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The Implications of Foliar Spraying Using Different Natural Plant Extracts on Fruit Set, Yield and Fruit Quality on "Anna" Apple Trees

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Abstract: The research aims to improve the quantity and the quality of the fruits of Anna apples, especially the color of the fruit, by using natural extracts compared to the chemical methionine. These extracts were Moringa, Henna, Licorice, Roselle, red beets, Radish, Cabbage and Novakey (contains methionine) at a concentration of 2% for each of them and they were sprayed for 4 times at petal full stage, then every 15. Days. The most important results were that treatment with Moringa leaf extract gave the highest tree yield, the highest hardness of the resulting fruits during harvest and after shelf life, less decay and fruit weight loss. Treatment with Roselle extract gave the best quality of fruits at harvest, with higher TSS, less hardness, more vitamin C content, more anthocyanin pigment content and better fruit coloring in both seasons.

Key words: Apple % Anna % Moringa % Roselle extracts % Yield % Fruit quality % Fruit coloring % Shelf life

INRODUCTION

Apples, (*Malus domestica*), Rosaceae family (Rosaceae), is one of the most widely cultivated fruit. It contains many vitamins and essential elements, like vitamin C, in addition to its' content of fibers which help in weight loss regimes besides its contribution to limiting cholesterol absorption in the body [1]. The total cultivated area of apples in Egypt in old land is 2574 feddans with a production of 22552 tons while in the new land (deserts) cultivated area is 77640 feddan with a production of 840818 ton [2].

Anna apples are among the widely cultivated varieties in Egypt, but they are criticized for their poor quality at the time of harvest in terms of poor quality, lack of red color of the fruit, high hardness of the fruit and lack of sugar at harvesting [3]. Therefore, some plant extracts were used to improve the quality of the fruits.

Some plant extracts, Such as Moringa, Henna, Licorice, Roselle, red Beets, Cabbage and Radishes, contain nutrients and natural plant hormones and thus can be used to increase yields, fruit quality and plant growth and development as an alternative, safe, environmentally friendly and less expensive natural source than synthetic compounds.

Moringa oleifera (family: *Moringaceae*) is one of such alternative sources, as several researchers indicated that moringa leaf extract (MLE) is equal to or even better in effectiveness than synthetic plant growth regulators [4]. Furthermore, MLE is easy to prepare. It is cheap and environmentally friendly and, therefore, can be used as a crop bio stimulant [5]. It is very valuable because it is a storehouse of phyto-nutrients such as vitamins A and C (7564 IU; 51.7 mg), calcium (185 mg/100 g), magnesium (147 mg/100 g) and phosphorus (112 mg/100 g), potassium (337 mg/100 g) and iron (4.0 mg/100 g) [6]. It also contains a group of important minerals, proteins, vitamins, beta-carotene, amino acids and various phenols with many flavonoid pigments [7]. Therefore, it is a good source of natural antioxidants [8]. In addition to many essential and non-essential nutrients, including nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), copper (Cu), iron (Fe) and zinc (Zn), manganese (Mn), selenium (Se) and it is rich in ascorbates and amino acids and the presence of gibberellin, auxin and cytokinin [9-11]. It contains high concentrations of zeatin (up to 200 micrograms/g) from the leaves. Zeatin is one of the natural forms of cytokinin in plants and it plays an important role in cell division and cell elongation, which has led to enhanced plant growth. It also has anti-aging potential and protective effects in plants [12-15].

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Since MLE contains many essential elements, auxins, gibberellins, cytokinins, proteins, polysaccharides, proline and vitamins, it is useful in improving plant nutrition, vegetative growth, photosynthesis and increasing yield and fruit quality. Furtherer more, it can boost plants resilience to a biotic stress, such as salinity, drought, by activating antioxidant enzymes [10, 16].

Henna (*Lawsonia inermis*) belongs to family *Lythreaceae*, Henna leaf powder contains Ca, P and K ranging from 0.2 to 4%. The Mg content was less than 2%, while Cu, Zn and Fe contents were above 0.5, 1.1 and 15 %, respectively, Mn content was less than 1.5 % while N content was less than 1.5 % [17]. It also contains coumarins, xanthones and flavonoids [18]. Lawsone (2-hydroxy-1,4-naphthoquinone as a Redox Catalyst) is the active ingredient [19]. Henna extract application induced the highest dry weight of leaves/plant, leaf area, total carbohydrates and N leaves contents of Schefflera arboricola [20]. Spraying strawberry plants with Henna extracts 2 g/l had a significant effect on the fruit weight, number of leaves/plant, shoot dry weight, total chlorophyll in leaves, N, P and K leaf contents, early and total yield/fed. as compared to the control [21].

Licorice, (*Glycyrrhiza glabra*) belongs to the family *Leguminoseae* the licorice extract contains more than 100 various compounds, some of which accumulates in large amounts, the most important of them are triterpene (the diterpenes to be mevalonic and then create gibberellins, an important group of plant hormones). Brassinosteroids, another class of plant hormones with growth-regulating functions, originate from triterpenes) saponins (including glycyrrhizin) and phenolic compounds [22, 23]. The yellow color of Licorice is due to the flavonoid content of the plant, which includes liquiritin, isoliquiritin and other compounds. The isoflavones glabridin and hispaglabridins A and B have significant antioxidant activity. In addition, licorice extract contains protein and amino acid (Asparagin), monosaccharide (glucose, fructose, sucrose and maltose), lignins, tannins, starch, choline, phytosterols, different types of vitamins such as B1, B2, B3, B6, C, E, biotin, folic acid, pantothenic acid, many mineral compounds (K, P, Ca, Fe, Mg, Zn, Si and cobalt) [24,25]. Foliar spraying with Licorice extracts significantly increased leaf area, dry weight of leaves and total chlorophyll content [23, 26]. And the highest yield and better fruit quality for apples treated with its' extract [27].

One of these plant extracts is the extract of the Roselle (*Hibiscus sabdariffa*) plant belonging to *Malvaceae* family, which is a good source of vitamins, amino acids and many nutrients like K, Mg, Ca and P, organic acids (ascorbic acid and Hibiscus acid). It also speeds up metabolic processes like photosynthesis, chlorophyll formation and cell division [28]. In addition, Roselle extracts contain a high percentage of phenolic acids e.g. protocatechuic acid (PCA, 3,4-dihydroxy benzoic acid) which is a major metabolite of anthocyanin [29]. Anthocyanins (delphinidin-3-sambubioside and cyanidin-3-sambubioside) are a class of water-soluble flavonoids that can scavenge antioxidants [30-32]. The conjugated double bond system in anthocyanin helps captures free radicals. In addition to anthocyanins, roselle petals also contain hydrocarbon carotenoid: â-Carotene (vitamin A) â-Carotene is a strong antioxidant and also a scavenger of singlet oxygen. â-Carotene is also a provitamin A as it can be converted into retinol. Thiamine (one of the water-soluble B vitamins) serves as a chemical reductant capable of transferring two protons and electrons, through one or more mechanisms [33, 34]. As a reluctant, thiamine can directly react with ROS in the form of hydroxyl radicals and superoxide [35]. And response to multiple stresses due to its need as a cofactor, as thiamine pyrophosphate is a required co-enzyme for several reactions in central metabolism [36]. Riboflavin (Vitamin B2) and niacin (Nicotinic acid is a type of vitamin B) [37]. Organic acid (citric acid, hydroxyl citric acid which a derivative of citric acid), hibiscus acid (3-hydroxy-5-oxooxolane-2, 3-dicarboxylic acid), malic acid (2-hydroxy di carboxylic acid) and tartaric acids as major compounds and oxalic acid (di-carboxylic acid) and ascorbic acid (Vitamin C is a water-soluble vitamin) as minor compounds [38]. Foliar spraying of the pear tree "Le-Conte cv." with Roselle water extracts gave the best fruits weight and fruits number per tree and increased total soluble solids and total fruit sugars content in comparison to control [39]. In addition, foliar sprays of roselle extracts significantly increased the dry weight of leaves, leaf potassium content, TSS, TSS/acid ratio, ascorbic acid content and reduced juice total acidity as compared with control of "Valencia" orange trees [40].

Red Beet root (*Beta vulgaris L.*) contains high amounts of biologically active substances including betalains, carotenoids are glycosides (compounds containing an attached sugar or sugars), phenols, B-vitamins (B_1, B_2, B_3, B_6 and B_{12}), folate minerals, fibers, as well as sugars with low energetical value and inorganic nitrate [41].

Radish (*Raphanus sativus Linn*), is a member of *Cruciferous* family. It. extract is known to contain alkaloids (derived from ornithine, an intermediate in arginine biosynthesis). The B vitamin nicotinic acid or niacin is a precursor of the pyridine ring of this alkaloid), glycosides, saponins, tannins carbohydrates, phenolic compounds, flavonoids, amino acids and volatile oil [42]. Cabbage (*Brassica oleracea*) is a member of *Cruciferous* family. It' extract is rich in macro and microelements, carbohydrates, protein, fiber, phenolic compounds, cellulose, hemi-cellulose and vitamins, i.e. thiamine, ascorbic acid and tocopherols (Vitamin E), as well as some amino acids [43].

The present research aims to improve the quality of Anna apple fruits, especially the coloring characteristics some natural extracts namely Moringa, Henna, Licorice, Roselle, red Beets, Radishes and Cabbage.

MATERIALS AND METHODS

The present study was carried out during two successive seasons of 2020 and 2021 On " Anna " apple trees (*Malus domestica L.*) budded on Balady rootstock, in a private orchard located at the Cairo Alexandria desert road (86 km) from Cairo, Beheira, Governorate, Egypt. Trees dedicated for the present investigation were ten years old at the beginning of the, similar to a large extent, spaced at 3*5, grown in sandy soil with a drip-irrigation used. All trees received the same cultural practices recommended by the Ministry of Agriculture.

The experimental deign was complete randomized design. Each three trees were sprayed with one of the following natural extracts. Each tree acted as a separate replicate. The trees were sprayed for 4 times at petal full stage, then every 15 days.

Foliar spray treatments by the following natural substances extracts:

- Moringa leaves extract at 2%.
- Henna leaves extract at 2%.
- Licorice extract at 2%.
- Roselle flowers extract at 2%.
- Red beets roots extract at 2%.
- Radish roots extract at 2%.
- Cabbage leaves extract at 2% (Farm waste from cabbage leaves).
- Novakey at 2% (it contains L-Methionine at concentration of 49.50g per liter as a commercial compound).
- Control (trees water spray).

It was extracted using an aqueous solution by adding Moringa leaves, Henna leaves, Licorice roots and Roselle flowers, soaking them in water for 24 hours and filtering them of impurities. As for red Beets roots, Radishes roots and Cabbage leaves, they are ground and filtered with cheesecloth.

After extracting 2 kg from each plant, as previously mentioned, the volume is added to 100 liters of water to obtain a concentration of 2%.

The Following Data Were Recorded

Fruit Set Percentage: For each of the considered trees 4 branches with nearly same load of spurs around the circumference were chosen and labeled. The fruit set percentage was calculated on the based on the initial number of flowers as follows:

Fruit set % = (Total No. of fruitlets / Total No. of flowers) * 100.

Number of Fruits/tree: Number of Fruits per Tree

Yield (kg/ Tree): At harvest, fruit yield was calculated by multiplying the number of fruits per tree * the average of fruit weight.

Fruit Characteristics: When fruits reached maturity according to Attia [44] on 4/6/2020 in the first season and on the first Jun/ 2021 in the second season. Twenty fruits from each considered tree were harvested and the following attributes were assessed:

Physical Attributes: Fruit weight (g), fruit volume (cm^3) fruit length (cm), fruit diameter (cm) and fruit firmness (Lb. /$inch^2$) by using a pressure tester (Advance Force Gorge RH13, UK).

Chemical Characteristics: Total soluble solids percentage (TSS %) was determined in fruit juice by using a hand Refractometer (Portable Refractometer ATC). Total acidity percentage (TA %) as malic acid was determined in fruit juice according to A.O.A.C. [45], TSS/acidity ratio, anthocyanin pigment according to Rabino and Mancinell, [46], Ascorbic acid content (V. C) as mg/ 100 ml fruit juice determined by using dye 2, 6 di-

chlorophenyl indophenols method A.O.A.C. [45]. Fruit flesh color and peel brightness (freshness): this parameter was estimated by Hue angle estimation and L value as cited by McGuire [47].

Feasibility Study: To assess the applicability of promising treatments the following simple feasibility study was carried out:

Cost of sprayed extracts/ feddan (LE) = Cost of sprayed material per one tree for 4 times* number of tree /feddan (280 trees).

Yield/ feddan (Ton) = Fruit yield kg/tree*No. of trees / feddan (280 trees).

Gros income/ feddan (LE) = Price of one ton in the farm * yield ton/ Feddan. The price of one ton (the price at the farm gate was 10000 for both seasons).

Net profit = Gros income - (Horticultural practices cost = 25000 and 3000 LE/feddan in both seasons respectively + cost of sprayed extracts)

Price per Kilogram by Egyptian Pounds: Moringa leaves= 150 pounds, Henna leaves = 40 pounds, Licorice roots= 40 pounds and Roselle flowers= 65 pounds, red Beets roots= 10 pounds, Radishes roots=5 pounds, Cabbage leaves= zero pounds (Farm waste from cabbage leaves) and Novakey = 100 pounds.

Shelf Life: Thirty-six mature fruits from each tree each 12 were placed in a perforated cartoon were harvested and placed at room temperature each box was dedicated for investigation at a specific date, (The maximum shelf-life period for fruits was 15 days from harvest). The flowing parameter was taken after 15 days from zero time (harvesting): Fruit firmness (Lb/inch^2), Juice TSS (%) and Juice acidity (%) were estimated after 15 days of shelf life of the fruits. Decay incidence %: per box was calculated according to the equation (number of decayed fruits/ total number of fruits) *100. Fruit weight loss % = A-B/A*100 (A= initial weight (at harvest); B = weight inspection date.

Statistical Analysis: The obtained data were subjected to analysis of variance according to Snedecor and Cachran [48]. Means were compared according to Duncan's multiple. Test at 5 % level using Microsoft program.

RESULTS AND DISCUSSION

Data in Table 1; show that all conducted treatments significantly increased the percentage of fruit set compared with control. The best treatment for the fruit set was the treatment with methionine for the two study seasons. As for both the number of fruits and yield per tree the highest significant results were attributed to the Moringa extract treatment. Whereas, the least results were due to control water sprayed treatment. The next treatment after Moringa in terms of the amount of tree yield was the result of the Roselle extract treatment, especially in the second season. The increase is due to the fact that the fruits are larger in size than the other treatments (Table 2) and the amount of crop resulting from the Moringa extract is a result of the increase in the number of fruits on the trees.

These results agree with Abd El-Hamied and El-Amary, [23] on Le-Conte pear; Mosa *et al.,* [49] on apple. Perhaps the increase in tree yield is due to the Moringa extract to reduce fallout, while the decrease in yield due to the methionine treatment, despite the increase in the percentage of fruit set. This may be due to the fact that methionine is the initiator of the formation of ethylene internally and with its repetition, it led to an increase in ethylene and thus increased fallout and decreased yield [50].

Roselle extract treatment resulted in a significantly the highest magnitude of both fruit weight and size compared with the other treatments and the control, which recorded the lowest magnitudes (Table 2). Moreover, Moringa extract induced the best fruit length, while the Roselle extract treatment gave the best fruit diameter parameters compared to the control, which recorded the lowest values for fruit length and diameter.

Results in Table 3; show that Moringa extract gave the highest fruit hardness compared to other treatments and Roselle extract gave the lowest fruit hardness. Despite this, the Roselle extract recorded the highest TSS values for the fruits compared to the other treatments and the control, which had the lowest TSS values.

All treatments led to a significant reduction in acidity compared to the control, which recorded the highest acidity of the fruits juice (Table 3). The lowest acidity percentage was attributed of treatments with red Beet, Radish and Cabbage extract during the two experimental seasons. Also, the treatments gave a clear and significant effect on the ratio of TSS to acidity compared to the control, which recorded the lowest values. The treatments

Table 1: Effect of treatments on fruit set (%), number of fruits per tree and yield (kg/tree).

	Fruit set (%)		Number of fruits/tree		Yield (kg/tree)	
Treatments	2020	2021	2020	2021	2020	2021
Moringa	16.65	19.69	414	374	72.86	68.82
Henna	15.80	11.34	360	295	63.36	53.69
Licorice	12.69	11.30	330	300	52.47	48.30
Roselle	16.05	13.92	355	306	63.19	59.98
Red beets	14.83	14.56	334	315	52.10	49.77
Radish	15.39	19.56	387	312	63.08	57.41
Cabbage	13.67	12.41	365	330	55.85	54.45
Methionine	25.98	21.68	360	310	60.48	52.70
Control	10.87	10.56	255	240	36.72	30
LSD at 0.05	0.24	0.12	3	1.9	2.59	1.75

Table 2: Effect of treatments on fruit weight, size, length and diameter

	Fruit weight (g)		Fruit size (cm^3)		Fruit length (cm)		Fruit diameter (cm)	
Treatments	2020	2021	2020	2021	2020	2021	2020	2021
Moringa	176	184	187	170	7.94	7.87	7.14	6.81
Henna	176	182	181	190	7.73	7.73	7.21	6.89
Licorice	159	161	158	170	7.71	7.51	6.77	6.84
Roselle	179	196	200	198	7.81	7.67	7.22	7.07
Red beets	156	158	156	154	7.41	7.20	6.61	6.55
Radish	163	184	176	183	7.48	7.70	6.68	6.91
Cabbage	153	165	154	159	7.41	7.41	6.55	6.86
Methionine	168	170	179	158	7.46	7.13	6.84	6.94
Control	144	125	144	111	7.28	6.65	6.41	6.08
LSD at 0.05	2.5	1.9	1.7	3.5	0.12	0.15	0.08	0.12

Table 3: Effect of treatments on fruit firmness, TSS, acidity and TSS/acidity

	Firmness ($Ib/inch^2$)		TSS (%)		Acidity (%)		TSS/acidity ratio	
Treatments	2020	2021	2020	2021	2020	2021	2020	2021
Moringa	9.87	9.83	15.05	15.10	0.65	0.73	23.15	20.41
Henna	9.46	9.41	15.17	15.10	0.70	0.78	21.67	19.36
Licorice	8.55	8.33	15.10	15	0.70	0.70	21.57	21.43
Roselle	8.04	8	15.93	15.13	0.73	0.77	21.82	19.65
Red beets	8.42	7.67	15.13	14	0.62	0.67	24.40	20.90
Radish	9.29	8.67	15.15	14.76	0.62	0.69	24.44	21.39
Cabbage	9.67	9.75	14.97	13.65	0.66	0.66	22.68	20.68
Methionine	8.69	8.83	15.27	13.77	0.75	0.81	20.36	17.00
Control	9.37	9.50	14.80	13.45	0.87	0.89	17.01	15.11
LSD at 0.05	0.19	0.15	0.22	0.18	0.08	0.07	0.24	0.46

that had the most effect on increasing the ratio of TSS to acidity were Radishes and red Beets in the first season, but in the second season, the treatments with Licorice extract and Radish were the most influential.

The results in Table 4 show the effect of treatments on vitamin C, anthocyanin pigment and dry matter percentage. All the treatments had a significant effect on increasing each of them compared to the control. Roselle extract treatment had the highest levels of vitamin C, anthocyanin content and dry matter percentage during the two study seasons.

From data in (Table 5) it is found that all treatments produced fruits with higher lightness (freshness) than the control group. Roselle treatment yielded the brightest red fruits (indicated by a low Hue angle of 1.3-1.4) and the highest anthocyanin concentration (0.189-0.202g/100g) in both seasons compared to other treatments and the control. Lower Hue angle values correspond to more intense red coloration.

Moringa extract spray application resulted in the greatest yield and net profit in both seasons compared to other treatments and the control group (Table 6). The control group produced the lowest yield and net profit per feddan in both seasons.

Results of shelf life in Table 7: declare that Moringa extract treatment induced the highest significant firmness after two weeks from zero time (harvesting) compared to other treatments, while the lowest hardness treatment was

Table 4: Effect of treatments on fruit content of vitamin C, anthocyanin pigment and dry matter percentage

	Vitamin C (mg/100g)		Anthocyanins (g/100g)		Dry matter (%)	
Treatments	2020	2021	2020	2021	2020	2021
Moringa	11.11	9.09	0.176	0.146	46.60	47.60
Henna	11.40	9.89	0.146	0.137	49.02	48.00
Licorice	9.30	8.40	0.119	0.144	46.33	48.50
Roselle	11.75	10.46	0.202	0.189	52.10	52.35
Red beets	10.08	8.86	0.132	0.132	48.33	48.47
Radish	9.51	8.49	0.106	0.108	40.14	45.74
Cabbage	9.76	8.95	0.115	0.121	39.50	44.73
Methionine	10.11	7.73	0.096	0.093	40.28	44.73
Control	6.91	7.42	0.093	0.072	36.90	39.70
LSD at 0.05	0.34	0.56	0.011	0.008	0.68	0.91

Table 5: Effect of treatments on fruit lightness (freshness) and Hue angle.

	Lightness		Hue angle	
Treatments	2020	2021	2020	2021
Moringa	62.90	66.86	3.25	3.76
Henna	68.50	67.23	5.67	6.20
Licorice	70.08	65.10	6.58	6.50
Roselle	72.95	65.15	1.30	1.40
Red beets	71.43	61.82	7.20	7.30
Radish	65.06	66.20	10.53	10.58
Cabbage	67.60	69.33	9.40	10.85
Methionine	66	63.56	19.60	11.55
Control	61.64	59.50	24.40	20.20
LSD at 0.05	0.89	0.36	0.61	0.69

Table 6: Feasibility study for treatment applied on "Anna" apple in 2020 and 2021 seasons

	Cost/fed (LE)		Yield/fed (Ton)		Income/fed LE total		Net profit (LE)	
Treatment	2020	2021	2020	2021	2020	2021	2020	2021
Moringa	11202	11202	20.40	19.27	192806	181494	167806	151494
Henna	2987	2987	17.74	15.03	174421	147345	149421	117345
Licorice	2987	2987	14.69	13.52	143929	132253	118929	102253
Roselle	4854	4854	17.69	16.80	172078	163090	147078	133090
Red beets	747	747	14.59	13.94	145133	138609	120133	108609
Radish	373	373	17.67	16.07	176251	160375	151251	130375
Cabbage	0	0	15.64	15.25	156380	152460	131380	122460
Methionine	7468	7468	16.93	14.76	161876	140092	136876	110092
Control	0	0	10.28	8.40	102816	84000	77816	54000

Table 7: Effect of treatments on fruit firmness, TSS and acidity after two weeks of shelf life

	Firmness (Ib/inch^2)		TSS (%)		Acidity (%)	
Treatments	2020	2021	2020	2021	2020	2021
Moringa	8.75	8.13	12.80	12.20	0.448	0.461
Henna	6.00	6.00	10.60	10.00	0.416	0.512
Licorice	6.50	6.25	8.50	8.25	0.384	0.410
Roselle	5.50	5.50	12.50	11.50	0.576	0.640
Red beets	6.60	6.00	12.50	12.30	0.320	0.384
Radish	7.50	6.75	13.80	13.50	0.410	0.422
Cabbage	8.00	7.75	12.40	12.30	0.461	0.480
Methionine	6.50	6.25	10.20	9.00	0.384	0.538
Control	7.25	7.40	12.70	12.60	0.448	0.461
LSD at 0.05	0.24	0.34	0.19	0.68	0.011	0.018

Table 8: Effect of treatments on fruit decay (%) and fruit weight loss (%) after two weeks of shelf life.

	Decay (%)		Fruit wight loss (%)	
Treatments	2020	2021	2020	2021
Moringa	29.65	33.30	2.68	12.00
Henna	35.9	40.00	2.85	14.45
Licorice	41.50	41.70	2.80	13.33
Roselle	47.40	50.00	3.64	15.14
Red beets	43.83	46.66	3.03	18.54
Radish	39.27	43.70	3.45	14.61
Cabbage	43.18	46.66	3.21	18.96
Methionine	37.04	40.00	3.34	10.59
Control	44.25	45.40	2.93	17.14
LSD at 0.05	1.05	1.25	0.15	0.41

due to Roselle extract. All treatments showed a decrease in TSS% after 15 days from zero time of harvest. Radish extract was the best treatments for TSS while the lowest percentage was Licorice extract. All treatments showed a decrease in the acidity percentage, due to consumption of organic acids in the respiration of the fruits [51]. While the highest acidity percentage was Roselle extract treatment.

Moringa leaf extract showed the best results in minimizing fruit decay and fruit weight loss throughout both seasons compared to other treatments and the control group (Table 8). Roselle extract treatment resulted in the highest percentage of decay (47.4-50%) in both seasons after 15 days of shelf life due to softer fruit texture and higher total soluble solids (TSS), which are favorable conditions for decay pathogens [52]. Other treatments displayed intermediate decay rates, ranging from 29.65 to 44.25% in the first season and 33.33 to 46.66% in the second season.

Several studies indicated that spraying Moringa leaf extract led to increased productivity and improved fruit quality [53, 54]. Moreover, it increases ascorbic acid, anthocyanin content and antioxidant activity in Hollywood plum [55]. Spraying Moringa leaf extract generally increases productivity by 20 and 35% [56].

This study found that Moringa leaf extract treatment gave the highest tree yield, the highest hardness of the fruits produced during harvest and after shelf life, less weight loss and decayed fruit percentage This may be due to the effect of Moringa as a growth regulator as it contains cytokinin (zeatin), auxins and gibberellins which plays an important role in cell division and cell elongation and contain macro- and micro-nutrients (K, P, Ca, Mg, S, Fe, Zn, Cu, Fe and Se) and vitamins A, B_1, B_2, B_3, C, E and amino acids [23, 54, 57, 58]. Therefore, it has a great impact on the productivity and could be used as an alternative to chemical fertilizers and improve fruit post-harvest during shelf life [58-60].

This study found that Roselle extract treatment gave the best quality of fruits at harvest, with higher TSS, lower hardness, more vitamin C content, more anthocyanin pigment content and better coloring of the fruits. It may be due to the increase in anthocyanin pigment by Roselle extracts which contain a high percentage of phenolic acids (esp. protocatechuic acid (PCA, 3,4-dihydroxy benzoic acid) is a major metabolite of anthocyanin [29]. In addition to, it's containing organic acids which lower the pH of the cell juice, which helps in the formation of the red anthocyanin pigment [61]. Also, Roselle extract treatment induced better coloration and anthocyanins concentration for fruit at harvesting (zero time) it is suitable for direct marketing and does not require coloring treatments and does not tolerate a shelf life.

Due to these superior qualities at harvest (including higher anthocyanin concentration), Roselle extract treatment produced fruits ideal for direct marketing without artificial coloring. However, these fruits may not tolerate long storage due to their advanced ripeness. Conversely, other treatments resulted in less mature and colorful fruits at harvest, leading to potential improvements in quality during shelf life.

CONCLUSION

The Moringa leaf extract (2%) treatment resulting in the highest tree yield, the highest hardness of the resulting fruits during harvest and least decay and fruit weight loss. Roselle extract treatment resulted in the best quality of fruits at harvest, with greater TSS, less hardness, more vitamin C content, more anthocyanin pigment content and better fruits coloring. Therefore, it is recommended spray Roselle flowers extract at 2% (sprayed for 4 times at petal full stage, then every 15) to increased the color, size and sugars of the fruits and reduce hardness at the time of harvest, it is suitable for direct marketing and does not require coloring treatments

and does not tolerate a shelf life. In case to increase production by spray Moringa extract and prolong the shelf life after harvest.

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