PAPER

DEVELOPMENT OF FRUIT LEATHER FROM *ACTINIDIA ARGUTA* BY-PRODUCT: QUALITY ASSESSMENT AND SHELF LIFE STUDIES

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ABSTRACT

Strategies are needed to reduce the substantial fruit losses of *Actinidia arguta* (speciality fruits) caused by the high perishability of the edible skin. Fruit leathers are considered a valuable opportunity to meet the requirements of today's consumers searching for healthy and time-saving products. This work aimed to (a) develop a novel baby kiwifruit leather product (four formulations) and (b) evaluate the best formulation under different shelf life conditions. Storage at 25°C and polyethylene samples presented the best colour and received acceptable scores for sensory evaluation at the end of the shelf life.

Keywords: *Actinidia arguta*, formulations, leather, shelf life, storage

1. INTRODUCTION

In 2014, the High Level Panel of Experts (HLPE) on Food Security and Nutrition of the United Nations Food and Agriculture Organisation (FAO) affirmed that 'A sustainable food system is a food system that ensures food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition of future generations are not compromised'. Today, the topic of the agro-food system sustainability transitions remains high on the agenda of many countries of the European Union and international organisations (International Energy Agency, Organisation for Economic Co-operation and Development, and the World Bank). The scientific community that works with the agro-food industry agrees with solutions about waste and food losses prevention, minimisation and valorisation (PORAT *et al*., 2018).

In the fruit and vegetable sector, this issue represents a critical point for products that belong to speciality foods, such as berry fruits (MURPHY *et al*., 2002; GIRGENTI *et al*., 2016), which need to be marked with high qualitative standards, and small aesthetic defects are enough to compromise the competitivity of these products in the market chain. Although several studies have reported about the opportunity to valorise fruit waste (MA *et al*., 1993; LAUFENBERG *et al*., 2003; FEDERICI *et al*., 2009; PATHAK *et al*., 2017) and suggested approaches to reduce the fresh fruit losses in the supply chain, there are currently limited research publications about the fate of specialities fruits that do not meet market specifications. A related option could be represented by the creation of new processed products with a high nutrient profile to fulfil the increasing demand for innovative and time-saving products (as well as the needs of consumers, who are looking for healthy products to prevent health issues, such as diabetes, obesity and cardiac diseases).

Earlier investigations evaluated the various effects of the drying (KAYA *et al*., 2010), pasteurisation (LESPINARD *et al*., 2012), freezing (CANO and MARÍN, 1992; PARK *et al*., 2016) and canning (CANO and MARÍN, 1992) of processed fruits. Processing of new fruit puree formulations revealed to be a well-performing strategy to prolong shelf life and diversify the market, by creating novel products, which may retain or even improve the nutraceutical profile (SIMAL *et al*., 2005; TORRES *et al*., 2013). Among these strategies, fruit leathers seem to be innovative dried products with high levels of convenience, as they represent a suitable choice for consumers searching for nutritious snacks (SHARMA *et al*., 2013).

Fruit leather processing is characterised by fruit puree dehydration, which is necessary to obtain a solid product. Apple, mango and a range of tropical fruit, for example, can be used to produce fruit leathers. However, the formulation is highly dependent on the type of fruit that is incorporated into the puree mix because of variations in the acid, sugar and pectin contents. Thus, the formulation may contain different types of sugars and, sometimes, additives, such as preservatives (VATTHANAKUL *et al*., 2010; QUINTERO *et al*., 2012; DIAMANTE *et al*., 2014) and hydrocolloids (VATTHANAKUL *et al*., 2010; AL-HINAI *et al*., 2012), which are occasionally included to improve the rheological characteristics or to retain the fruit's natural colour (QUINTERO *et al*., 2012; DIAMANTE *et al*., 2014).

Processed fruit products are overall healthy since they are less caloric than traditional snacks and are also an important source of fibre that promotes a sense of satiety (DIAMANTE *et al*., 2014), so many feasibility studies have been developed to assess fruit leather production (CONCHA-MEYER *et al*., 2016). Given that baby kiwifruit (*Actinidia arguta*) suppliers (due to the high perishability of the edible skin of the berries) have not yet found specific strategies for fruit non-compliant with the fresh market standards, and no prior literature has assessed the shelf life stability of baby kiwifruit leather, this work

had two goals. The first was to develop a novel baby kiwifruit leather product (four formulations) presenting a composition as close as possible to the fresh fruit profile, namely, with low sugar and an attractive bright green appearance, and second, to evaluate the physicochemical quality of the developed product during storage.

2. MATERIAL AND METHODS

2.1. Materials

Frozen baby kiwifruit (*A. arguta*) puree added with 10% sucrose was provided by FAR, a fruit processing industry located in Cuneo (Italy). Fresh apples (*Malus domestica*, cv Granny Smith), glucose syrup 33 dextrose equivalent (DE) (SELCA Srl, Italy), sucrose (Reire, Italy), invert sugar (Zucchero & C., Italy), low-methylated pectin powder (Reire), citric acid powder (Reire), fructose powder (Reire) and fresh lemon (*Citrus limon*) were provided by the Department of Agricultural, Forest and Food Sciences (DISAFA Department). Polyamide/polyethylene (PA/PE) pouches, with a thickness of 0.09 mm, a water vapour rate of 5 g m^{-2} d^{-1} (at 23°C, 85% relative humidity), and an oxygen permeability of than 65 cc m^{-2} d^{-1} atm^{-1} (at 23°C, 75%), were used for shelf life studies.

2.2. Formulation development

Preliminary trials were conducted to select the best formulation. The first trial involved thawing 4 kg of frozen puree that was then weighed and combined with varying proportions of the ingredients mentioned above (section 2.1) to generate four different formulations (Table 1). Whole apples were cut and blended into a puree before being added to all formulations, to improve the texture uniformity of the final product. Direct heat treatment with an open copper pan (100°C, for about 30 min) was applied to allow proper mixing of the product during the concentration process. All formulations were concentrated until the soluble solids content (SCC) reached 70% Brix. Afterwards, the formulations were transferred to four separate trays, covered with baking paper to avoid external contamination, and left at 25°C for almost 24 h, to allow gelatinisation. The definitive formulation was chosen by a sensory evaluation panel of ten semi-trained judges, using a 5-point hedonic scale to describe the overall acceptance (1 = "dislike extremely", 5 = "like extremely").

Table 1. Formulations 1, 2, 3, 4 produced on first trial.

Formulation 1	Formulation 2	Formulation 3	Formulation 4
39% baby kiwi puree 8% Granny Smith apple 33% sucrose 14% invert sugar 3% water 2% low methylated pectin powder 1% citric acid powder	38% baby kiwi puree 58% sucrose 2% low methylated pectin powder 1% citric acid powder 1% water	71% baby kiwi puree 22% Granny Smith apple 5% glucose syrup 33 DE 1% citric acid powder 1% water	43% baby kiwi puree 28% Granny Smith apple 28% glucose syrup 33 DE 1% water

2.3. Shelf life test and fruit quality assessments

The best solid formulation (formulation 3A) was cut into 36 leathers (5.0 cm × 5.0 cm × 0.5 cm) that were divided into four samples: two samples were stored at 25°C (room temperature) and the remaining two samples maintained under an accelerated shelf life condition (37°C) in a static air oven for 21 days, respectively. For both shelf life tests, one of the two samples was packaged in awith polyethylene (HDPA/PE) foils, giving rise to four definitive leather samples: Environment (E), Environment PE (EPE), Oven (O) and Oven PE (OPE). PA/PE packaging was selected due, owing to its transparent surface, in order to that, alloweding the consumers to appreciate the product's appearancespect. At the start of storage (day 0), Baby baby kiwifruit raw puree (raw puree), raw formulation and the leather samples were analysed for SCC, colour, texture parameters, total phenolic content (TPC), antioxidant capacity (AC) and sensory attributes. Leather samples were assessed every 7 days for 21 days, using the same criteria as applied at the start of storage (0 day) plus weight loss.

2.3.1 Weight loss determination

Leather samples were weighed on an electronic balance (SE622, WVR Science Education) (±0.001 g) at day 0 and every 7th day. The average of triplicate measurements was calculated, and the percentage weight loss was computed as follows:

$$\text{Weight loss } (\%) = \frac{(a-b)}{a} \times 100 \quad (1)$$

where a is the initial weight (day 0), and b is the weight recorded every 7 days for 21 days.

2.3.2 Soluble solids content (SCC)

The SSC was determined using an Atago Pocket PAD-1 digital refractometer for raw puree, raw formulation and leather at day 0, and on every 7th day for the leather sample (AOAC 932.12). Ten grams of each leather sample was homogenised, and the SCC (%) of the filtered pulp was measured in triplicate.

2.3.3 Colour and browning index (BI)

Colour was measured in triplicate at day 0 and every 7th day for leather samples, using a Minolta CR-400 chromameter (Konica Minolta Sensing, Inc., Osaka, Japan) pre-calibrated against a standard white tile. Parameters L^*, a^* and b^* were recorded at three different points on each sample, and browning index (BI), defined as brown-colour purity, which is usually used as an indicator of the extent of browning in sugar-containing food products (PEREZ-GAGO *et al*., 2005) was also calculated (QUINTERO RUIZ *et al*., 2012):

$$\text{BI} = \frac{(x - 0.31)}{0.172} \times 100 \quad (2)$$

where x is the chromaticity coordinate calculated from the X, Y, Z tristimulus values, according to the following formulae:

$$x = \frac{X}{(X + Y + Z)} \quad (3)$$

$$X = Xn \times \left[\left(\frac{a*}{500}\right) + \left(\frac{(L*+16)}{116}\right)\right]^3 \quad (4)$$

$$Y = Yn \times \left(\frac{(L*+16)}{116}\right)^3 \quad (5)$$

$$Z = Zn \times \left[\left(\frac{-b*}{200}\right) + \left(\frac{(L*+16)}{116}\right)\right]^3 \quad (6)$$

where Xn, Yn and Zn correspond to white reference tristimulus values of Xn = 91.97, Yn = 93.8 and Zn = 107.98.

2.3.4 Texture parameters

A texture profile analysis (TPA), acquired using a TA.XTplus texture analyser (Stable Micro Systems, USA) (30 kg load cell), was evaluated to determine some of the most important TPA parameters. A compression test was conducted, using a 75-mm aluminium flat probe to a 55% strain, with a pre-test, test and post-test speed of 5, 1 and 5 mm s^{-1}, respectively, and 5 g trigger force.

2.3.5 Total phenolic content (TPC) determination and antioxidant capacity (AC)

The Folin–Ciocalteu (SINGLETON and ROSSI, 1965) and ferric reducing/antioxidant power (FRAP) tests (BENZIE and STRAIN, 1996) were undertaken to assess the TPC and AC, respectively. For both analyses, 10 g of raw puree, 10 g of raw formulation and 10 g of leather, were each extracted with solvent (500 mL methanol, 1.4 mL concentrated HCl and 23.8 mL of deionised water [DW]) for 60 min under reduced light conditions, followed by homogenisation (15 min) to obtain sample extracts.
For the TPC test, the supernatant of each sample was mixed with 30 mL DW and 2.5 mL Folin–Ciocalteu reagent. After 8 min incubation, the mixture was combined with 10 mL of sodium carbonate solution (15% w/v) and incubated at room temperature (25°C) for 2 h. Absorbance was measured at 765 nm (UV-1600 PC spectrophotometer, VWR), and the results expressed as milligrams of chlorogenic acid equivalents (CAE) per 100 g DW (TORRES *et al*., 2015).
The AC assay was carried out using stock solutions (FRAP) containing 0.3 M acetate buffer (3.1 g sodium acetate, 1 L DW and 16 mL acetic acid), 10 mM 2,4,6-tripyridyl-s-triazine solution in 40 mM HCl, and 20 mM $FeCl_3$ solution. Readings of the coloured product (ferrous–tripyridyltriazine complex) were recorded at 595 nm, and the results expressed as mmol Fe^{2+} kg^{-1}. Triplicate measurements were acquired for both assays.

2.3.6 Sensory analysis

A sensory evaluation was undertaken on leather samples at day 0 and 21, by a panel of ten semi-trained judges (aged 25-65 years) from the DISAFA Department. Leathers were brought to 25°C and presented to panellists coded, who appraised the samples for hardness, sweetness, sourness, flavour and overall acceptance, using a 5-point hedonic scale. Panellists' average responses were considered for each attribute.

2.4. Statistical analysis

All the statistical analyses were computed using SPSS 20 for Windows (SPSS, Inc., Chicago, IL, USA). Analysis of variance (ANOVA) was conducted, using the software IBM-SPSS 22 (2015), followed by Tukey's honestly significance difference test ($P<0.05$).

3. RESULTS AND DISCUSSION

3.1. Formulation development

At the end of the first trial, all formulations differed by colour, texture and taste. Formulations 1 and 2 presented the desired firmness and flexibility, due to low-methylation pectin powder addition and its gelling property, which promotes hydrogen bonds between carboxyl groups and water, and ionic bonds with calcium (Ca^{2+}) and other divalent metals (VALENZUELA and AGUILERA, 2015). Although *Actinidia* species are known to have low-pectin content (REDDY *et al*., 2015), formulation 3 with no added pectin powder presented an acceptable texture, afforded by the endogenous pectic compounds of the Granny Smith apples that comprised 22% of the recipe (Table 1) and are known to have a high pectin content (QUINTERO RUIZ *et al*., 2012). Furthermore, the extremely low amounts of glucose syrup (5%) and fructose (5%) in this formulation favoured concentration and the outcome of a desirable texture. The addition of sugar compounds strengthens pectic gels up to a maximum point, after which, such property may reduce (OREGO *et al*., 2014). This behaviour is explained by the presence of low molecular weight compounds, such as glucose, fructose, sucrose and organic acids, which have a low glass transition temperature. These molecules may affect the product texture because they are highly hygroscopic in their amorphous state and show high molecular mobility at temperatures above the glass transition temperature leading to a less stable, sticky and rubbery leather (DIRIM *et al*., 2015). In this work, this undesirable texture was observed only in formulation 4, which had the greatest glucose syrup content (28 %), in the absence of pectin powder.

Besides texture, sourness was also an important factor in determining the overall acceptance of baby kiwifruit leathers. While formulations 1, 2 and 4 presented a sugary and well-balanced taste, respectively, formulation 3 was considered too sour by the panellists. A second trial was, therefore, necessary to optimise baby kiwifruit formulations. Given the aim was to develop a formulation that produced a leather presenting a composition as similar to that of the fresh fruit, only formulations 3 and 4 were modified in the second trial, generating formulations 3A and 4A, respectively. These formulations were preservative-free, with a relatively less sour taste (created by replacing the citric acid powder with fresh lemon juice) and an appropriate texture (Table 2). Formulation 4A had less glucose syrup than formulation 4, to reduce the low molecular weight compounds while the glucose syrup content of formulation 3A was higher than formulation 3, to improve taste. Fructose power was added to both formulations as a sweetener. Finally, formulation 4A incorporated green apple to enhance the gel flavour.

The same concentration process and sensory analysis of the original formulations were applied to formulations 3A and 4A. Although both formulations presented a desirable texture and taste, formulation 4A did not keep a desirable colour, due to its high sugar content, so only formulation 3A was assessed for shelf life quality.

Table 2. Formulations 3A and 4A, produced during second trial obtained by optimization of formulations 3 and 4.

Formulation 3A	Formulation 4A
66% baby kiwi frozen puree	47% baby kiwi frozen puree
22% apple Granny Smith	31% apple Granny Smith
5% glucose syrup 33 DE	10% glucose syrup 33 DE
5% fructose powder	10% fructose powder
1% lemon juice	1% lemon juice
1% water	1% water

3.2. Shelf life test and fruit quality assessments

3.2.1 Weight loss, soluble solids and acidity

Weight loss was statistically different among all leather samples and did not alter during shelf life (Fig. 1), except sample OPE, which demonstrated a slight increment at 21 days.

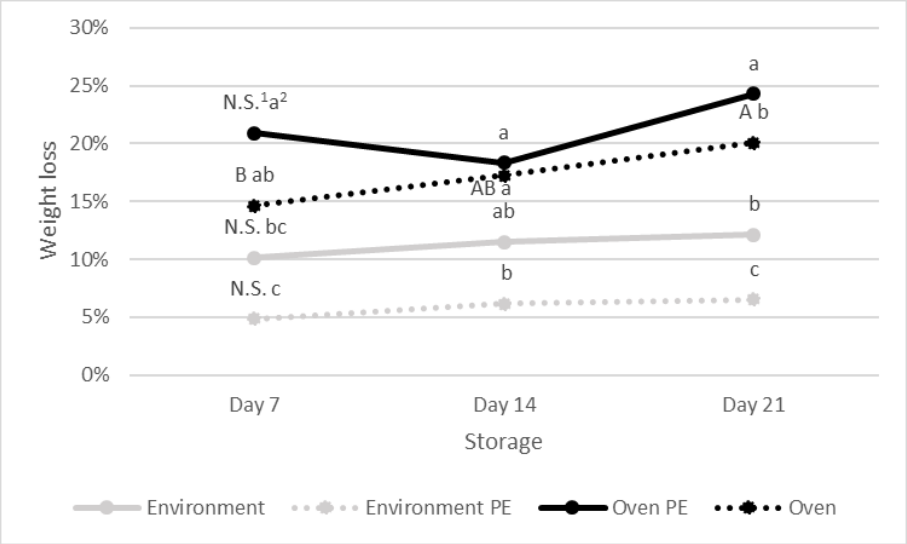

Figure 1. Weight losses (%) of Environment (E), Environment PE (EPE), Oven (O) and Oven PE (OPE) samples during storage.

[1]Different capital letters (A–B) show significant differences (P≤ 0.05) within treatment.

[2]Different lower-case letters (a-d) show significant differences among treatments (P ≤ 0.05) for each storage time.

Major weight loss was observed for OPE and O samples. In this work, even though moisture content was not determined, weight loss might be related to the moisture loss during shelf life, as demonstrated in previous trials (DIAMANTE *et al.*, 2014). Enhancement of this parameter might indicate a poor shelf life stability of samples since this trend could change the texture, colour and nutrient composition. Lower weight loss was noted for the PA/PE packaged samples than the unpackaged ones, under both storage conditions, suggesting that PA/PE packaging was efficient to avoid or delay weight loss in OPE, E and PE samples when compared with their unpackaged

counterparts, stored under the same temperature condition. Conversely, the PA/PE packaging was insufficient to circumvent the augmented weight loss trend of OPE sample during simulated long-term shelf life (i.e., the accelerated storage condition).

3.2.2 Soluble solids content (SSC)

Figure 2 shows the SSC of raw puree, raw formulation and leather samples. During leather manufacturing, the addition of glucose syrup increased the SSC from 16% (raw puree) to 25% (raw formulation). Owing to the concentration process, leather samples at day 0 reached 75%, which was higher than the 65% SCC needed for sugar-acid-high-methoxyl pectin gelation (QUINTERO *et al*., 2012). An increase in the SSC is mainly a result of the concentration of the sugars and is important to the gel flavour, as the hydrogen bonded sugar–water molecules will be entrapped in the pectic gel. This phenomenon is possible only at a high sugar concentration of 55 g 100 g^{-1} (TORRES *et al*., 2013). Differences between samples were observed, especially at 14 and 21 days. Oven samples registered significantly higher SSC values than environment samples, irrespective of the storage time. This finding was consistent with the literature that indicates an increase of SSC during storage is a consequence of dehydration and possible conversion of complex carbohydrates into sugars and other soluble components (KUCHI *et al*., 2014). In this work, carbohydrates were probably represented by the starch content since frozen puree was produced from unripe fruit, not suitable for the fresh market, though further analysis of those components should have been done, to provide a better understanding of the product composition. The SSC trend demonstrated in this work also occurred in the simulated long-term storage products (O/OPE samples), corroborating the work of CHAVAN and SHAIK (2015). Differences between packaged and unpackaged samples were also noticed: those with PE packaging presented lower SSC values at the end of shelf life when compared with the unpackaged samples under the same temperature condition. Although, from day 7, the Brix values within samples fluctuated and, at the end of the shelf life, were higher than the initial values (0 day), demonstrating poor stability of the samples, with and without packaging. These results are different from QUINTERO *et al.* (2012), wherein apple leathers packaged with a metalised-plastic material did not show any modifications because of the superior protective property of the packaging material. As far as we know, there are no other shelf life studies of PA/PE packaged fruit leather. Although, the high water vapour transmission rate (5 g m^{-2} d^{-1}) of PA/PE packaging means it is not as efficient at preserving the product's quality as other packaging materials, such as polyester/aluminium/polyamide/polyethylene, which has a water vapour transmission rate of 0.1 g m^{-2} d^{-1} (FU *et al*., 2018).

3.2.3 Colour and browning index (BI)

The colour degradation of leather samples was highly correlated with the evolutions of L^* and BI during shelf life, so only those two parameters are presented in this work. At the end of shelf life, L^* values decreased significantly for O, OPE and E samples, indicating a darkening of the colour. Only EPE samples retained initial L^* values (Table 3), which demonstrates a protective effect of PA/PE packaging but exclusively in simulated short-term shelf life. Parameter L^* expresses the degree of brightness, which can be related to browning reactions and production of dark pigments, such as melanoidins (QUINTERO *et al*., 2012; PATEL *et al*., 2013), caused by oxygen exposure, moisture and an extended shelf life (PATEL *et al*., 2013). Thus, the trend found for OPE when simulating a longer shelf life, illustrated the inadequacy of PA/PE in preventing the quality loss of this sample, as its L^* values were even higher than those of O samples.

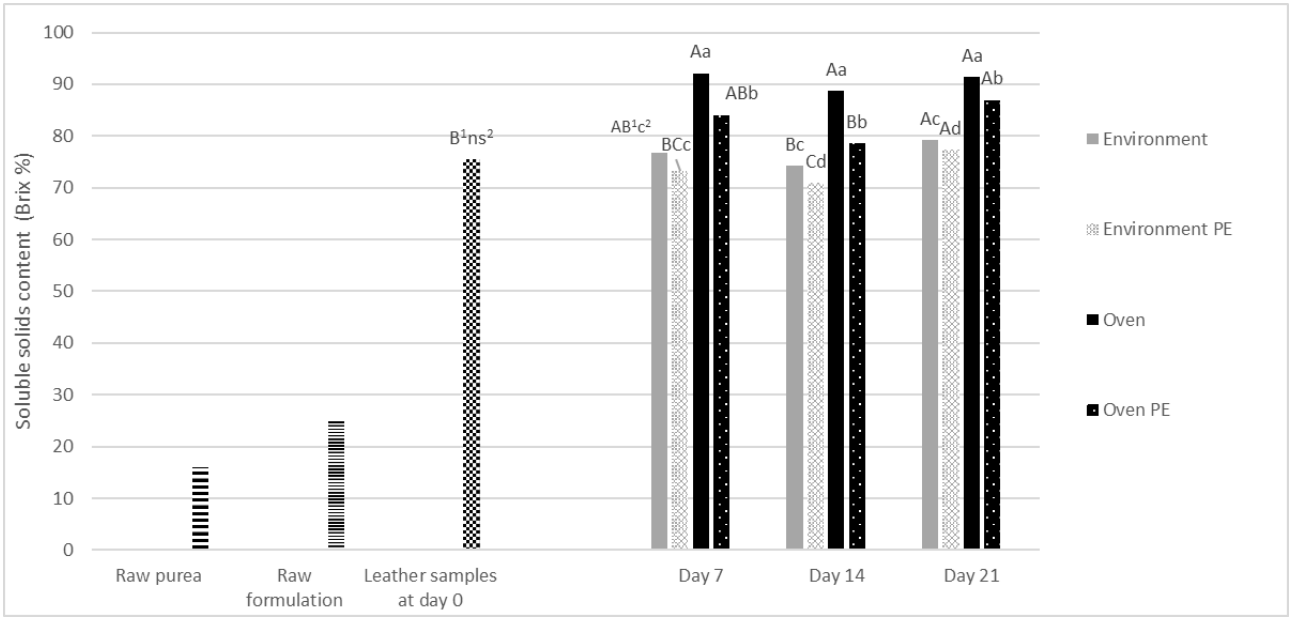

Figure 2. Soluble solids content of raw puree, raw formulation and leather samples at day 0; and brix of Environment (E), Environment PE (EPE), Oven (O) and Oven PE (OPE) samples during storage.

[1]Different capital letters (A-C show significant differences ($P \leq 0.05$) within treatment.

[2]Different lower-case letters (a-d) show significant differences among treatments ($P \leq 0.05$) for each storage time.

Table 3. L* evolution of Environment (E), Environment PE (EPE), Oven (O) and Oven PE (OPE) samples during storage.

Samples	L*							
	Day 0		Day 7		Day 14		Day 21	
E	26,71	A[1] n.s.[2]	26,04	AB bc	25,85	AB a	25,13	B a
EPE	26,71	N.S. n.s.	26,76	N.S. ab	25,62	N.S. a	25,81	N.S. a
O	26,71	AB n.s.	28,03	A a	25,88	B a	25,68	B a
OPE	26,71	A n.s.	24,78	B c	22,40	C b	23,24	C b

[1]Different capital letters (A-C) in the same row show significant differences ($P \leq 0.05$) within treatment.
[2]Different lower-case letters (a-b) in the same column show significant differences among treatments ($P \leq 0.05$) for each storage time.

The BI (Fig. 3), which is a combination of the *L**, *a** and *b** values, and used as a colour darkening indicator of leathers (QUINTERO RUIZ *et al.*, 2012; TORRES *et al.*, 2013), contrasted with the *L** values and demonstrated colour quality loss only for O samples. For these samples, the BI increased from 54.11 to 89.68. Conversely, E and EPE samples were stable, and OPE displayed only a slight decrease at 14 days of shelf life, probably related to the decline in *b**, from 6.25 to 2.46, as the *b** values of the other samples increased from 6.22 to 4.32 (E), 4.90 (EPE) and 7.52 (O), thereby affecting the estimation of the BI of OPE throughout the shelf life. For this reason, the *L** values were a better indicator of colour quality loss during shelf life. The browning reactions were probably caused by the degradation of ascorbic acid, present at high amounts in the raw material (MCNEILAGE *et al.*, 2001; MCNEILAGE *et al.*, 2004) and probably initially reduced by the

concentration process and preparation of leather samples, but degraded further during shelf life studies. Ascorbic acid is strongly affected by temperature but may incur browning reactions, even at 25°C (PATEL *et al*., 2013). The formation of browning compounds during storage could also be due to the Maillard reaction initiated by the interaction between reducing sugars and amino groups, and ultimately generates brown pigment precursors, such as hydroxymethylfurfural (MASKAN, 2001; LESPINARD *et al*., 2012).

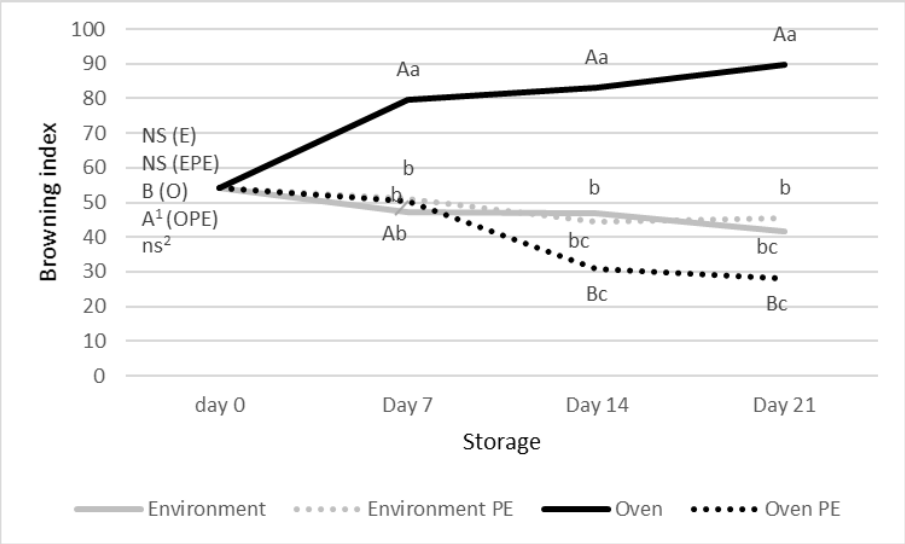

Figure 3. Browning Index evolution for Environment (E), Environment PE (EPE), Oven (O) and Oven PE (OPE) samples during storage.

[1]Different capital letters (A-B) show significant differences ($P \leq 0.05$) within treatment.

[2]Different lower-case letters (a-b) show significant differences among treatments ($P \leq 0.05$) for each storage time.

3.2.4 Texture parameters

Adhesiveness and springiness express the rheological and mechanical properties of organic materials (ARANA, 2012) and might indicate the efficiency of the packaging material adopted for stabilising the leather texture, as well as how the endogenous pectin and low molecular weight compounds might affect texture during the concentration process and shelf life. A limited amount of literature has demonstrated the TPA measurements of leather (OREGO *et al*., 2014). Adhesiveness is an important parameter of dried fruit products since it could infer the stickiness of the products (NISHINARI and FANG, 2018). The adhesiveness values (Table 4) of samples enhanced to become closer to 0, indicating a lower sensation of stickiness of samples at the end of shelf life. Samples O and OPE had significantly different values from the other samples during shelf life since they were the least sticky. According to VALENZUELA and AGUILERA (2015), high adhesiveness values of leather at day 0 (-237.68) could be related to the presence of low molecular weight compounds in the leather formulation. It means the high adhesiveness levels found in the current work are probably explained by the use of fructose and glucose syrup 33 DE in the leather formulations. These components contribute a large number of monomers relative to the other ingredients and with lower DE values, lowering the glass transition temperature, which is the temperature at which products may become increasingly sticky. In contrast, glucose syrup 17 DE and 19 DE, used by VALENZUELA and AGUILERA (2015), contribute to relatively high molecular weight polymer

compounds, which can compete with sugars for hydrogen bonding with water, thereby avoiding the product stickiness. During shelf life, the water loss of samples (suggested by the weight loss and SSC concentration) might have reduced the adhesiveness, a phenomenon most frequently apparent for O samples, attributed to the higher temperature condition of 37 versus 25°C. Similarly, Al HINAI *et al*. (2013) verified that adhesiveness was also influenced by the moisture content of leather samples.
Springiness values (Table 5) fluctuated during shelf life. Pectin was found to be the most important factor influencing (increasing) springiness of fruit leather (OREGO *et al*., 2014). Consequently, the decrease in springiness is possibly explained by endogenous pectin gel degradation, leading to the formation of new compounds, such as pectic acids and uronic acid (KUCHI *et al*., 2014) that might have occurred during shelf life. The absence of significant differences between packaged and unpackaged samples for both texture parameters at the end of shelf life reaffirmed the PE packaging was inadequate in maintaining the texture stability of the leathers.

3.2.5 Total phenolic content (TPC) determination and antioxidant capacity (AC)

During leather production, the TPC of the raw puree decreased in the raw formulation but then increased in the leather samples at day 0. The TPC values did not differ significantly among the leather samples or during shelf life (Fig. 4).

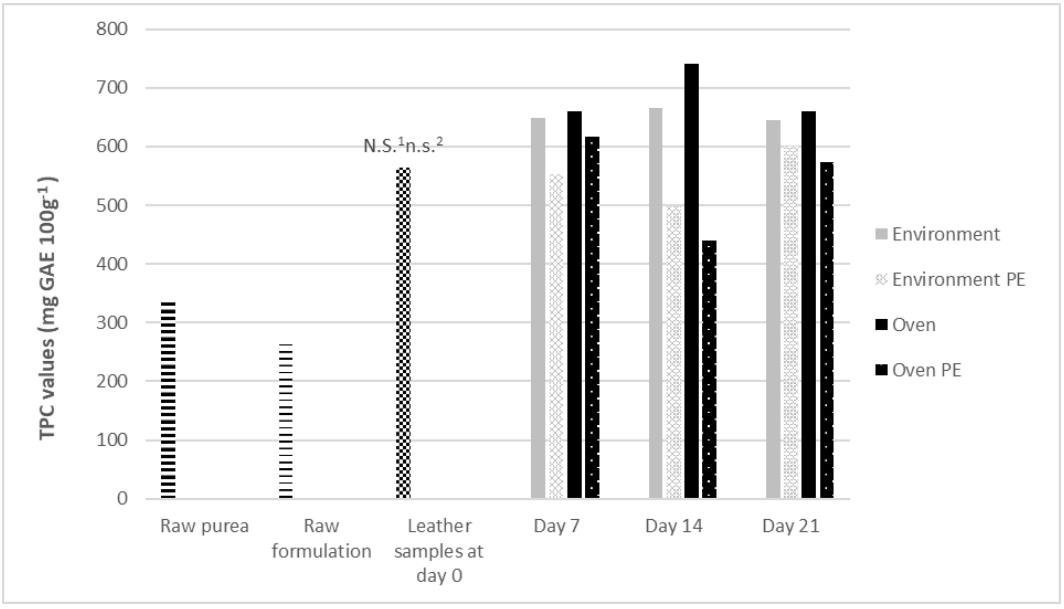

Figure 4. Total polyphenol content of raw puree, raw formulation and leather samples at day start, and total polyphenol content evolution for Environment (E), Environment PE (EPE), Oven (O) and Oven PE (OPE) samples during storage.

[1]Capital letters (N.S) show absence of significant differences($P \leq 0.05$) within treatment.

[2]Lower-case letters (n.s.) show absence of significant differences among treatments ($P \leq 0.05$) for each storage time.

The major polyphenol compounds in baby kiwifruit are phenolic acids, tannins and flavanols (LEONTOWICZ *et al*., 2016). In our work, the TPC of raw puree (334.79 mg GAE 100 g^{-1}) was very similar to fresh fruit, as also shown by ZOU *et al*. (2012). Baby kiwifruit is currently marked in Europe as berries, due to its size, commercial availability and

nutraceutical quality. However, even though the TPC values are higher than raw apple puree (LANDL *et al*., 2010), they are still lower than strawberry and blueberry puree (PATRAS *et al*., 2009). Moreover, the addition of apples to the raw puree during the formulation process further lowered the TPC amounts in the raw formulation, thereby deviating the product from the berries nutraceutical profile.

Leather samples at day 0 presented an increased TPC (563.93 GAE 100 g^{-1}), as a result of the concentration process, wherein water loss meant all the compounds present were concentrated, in concurrence with observations by SUNA *et al*. (2014), LUTZ *et al.* (2015) and CONCHA-MEYER *et al*. (2016). In this work, the SSC increased almost three-fold while the TPC values only doubled. Thus, on a dry weight basis, it is suggested that heat treatment would have led to a loss of phenolic compounds, despite the absolute increased values.

No changes within and between leather samples during shelf life affirmed that shelf life and packaging conditions did not affect the TPC, in agreement with QUINTERO *et al*. (2012) and TORRES *et al*. (2013). Although, Fig. 5 emphasises the large variability in the data, especially among O and OPE samples. Considering the substantial fluctuations in the data of almost all analysis, blending of the ingredients must be further improved to ensure homogeneity of the samples.

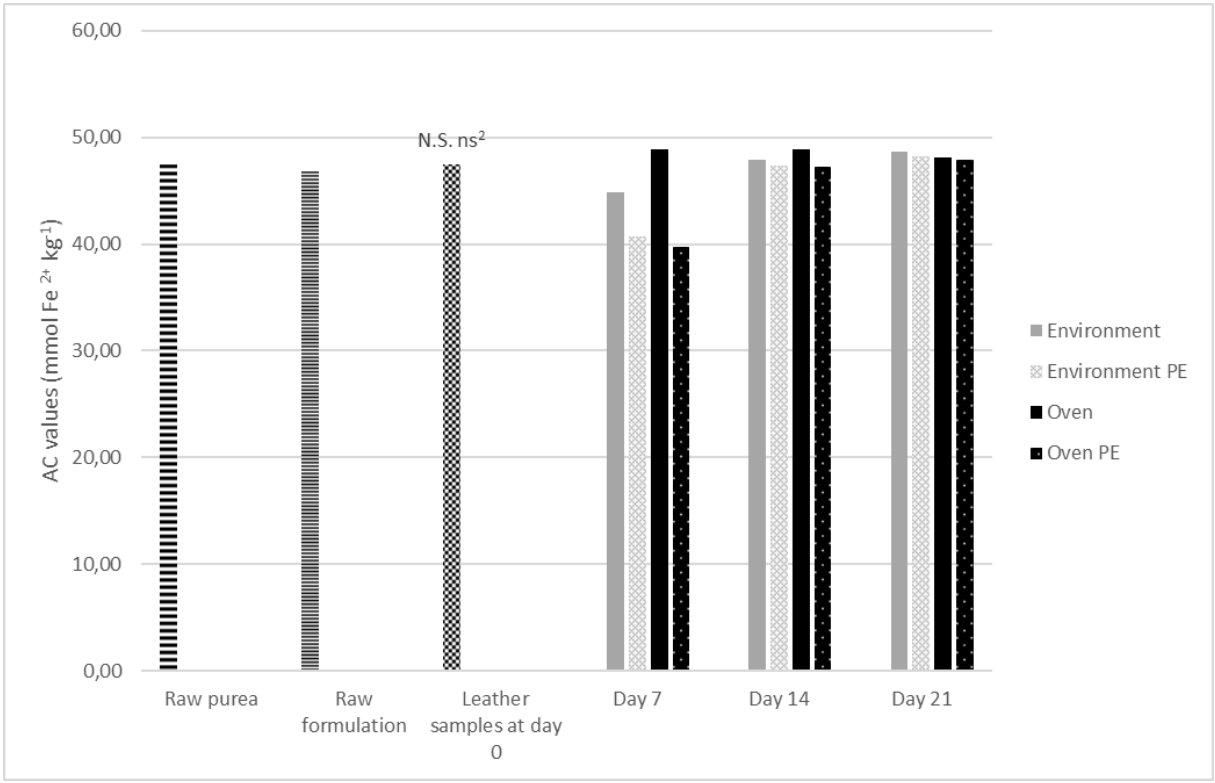

Figure 5. Antioxidant capacity of raw puree, raw formulation and leather samples at day 0. Antioxidant capacity of Environment (E), Environment PE (EPE), Oven (O) and Oven PE (OPE) samples during storage.
[1]Capital letters (N.S).show absence of significant differences ($P \leq 0.05$) within treatment.
[2]Lower-case letters (n.s.) show absence of significant differences among treatments in($P \leq 0.05$) for each storage time.

The AC of raw puree, raw formulation and leather samples at day 0 were similar to each other. This trend was not expected since TPC has been well correlated to AC in fresh, pureed and dried fruits, respectively (KARADAG *et al*., 2009; OREGO *et al*., 2014). The

absence of significant differences within and among samples highlights that PE packaging and storage time did not affect the AC of leathers (Fig. 5). The AC stability after day 7 well correlated with the TPC trend. This pattern was also observed by SACCHETTI *et al.* (2008) and CONCHA-MEYER *et al.* (2016).

3.2.6 Sensory evaluation

Figure 6 illustrates the scores obtained for each leather sample at days 0 and 21. Overall, at day 0 the descriptors hardness (3.2), sweetness (3.2), flavour (4.2) and overall liking (3.5) scored highest while sourness (2.2) scored lowest, for all samples. At the end of storage, flavour decreased, and sourness increased, in all samples. Sweetness decreased for O and OPE samples while hardness remained stable for E and EPE. These results contrasted with the SSC analysis, which showed an increase in SSC content of O and OPE samples, suggesting an increased sweetness. Probably, the SSC increase was accompanied by a similar trend in the acidity content, which was not assessed in this work. Both O and OPE exhibited particularly enhanced hardness values, arising from the intense dehydration of the leathers. Overall acceptance remained stable during the shelf life of E and EPE samples while for O and OPE samples, this descriptor drastically decreased, as a result of hardening.

Table 4. Adhesiveness parameter of TPA for Environment (E), Environment PE (EPE), Oven (O) and Oven PE (OPE) samples during storage.

Samples	Adhesiveness (N*s)							
	Day 0		Day 7		Day 14		Day 21	
E	-237,68	B[1] n.s.[2]	-69,91	Aab	-58,02	Aab	-47,98	Aab
EPE	-237,68	B. n.s.	-115,64	Ab	-67,71	Ab	-71,10	Ab
O	-237,68	B n.s.	-1,01	Ab	-21,64	Aa	-1,08	Aa
OPE	-237,68	B n.s.	-70,92	Aab	-59,98	Aab	-17,95	Aa

[1]Different capital letters (A–C) in the same row show significant differences ($P \leq 0.05$) within treatment. [2]Different lower-case letters (a–b) in the same column show significant differences among treatments ($P \leq 0.05$) for each storage time.

Table 5. Springiness parameter of TPA for Environment (E), Environment PE (EPE), Oven (O) and Oven PE (OPE) samples during storage.

Samples	Springness (s)							
	Day 0		Day 7		Day 14		Day 21	
E	0,49	N.S.[1]n.s.[2]	0,63	N.S. b	0,71	N.S.ab	0,88	N.S.n.s.
EPE	0,49	B n.s.	0,69	A b	0,45	B b	0,72	A n.s.
O	0,49	C n.s.	0,56	B a	0,90	A a	0,88	A n.s.
OPE	0,49	B n.s.	0,56	AB b	0,71	A ab	0,77	A n.s.

[1]Different capital letters (A–C) in the same row show significant differences ($P \leq 0.05$) within treatment. [2]Different lower-case letters (a–b) in the same column show significant differences among treatments ($P \leq 0.05$) for each storage time.

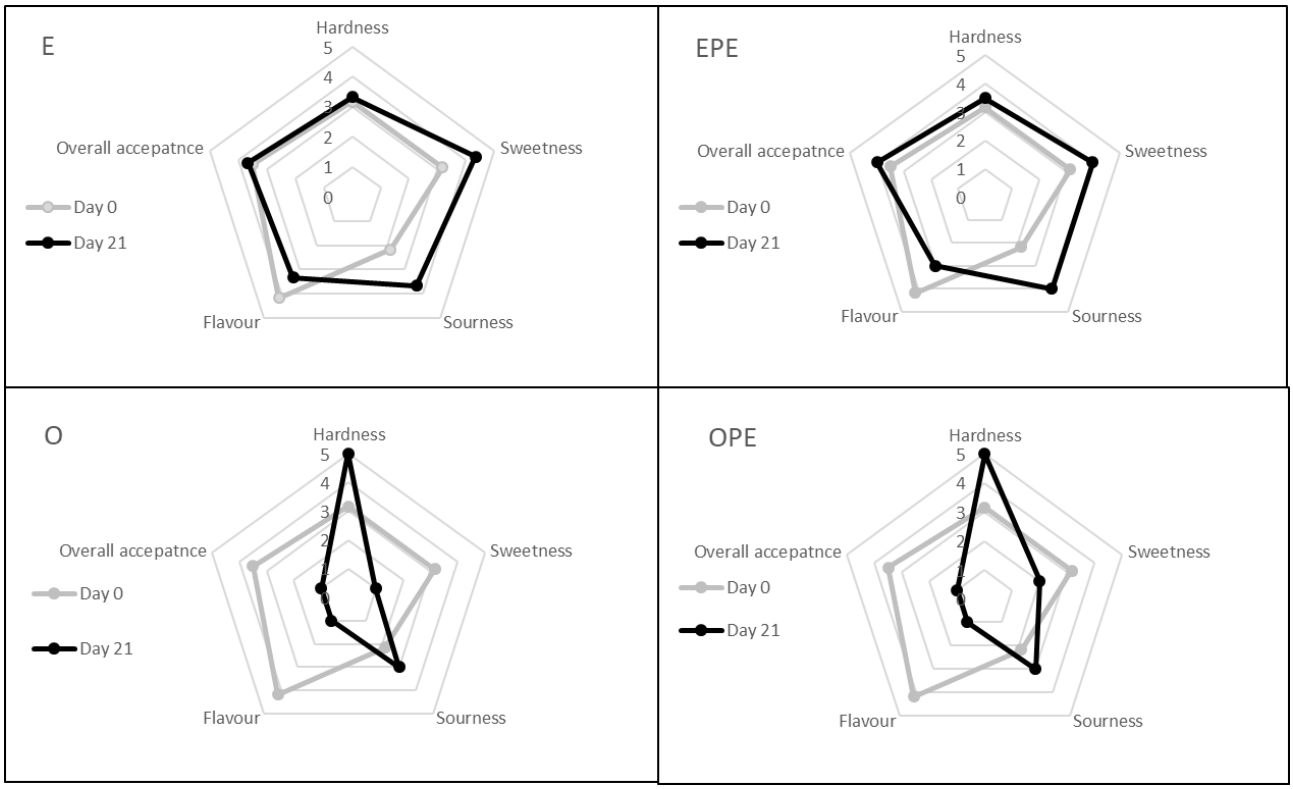

Figure 6. Sensory analysis scores of Environment (E), Environment PE (EPE), Oven (O) and Oven PE (OPE) samples at day 0 and after day 21.

4. CONCLUSIONS

The development of leather formulations could be a promising opportunity to improve the baby kiwifruit supply chain, solving the *A. arguta* losses and offering a processed product that meets the requirements of current consumers seeking healthy and convenient food. Baby kiwifruit formulations considered for obtaining a healthy product with low sugar and a bright green appearance were achieved by adjusting the recipe to offer a balanced content of fructose and glucose syrup. In turn, it reduced the Maillard reaction and favoured formation of a desirable texture, generating a flexible but solid product after the concentration process. In this investigation, preparing baby kiwifruit leather with high fruit content allowed shelf life extension and improved the nutritional properties of the fresh raw material by the concentration-induced reduction in the water content and, consequently, enhanced sugar and polyphenol concentrations. However, the accelerated shelf life experiment (simulating long-term conservation) exposed baby kiwifruit leathers to intense browning reactions and dehydration, leading to the darkening of O and OPE samples and hardening of the texture up to a level that highly compromised the overall acceptance. PA/PE packaging was inconsistent at maintaining leather quality by the end of the shelf life experiment, regardless of a shelf life extension. Additional research is needed to identify new material packaging that is suitable to prevent quality loss during shelf life, and further analysis should be done to characterise the product's composition, including the presence of nutraceutical compounds other than the TPC, such as ascorbic acid and carotenoids.

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