

**QUALITY OF PHYSALIS (*PHYSALIS PUBESCENS* L.) JUICE
PACKAGED IN GLASS BOTTLES AND FLEXIBLE LAMINATED PACKS
DURING STORAGE AT 5°C**

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ABSTRACT

Husk tomato (*Physalis pubescens* L.) is one of the important 100 species in the *Physalis* genus of the *Solanaceae* family. Among unexploited tropical fruits, *Physalis* is a very promising fruit. *Physalis* is included in the priority list of many governments' horticulture and fruit export plans. It is relatively unknown in importing markets and remains an exotic fruit. The important step toward developing *Physalis* as a commercial crop was maximizing its technological applications. The objective of our study was to prepare a new processed pasteurized *Physalis* juice and to study the effects of storage and packaging on its nutritional properties. The pulp was yellowish or orange with a yield of 64%. The fresh juice had a light sweet and acidic taste (pH 3.5). The titratable acidity was 1.43%, polyphenols 76.6mg/100mL and vitamin C 38.8mg/100mL. *Physalis* juice was rich in carotenoids (70µg/mL). The nutritional and bio-physical characteristics of *Physalis* juice packaged in glass bottles and flexible laminated packs during storage under refrigeration (5±1°C, 85-90%RH) for 6 months were studied. Carotenoids, polyphenolic substances and ascorbic acid contents were gradually reduced throughout cold storage, where this reduction was more pronounced in juice packaged in flexible laminated packs. A slight increase in total acidity was observed with cold storage prolongation, especially in juice packaged in flexible laminated packs. Significant differences in color were found between the same juice packaged either in glass bottles or in flexible laminated packs, where the juice color was darker in flexible laminated packs. It could be noticed that, there was no migration of Na ions from glass bottles to processed juice formulas during the cold storage period. In flexible laminated packs, a slight increase of Al ions throughout the cold storage period but not exceeding the safety limit of Al daily intake (3.5mg/day). It was concluded that *Physalis* juice packaged in glass bottles had higher storage stability than that packaged in flexible laminated packs.

Key words: *Physalis pubescens*, Juice, Storage stability, Packaging

INTRODUCTION

Husk tomato fruit belongs to the *Solanaceae* family. It is native to tropical and subtropical American regions. Physalis fruit and juice are nutritious, containing particularly high levels of niacin, carotenoids and minerals [1]. A single plant may yield up to 0.5 kg fruits and carefully tended plants can provide 20-33 tons/hectare [2]. The fruit is a berry (1.25-2 cm, wide), with smooth, waxy, orange-yellowish kernels. The part of the Physalis that can be used is composed of husk (6%) and berry (94%). They are protected by papery husks with many minute seeds in a juicy pulp which is sweet and tangy resembling Chinese lanterns [3]. Physalis already carries prestige in some international markets. Europeans, for example, often pay premium prices to dip the berries in chocolate or decorate cakes and pies. In addition to having a future as fresh fruits, the exotic fruit can be enjoyed in many ways as an interesting ingredient in salads, cooked dishes, dessert and jam and natural snacks [4]. Fruits are long-lasting, can be stored in a sealed container and can be frozen or kept in a dry atmosphere for several months [5].

Physalis is included in the priority list of many governments' horticulture and fruit export plans. It is relatively unknown in importing markets and remains an exotic fruit [6]. It is exported from several countries including Colombia and African countries; Egypt, Zimbabwe and South Africa, but Colombia stands out as one of the largest producers, consumers and exporters [7]. In that country, Physalis occupies second position in the priority list of 15 exportable fruits. Exports of this crop in 2004 were worth 14 million USD [8]. In Egypt, Physalis has been known for a long time. Recently, the economic importance of Physalis is rising due to high acceptance for local consumption, achieving a great success in Arabic and European markets [6].

The quality and shelf life of fruit juice depend upon a range of internal parameters related to the product and several external factors, packaging being one of them [9]. Intermediate Technology Development Group [10] reported that glass containers are inert and do not react with/or migrate into food products. However, Pankow [11] believed that sodium migration is involved in the delaminating mechanism of soda lime glass. Sodium plays a pivotal role in enzyme operation and muscle contraction. It is important for osmo-regulation and fluid maintenance of the human body. Other health implications of sodium include heart performance, nervous system and glucose absorption. Though sodium is an essential nutrient in the balanced diet, it also causes stomach cancer and hypertension [12]. Those who are suffering from kidney problems and edema should strictly restrict the consumption of sodium in their daily diet [12].

Over the last few years, there has been concern about aluminum exposure resulting from leaching of aluminum from cookware and beverage packs [13]. Certain aluminum compounds have been found to be an important component of the neurological damage seen with Alzheimer's disease. Much research over the last decade has focused on the role of aluminum in the development of this disease [14].

Additionally, no attention has been paid to the utilization of *Physalis* fruits in food industries, and there is little available data in the literature regarding its nutritional properties and industrial utilization. This work is for the first time providing useful information for storage properties and industrial applications of *Physalis*. The purpose of this study was to evaluate the nutritional and bio-physical characteristics of *Physalis* juice packaged in glass bottles and flexible laminated packs during storage for 6 months under refrigeration ($5\pm 1^{\circ}\text{C}$, 85-90%RH). With the aim of developing *Physalis* as a commercial crop, the data obtained will be important as an indicator of the potential nutraceutical and economical utility of *Physalis* as an unexploited tropical source of fruit juices.

MATERIALS AND METHODS

Biological material

Ripe *Physalis pubescens* L. fruits were obtained from local growers at Arab El-Rawshda village, Toukh region, Qalyoubia Governorate located in the north of Egypt during the mid-May 2004 season. Intact fruits were carefully selected according to the degree of ripeness measured by fruit color (brilliant orange). The fresh fruits were analyzed immediately after harvesting.

Packaging material

Colorless glass bottles with capacity of 240g were obtained from El-Nasr Glass Industry Co., Cairo, Egypt. Flexible laminated packs consisted of three laminars: polyester, aluminum foil and high density polyethylene (PES/FOIL/HDPE). The specifications of flexible laminated films are given in Table 1. Flexible laminated packs were purchased from Egyptian Canning Co., Aga, Dakahlia Governorate, Egypt.

Extraction and preparation of *Physalis* fruit juice

Physalis fruits were dehusked manually, sorted to select the ripe and intact ones and graded depending mainly on their color, then washed. Then, the fruits were pulped using a fruit pulper (Braun, Model 2001, Germany) for juice extraction. Juice was filtrated in cheesecloth to separate seeds and skins and sucrose was added up to 17% of Total Soluble Solids "TSS"; *Physalis* juice was pasteurized at 90°C for 3 min. After heat treatment, 0.3% citric acid and 0.1% sodium benzoate were added to prevent the growth of undesirable microorganisms such as lactic acid bacteria and fermentation yeast. The pasteurized juice was packaged by hot filling in glass bottles and capped tightly then cooled suddenly in a cold water bath. Processed juices were stored in refrigerator at $5\pm 1^{\circ}\text{C}$, 85-90%RH for 6 months.

Determination of major nutrient components of *Physalis* juice

Crude protein was determined by micro Kjeldahl method and calculated by using the conversion factor ($\%N \times 6.25$) according to the method mentioned in AOAC [15]. The pH value of the prepared samples were measured at 25°C by using a digital pH-meter (Jenway, Model 3020, England) according to the method described in AOAC [15]. The total carotenoid content was determined in the 80% acetone extract and

measured spectrophotometrically at 440 nm as ($\mu\text{g}\cdot\text{mL}^{-1}$) according to the method of AOAC [15]. Reducing sugars were determined (as glucose) colorimetrically at 490 nm as reported by Dubois *et al.* [16]. Total acidity was titrated with 0.1 N NaOH using phenolphthalein as an indicator and was expressed as anhydrous citric acid/100g of sample. Ascorbic acid was estimated by the colorimetric method of Folin-Ciocalteu at 760 nm [17]. Total polyphenolic substances were measured (as tannic acid) colorimetrically at 640nm by the Folin-Ciocalteu method [18].

Statistical analysis

The data of the storage study were subjected to two way ANOVA analysis (Variance Analysis), significance was set at $p < 0.05$. Least significant difference (LSD) as multivariate test enabled to set up average homogenized groups as reported by Dagnelie [19]. The analysis was performed using XLSTAT 2007.2 (Statistical Software for MS Excel, version 2007, Addinsoft, USA).

RESULTS

Nutritional evaluation of fresh Physalis juice

Physalis pulp was yellowish or orange with a yield of 64%. The fresh juice had a light sweet and acidic taste (pH 3.5). The titratable acidity was 1.43%. Carotenoid content was $70\mu\text{g}/\text{mL}$. The fresh juice contained a considerable amount of polyphenols ($76.6\text{mg}/100\text{mL}$) as tannic acid; this amount covered approximately 8% of Dietary Reference Intakes "DRIs" of polyphenols (1g/day) [20, 21]. Ascorbic acid was $38.8\text{mg}/100\text{mL}$ whereas this amount covered approximately 43-52% of DRIs of ascorbic acid (75-90g/day) [20, 21]. On the other hand, fresh Physalis juice was poor in protein (1.02% ww) [21] whereas this amount covered approximately 1.8-2.3% of DRIs of proteins.

Storage and packaging effects on physico-chemical characteristics

Changes in pH and total titratable acidity

Fig. 1 shows the decrease of pH-values ($p < 0.05$) of processed Physalis juice during the first four months and stable in the fifth month, then increase in the sixth month of the storage time under refrigeration at 5°C in two packaging materials. The pH decreased conversely to total titratable acidity (Fig. 2). Significant differences ($p < 0.05$) of pH-values and total titratable acidity were found between the two studied packaging materials (Table 2). Moreover, there were significant variances ($p < 0.05$) in pH-values and total titratable acidity due to the interaction between the storage time under refrigeration conditions and the packaging materials.

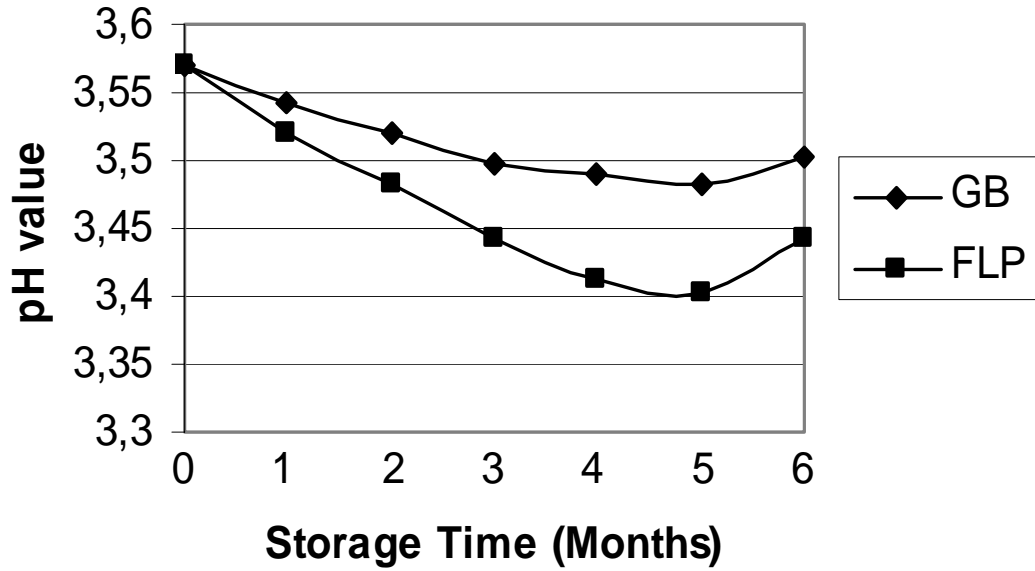


Figure 1: pH-value of refrigerated ($5\pm 1^{\circ}\text{C}$, 85-90%RH) Physalis juice stored in glass bottles (GB) and flexible laminated packs (FLP)

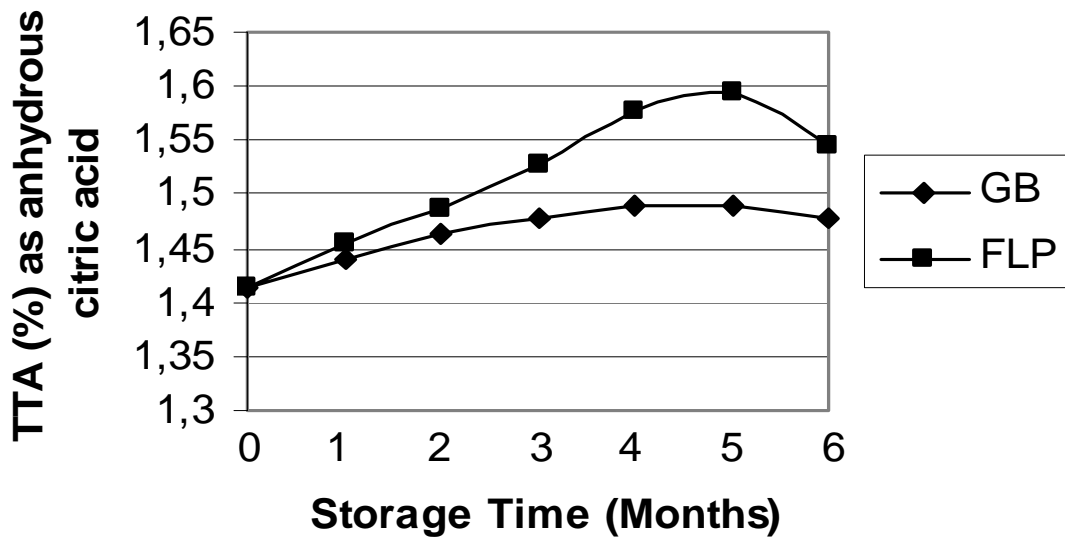


Figure 2: Total titratable acidity (TTA %) as anhydrous citric acid of refrigerated ($5\pm 1^{\circ}\text{C}$, 85-90%RH) Physalis juice stored in glass bottles (GB) and flexible laminated packs (FLP)

Changes in color index (as O.D. at 420 nm)

The color index of refrigerated Physalis juice throughout 6 months of storage increased significantly ($p < 0.05$) (Fig. 3). Table 2 shows significant variation ($p < 0.05$) in juice color index measurements due to the packaging materials and their interactions.

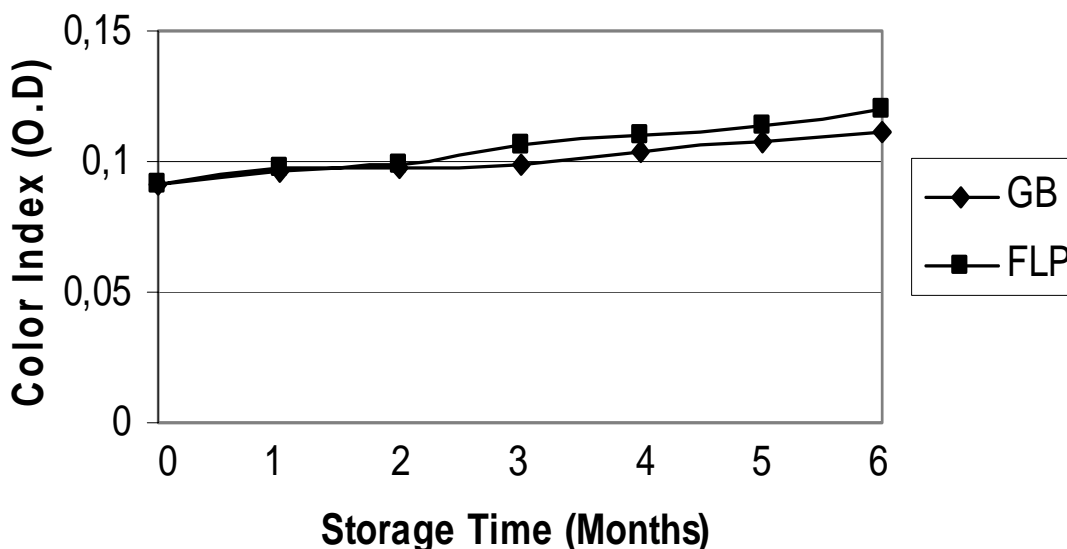


Figure 3: Color index as (O.D at 420 nm) of refrigerated ($5 \pm 1^\circ\text{C}$, 85-90%RH) Physalis juice stored in glass bottles (GB) and flexible laminated packs (FLP)

Storage and packaging effects on chemical composition

Changes in reducing sugars

Reducing sugars content increased from 39.5% (dw) at T_0 to 45.5% (dw) after 5 months proportionally to the increase of the storage time under refrigeration but decreased in the sixth month (Fig. 4). Significant differences ($p < 0.05$) could be clearly noticed for reducing sugars values during the storage period (Table 2). In addition, it could be clearly noticed that there were significant differences ($p < 0.05$) in reducing sugars values between packaging materials and the interactions between both factors studied.

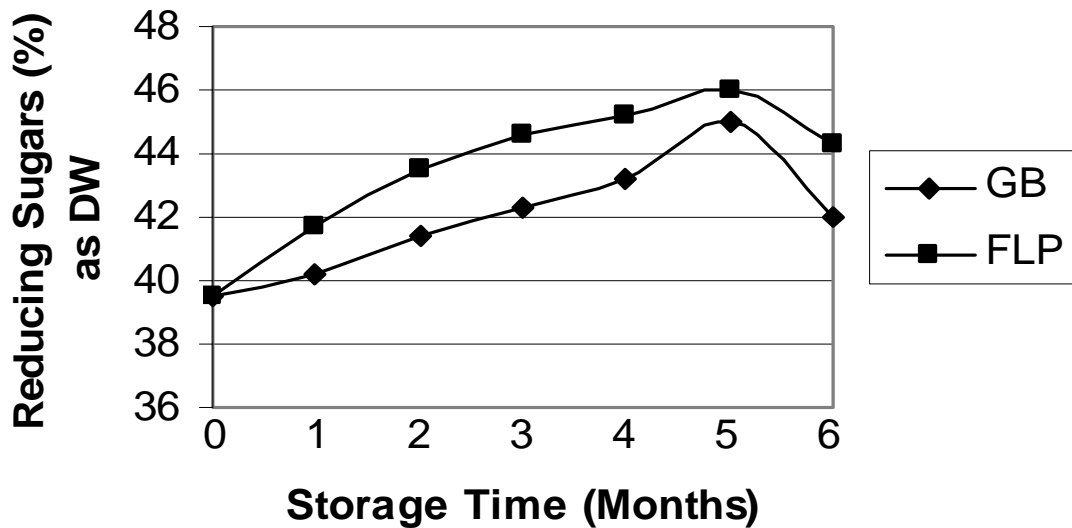


Figure 4: Reducing sugars content (%) of refrigerated ($5\pm 1^{\circ}\text{C}$, 85-90%RH) Physalis juice stored in glass bottles (GB) and flexible laminated packs (FLP)

Changes in carotenoid content

Carotenoid content decreased significantly ($p < 0.05$) during the cold storage for 6 months (Fig. 5). Table 2 shows significant differences ($p < 0.05$) in carotenoid content between the two different packaging materials which are used for packaging juice formulations. There were non-significant interactions ($p < 0.05$) between the storage time under refrigeration conditions and the packaging materials.

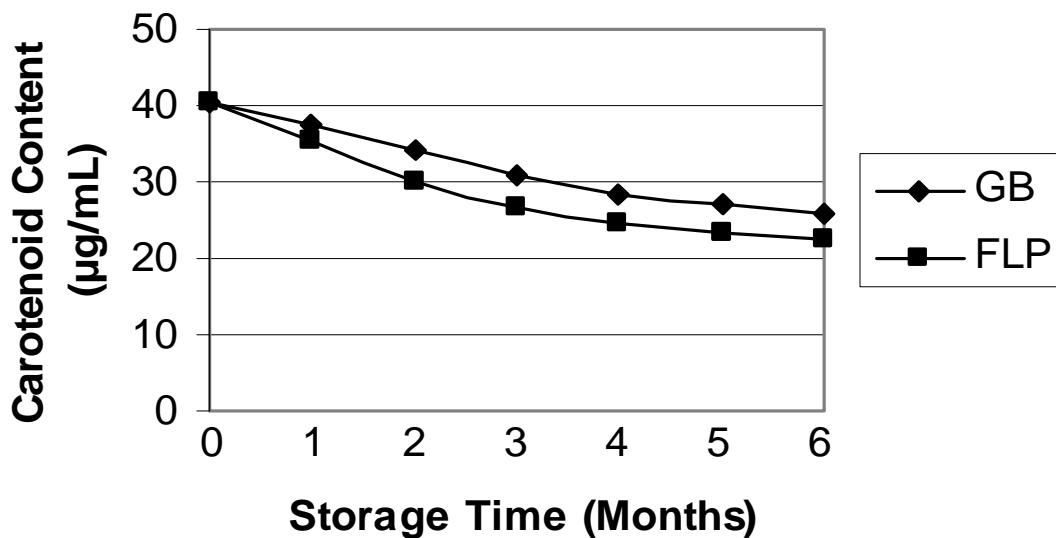


Figure 5: Carotenoid content ($\mu\text{g/mL}$) of refrigerated ($5\pm 1^{\circ}\text{C}$, 85-90%RH) Physalis juice stored in glass bottles (GB) and flexible laminated packs (FLP)

Changes in polyphenolic substances

Fig. 6 and Table 2 reveal a large significant decrease ($p < 0.05$) in polyphenolic content with storage time, regardless of the packaging materials and the interactions between the storage time and the packaging materials.

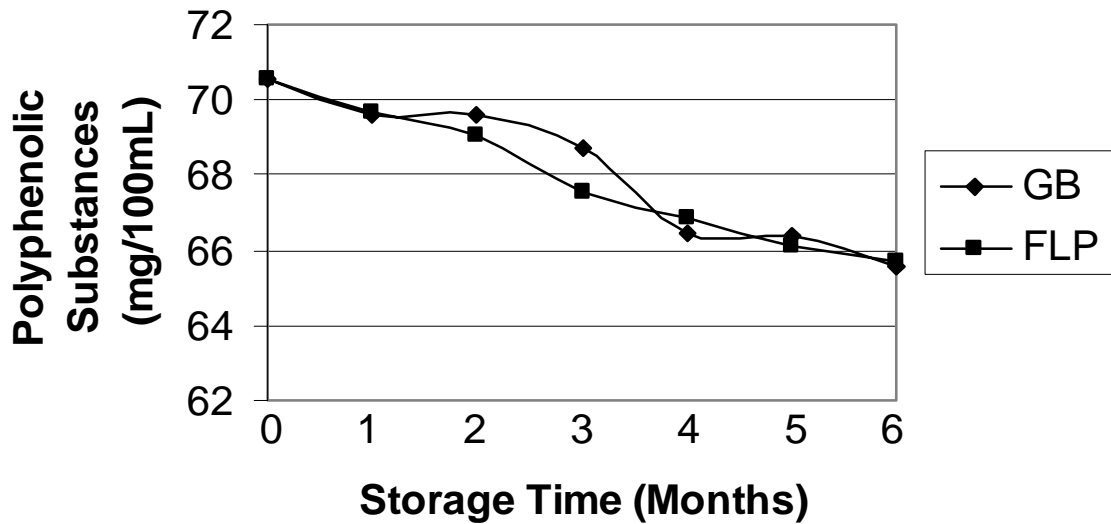


Figure 6: Polyphenolic substances (mg/100mL) of refrigerated ($5 \pm 1^\circ\text{C}$, 85-90%RH) Physalis juice stored in glass bottles (GB) and flexible laminated packs (FLP)

Changes in ascorbic acid content

With the increase in cold storage time, ascorbic acid content decreased significantly ($p < 0.05$) (Fig. 7). Data presented in Table 2 illustrated significant variation ($p < 0.05$) in ascorbic acid content in processed juice due to packaging materials and interactions between the storage time under refrigeration conditions and the packaging materials.

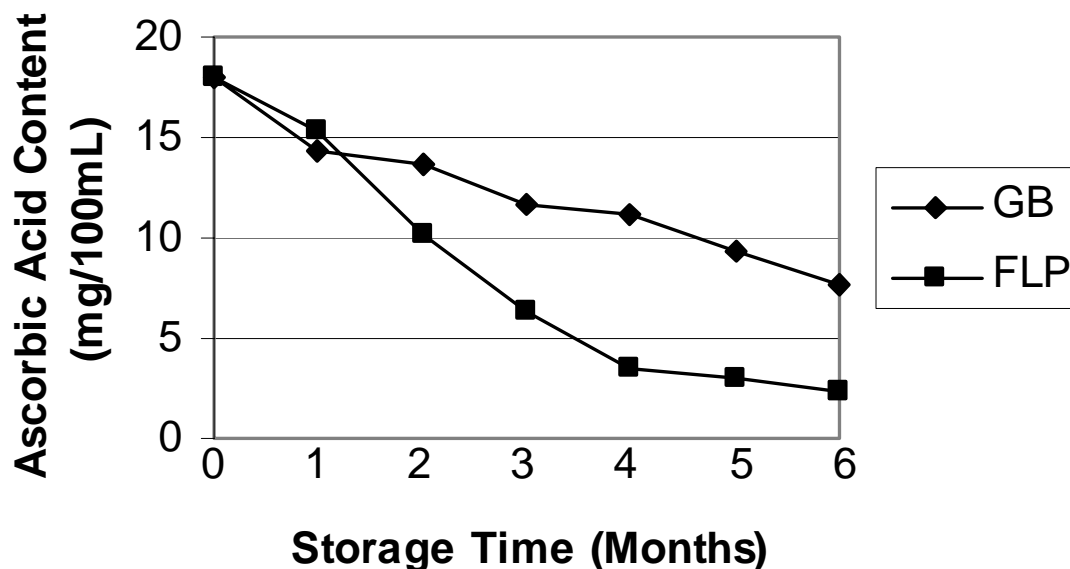


Figure 7: Ascorbic acid content (mg/100mL) of refrigerated ($5\pm 1^{\circ}\text{C}$, 85-90% RH) Physalis juice stored in glass bottles (GB) and flexible laminated packs (FLP)

Migration of sodium and aluminum ions from packaging material to processed juice

The sodium ions concentration of processed juice ranged between 37.3 parts per million (ppm) to 37.5 ppm during cold storage for 6 months. There was no migration of Na ions from glass bottles to the processed juice. Results given in Table 2 showed a significant increase ($p < 0.05$) in aluminum ions of juice packaged in flexible laminated packs but not exceeding the safety limit of Al daily intake (3.5mg/day).

DISCUSSION

Nutritional evaluation of fresh Physalis juice

The fresh juice had the same color as the fruit due to its very high carotenoid content ($70\mu\text{g/mL}$), in comparison with cantaloupe juice which contains only $7.6\mu\text{g/mL}$ [22], lemon juice ($0.3\mu\text{g/mL}$), orange juice ($3.2\mu\text{g/mL}$) and passion fruit juice ($4.4\mu\text{g/mL}$) [23]. This type of color was also found for *Physalis peruviana* juice [24], *Physalis ixocarpa* juice [25] and *Physalis pruinosa* juice [26].

The pH of the fresh Physalis juice (3.6) was higher than citrus juices such as lime juice (pH 2.3) and lemon juice (pH 2.4) [27]. It was close to that of pineapple (pH 3.2) [28] and orange juice (pH 3.6) [29], but lower than in fresh juice of *Physalis peruviana* (pH 3.86; Ramadan and Moersel [30]). The titratable acidity (1.43%) was higher than that reported for *Physalis peruviana* (0.92%) [30] and lemon juices 1.15% [27], but lower than that in two varieties of mango fruit juices (2.29% and 4.11%) [31].

The polyphenols content of the fresh *Physalis* juice (70mg/100mL) was lower than that of fresh apricot juice (150.3mg/100mL) [6].

Ascorbic acid contents (39mg/100mL) were higher than those of cantaloupe juice (37mg/100mL) [22], passion fruit juice (29.8mg/100mL), lime juice (30mg/100mL) and tangerine juice (31mg/100mL), but it had lower content than that in *Physalis peruviana* juice (46mg/100mL) [30], lemon juice (46mg/100mL) and orange juice (50mg/100mL) [23].

Fresh *Physalis* juice had a higher protein amount (1.02%) than in *Physalis peruviana* juice (0.44%) [30], cantaloupe juice (0.69%) [22], lemon juice (0.38%), lime juice (0.50%) and orange juice (0.70%) [23].

Storage and packaging effects on physico-chemical characteristics

The acidity is considered one of the physico-chemical properties, which affects both organoleptic and keeping qualities of a product [1]. Decrease in pH-values and increase in total titratable acidity during the cold storage period may be due to activity of some acid-producing bacteria such as *Alicyclobacillus acidoterrestris* [32]. These authors also described *Alicyclobacillus* species as thermo-acidophilic bacteria could survive in fruit juices at pH 3.0.

The increase of the juice optical density is usually an index for undesirable changes in its quality and safety [1]. The darkening may be due to non-enzymatic browning reactions, as cited by Buglione and Lozano [33]; Robards *et al.* [34] and Gerschenson and Rojas [35].

Storage and packaging effects on chemical composition

It was clear that the hydrolysis of non-reducing sugars to reducing ones was due to the effect of acidity. This means that non-reducing sugars were inverted or hydrolyzed at a low rate under storage conditions [22, 32].

Carotenoids constitute the major coloring substances in juices. In addition, carotenoids have an effect on the juice nutritive value as they are considered as natural antioxidants and pro-vitamin A [1]. The decrease of carotenoids throughout the cold storage time could be explained by oxidation and also by Maillard reactions [36].

Polyphenolic substances are considered as dietary antioxidants, which play an important role in maintaining optimal human health. They have protective effects against heart and cancer diseases [37]. This slight decrease was inversely proportional to the non-enzymatic browning reactions [34] which increased slowly throughout the cold storage time (Fig. 6, Table 2).

Ascorbic acid is one of the most important nutrients in fruit juice, which generally reflects the nutritional and technological characteristics of the final product [1]. The

significant decrease of ascorbic acid during cold storage time may be due to its oxidation [35].

There was no migration of Na ions from glass bottles to processed juice formulas as was also found by Weinberger et al. [38]. These results proved that the glass type of these bottles not active, this mean no reaction between glass as packaging material and Physalis juice.

A slight increase in aluminum ions was observed in juice packaged in flexible laminated packs but not exceeding the safety limit of Al daily intake (3.5mg/day) [39]. Intake of large amounts of aluminum can cause many harmful effects on human health; anemia, osteomalacia (brittle or soft bones), glucose intolerance, and cardiac arrest in humans [39].

CONCLUSION

Physalis has the potential to become a commercial fruit of particular interest to the world's up-scale food industry. It could follow the strategy of kiwifruits in the 1960s that got a multimillion-dollar market. This research proved that Physalis could be an interesting candidate for processing of new functional products. The development of adequate agro-technical and storage practices could make this fruit a promising profitable new crop for African countries if it has remarkable agronomical potential that has not fully been appreciated yet. Fruit juices can be regarded as the most beneficial/attractive example of functional food, because they are naturally concentrated sources of physiologically valuable micronutrients. Fresh Physalis juice is a rich source of polyphenols and carotenoids with a high yield of juice (64%). It contained moderate amounts of vitamin C and small amount of proteins. It was shown that pasteurized Physalis juice packaged in glass bottles had higher storage stability than that packaged in flexible laminated packs because it kept its nutritional and bio-physical characteristics throughout storage for 6 months under refrigeration ($5\pm 1^{\circ}\text{C}$, 85-90%RH).

Table 1: Specifications of flexible laminated films *

| Films | Thickness • (mm) | Water vapor permeability at 38°C $\times 10^{12}$ mol. mm ⁻² . S ⁻¹ • Pa ⁻¹ ♦♦ | Oxygen transmission cm ² . m ⁻² . 25.4 micron ⁻¹ thickness. 24 ⁻¹ h. atm ⁻¹ at 25°C | Relative humidity (%) |
|-------------------|---------------------|-----------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Polyester | 0.015 | 0.0402 | 46.5 – 62 | 90 |
| Aluminum foil | 0.020 | 0.000289 | 0.00 | 95 |
| HDPE [°] | 0.025 | 0.0122 | 2667 | 97 |

• Thickness of the films was measured by using an electronic digital vice caliper with accuracy of 0.01 mm.

♦ S = Package surface area.

♦♦ Pa = Pressure in the package.

° HDPE = High density polyethylene.

* **Source:** Cuq *et al.* [40].

Table 2: Analysis of the differences in physico-chemical properties and chemical composition of refrigerated (5±1°C, 85-90%RH) Physalis juice stored in glass bottles (GB) and flexible laminated packs (FLP) throughout storage period for 6 months with a confidence interval 95%

| Properties Storage period (Months) & Packaging Material | pH* | Total Titratable Acidity* (%) | Reducing Sugars* (%) | Carotenoids* (µg/ml) | Polyphenolic Substances* (mg/100ml) | Ascorbic Acid* (mg/100ml) | Color Index* | Al Ions* (ppm) |
|------------------------------------------------------------------|---------------------------|-------------------------------|-----------------------|------------------------|-------------------------------------|---------------------------|--------------------------|--------------------------|
| | | | | | | | | |
| Zero time | 3.57 ± 0.01 ^A | 1.41±0.01 ^E | 39.5±0.1 ^G | 40.6±0.5 ^A | 70.6± 0.3 ^A | 18.0±0.4 ^A | 0.091±0.001 ^G | 1.097±0.01 ^G |
| First month | 3.53 ± 0.01 ^B | 1.45±0.01 ^D | 40.9±0.5 ^F | 36.3±0.6 ^B | 69.6±0.7 ^B | 14.9±0.6 ^B | 0.096±0.001 ^F | 1.103±0.03 ^F |
| Second month | 3.50 ± 0.01 ^C | 1.47±0.02 ^C | 42.5±0.2 ^E | 32.1± 0.5 ^C | 69.3±0.2 ^B | 11.9±0.9 ^C | 0.098±0.002 ^E | 1.11 ± 0.04 ^F |
| Third month | 3.47 ± 0.005 ^D | 1.5± 0.01 ^B | 43.5±0.1 ^C | 28.8±1.6 ^D | 68.1±0.2 ^C | 9.1±0.9 ^D | 0.103±0.001 ^D | 1.12±0.02 ^D |
| Fourth month | 3.45 ± 0.01 ^E | 1.53±0.01 ^A | 44.2±0.1 ^B | 26.5±2.1 ^E | 66.7±0.3 ^D | 7.4± 0.9 ^E | 0.107±0.002 ^C | 1.13±0.05 ^C |
| Fifth month | 3.44 ± 0.005 ^F | 1.54±0.03 ^A | 45.5±0.1 ^A | 25.2±1.1 ^F | 66.3±0.3 ^D | 6.1±1.0 ^F | 0.111±0.001 ^B | 1.14±0.06 ^B |
| Sixth month | 3.47 ± 0.005 ^D | 1.51±0.01 ^B | 43.2±0.1 ^D | 24.3±0.5 ^F | 65.6± 0.4 ^D | 4.9± 0.6 ^G | 0.115±0.001 ^A | 1.15±0.04 ^A |
| Glass bottles (GB)** | 3.51 ^{5A} | 1.46 ^{5B} | 41.9 ^{6B} | 32.0 ^{3A} | 68.1 ^{1A} | 12.2 ^{5A} | 0.10 ^{1B} | |
| Flexible laminated packs (FLP)** | 3.46 ^{8B} | 1.51 ^{4A} | 43.5 ^{4A} | 29.0 ^{6B} | 67.9 ^{3A} | 8.4 ^{2B} | 0.10 ^{5A} | |

* Results are mean values of triplicates ± SD, where mean values in each column bearing the same superscripts are not significantly (P<0.05) different from one another.
 ** Results are estimated average throughout storage period for 6 months, where mean values in each column bearing the same superscripts are not significantly (P<0.05) different from one another.

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