yu, J., Bai, S., Wang, P. Ding, Y. (2010) *Research status of jujube processing technology at home and abroad*. Acad. Period. Farm Prod. Process. 2: 52–55.

Chen, K., Fan, D., Fu, B., Zhou, J., Li, H. (2019) *Comparison of physical and chemical composition of three chinese jujube (Ziziphus jujuba Mill.) cultivars cultivated in four districts of Xinjiang region in China*. Food Science and Technology, 39: 912–921.

Dubey, H., Parihar, P., Kumar, S. (2014) *Quality attributes of ber jam during storage*. Review Paper Advances in the cultivation technology of tropical mushrooms in India, 203: 120–135.

El-Warraki, A.G., Abdel-Rehman, N.R., Abdallah, M.A., Abdel-Fattah, T.A. (1976) *Physical and chemical properties of locally canned orange juice*. Annals of Agriculture Science, MoshtoHor, 6: 195-209.

Garcia-Viguera, C., Zafrilla, P., Romero, F., Abellan, P., Artes, F., Tomas-Barberan. F.A. (1999) *Colour stability of strawberry jam as affected by cultivar and storage temperature*. Journal of Food Science, 64: 243-247.

Guo, H., Cheng-rui, T. (2013) *The Key Technology Research of Preparation of Low Sugar Jujube Jam*. Food Research and Development, 33: 67–70.

Hossain, M. A. (2011) *Studies on the physico-chemical characteristics and products processing stability of selected jackfruit (Artocarpus heterophyllus Lam.) genotypes in Sylhet region*. PhD. Thesis. Department of Horticulture, Hajee Mohammad Danesh Science and Technology University, Dinajpur. pp. 109-115.

Hoxha, L., Kongoli, R. (2016) *Pretreatment influence on the drying rate and bioactive Compounds of dried figs*. Proceedings of the VIII International Agricultural Symposium „AGROSYM 2017“ ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

Hoxha, L., Kongoli, R., Karaulli, J., Laçi, L., (2020) *Physico-chemical and antioxidant properties of jujube fruit (Ziziphus jujuba) grown in Albania*. Albanian j. agric. sci.19 (4): 14-22

Jain, M.S., Agawal, G. (2005) *Studies on Physico-chemical changes in selected fruits during storage*. Beverage and Food World. 32(11): 72-75.

Ji, Q. (2008) *Study on the Processing Technology of Red Jujube Fermented Wine*. Shandong Agricultural University, Taian.

Jiang, H.-B., & Yan, Y. (2007) *Development of Konjac and Jujube Jelly*. Journal of Yangtze University (Natural Science Edition) Agricultural Science, 4: 99–101.

Klopotek, Y., Otto, K., Böhm, V. (2005) *Processing strawberries to different products alters contents of vitamin c, total phenolics, total anthocyanins, and antioxidant capacity*. Journal of Agriculture and Food Chemistry, 53: 5640-5646.

Krška, B., Mishra, S. (2009) *Sensory Evaluation of Different Products of Ziziphus Jujuba Mill*. ISHS Acta Horticulturae 840: 557-562.

Li, J.; Fan, L.; Ding, S.; Ding, X. (2007) *Nutritional composition of five cultivars of Chinese jujube*. Food Chem., 103: 454−460.

Liu, M. (2004) *Technical Manual for Quality Production in Chinese Jujube*. China Agriculture Press.

Motevali, A. Abbaszadeh, A., Najafi, G.H., Minaei, S., Ghobadian, B. (2012) *Drying of jujube (zizyphus jujube mill) fruit: comparison of prediction from mathematical models and artificial neural networks.* AJCS 6(2):210-218.

Mussa, S.B., Sharaa, I.S. (2014) *Analysis of vitamin C (ascorbic acid) contents packed fruit juice by UV-spectrophotometry and redox titration methods*. IOSR J Appl Physics 6:46-52.

Najjaa, H, Ben, A. A, Elfalleh, W., Zouari, N., Neffati, M. (2020) *Jujube (Zizyphus lotus L.): Benefits and its effects on functional and sensory properties of sponge cake*. PLOS ONE 15(2): e0227996. https://doi.org/10.1371/journal.pone.0227996.

Purlis, E, Salvadori, V.O. (2007) *Bread browning kinetics during baking*. Journal of Food Engineering. 80: 1107–1115.

Rao, V.S., Roy, S.K. (1980) *Studies on dehydration of mango pulp, I. Standardization for marketing mango sheet/leather*. Indian Food Packer. 34: 64-71.

Shin, Y., Yun, M., Kim, T., Kim, Y., & Lee, K. (1992) *A study on the processing suitability of pear and Chinese jujube cultivars*. Research Reports of the Rural Development Administration (Korea Republic), 34: 58–65.

Sogi, D.S. Singh, S. (2001) *Studies on bitterness development in kinnow juice, ready to serve beverage squash jam and candy*. Journal of Food Science and Technology, 38(5): 433-438.

Uddin, M. B., Hussain, I. (2012) *Development of diversified technology for jujube (Ziziphus jujuba L) processing and preservation*. World J. Dairy Food Sci, 7: 74–78 http://www.idosi.org/.../9.pdf.

Wills, R.B.H., Bembridge, P.A., Ccott, K.J.C. (1990) *Use of flesh firmness and other objective tests to determine consumer acceptability of Delicious apples*. Australian Journal of Experimental Agriculture and Animal Husbandry, 20:252-256.

Zhang, B.S., Chen, J. P., Li, H. Y. (2006) *Effect of hot air drying on nonenzymatic browning of Chinese jujube*. Food Science, 27(10): 139-142.

Zhao, J., Lu, Z., Jiao, W., Hua, Z., Li, Q. (2012) *Research on the technology of lowsugar jujube jam*. Journal of Northwest A & F University. Natural Science Edition, 40: 55–60.