Quality Decay Kinetics of Semi-preserved Sauce as Affected by Packaging

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ABSTRACT: Semi-preserved tomato sauces packaged in polymeric containers have gained in popularity and market share, as opposed to traditional fully preserved tomato sauces. As a consequence of the different technologies applied, microbiological, enzymatic, and chemical problems are considered and compared with those related to traditional processing. This research represents a comparative study of the influence of different packaging (glass, polyethylene terephtalate [PET], PET added with an oxygen scavenger, and polypropylene [PP]) on the quality decay kinetics of a semi-preserved sauce. Results suggest that the packages chosen for our experiments can be used interchangeably because of the scant influence of the packaging materials on most of the quality indices. Two exceptions are represented by lycopene content (whose decrease was faster in PET and PP than in glass and PET containing the oxygen scavenger) and the peroxide data (which reached the highest values for PET containers).

Keywords: lycopene, oxygen scavenger, packaging, PET, semi-preserved sauce, shelf life

Introduction

According to a generally accepted definition, semi-preserved foods are products submitted to a heat treatment unable to guarantee commercial sterility and, for this reason, must be stored under refrigerated conditions for a limited time. This class of products includes a lot of different types of foods such as soft cheeses, sliced sausages, pasteurized milk, and sauces. Until recently, sauces suitable to dress pasta, meat, salads, and sandwiches were sold only as preserved products, which were 1st packed into glass jars or metal cans and then submitted to severe heat treatments. These preserved products had a shelf life at room temperature of more than 1 year. Today, the market is oriented to the semi-preserved sauces due to their freshlike appearance and the greater preservation of taste and aroma typical of the ingredients used. Semi-preserved foods are submitted either to mild heat treatments before packaging or to pressurization of the filled containers. Retail containers are generally made of polymeric materials, and products are sold under refrigeration temperature. Shelf life for these products is limited to about 60 d.

As a consequence of the different technologies applied, microbiological, enzymatic, and chemical problems are considered and compared with those related to the previous processing methods. Sauces typically contain a lipidic fraction (vegetable oils or animal fats) as a minor component and a greater aqueous phase (strained tomatoes, whole vegetable or juices, and so forth). Fabiano and others (2000) identified the modified atmosphere packaging conditions able to extend the shelf life of "pesto" sauce up to 120 d at 5 °C. They chose a target atmosphere of 10% CO_2 and 90% N_2 at steady-state and multifilm packages based on polypropylene, polyamide, and polyethylene. They demonstrated an inhibition of the microbial growth by CO_2 with no significant changes in odor and color.

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Interest of researchers has been also focused on oxidative stability of sauces. Wills and Cheong (1979) studied the onset of rancidity in mayonnaise and found that peroxide value, whose initial value was around 0, increased up to 3.5 mEq/kg after 15 d at 20 °C and then decreased, whereas rancidity appeared after 30 d as a consequence of the rapid increase in carbonyl compound concentration. For oil in water emulsions, oxidation initiated at the oil droplet–water interface, and initiation was favored by small droplet size. The propagation phase of oxidation was independent of droplet size (Jacobson and others 2000). It has also been shown that short wavelength light promotes oxidation of lipid. In fact, Lennersten and Lingnert (2000) found that light between 365 nm and visible lights (blue) below 470 nm promoted the oxidation of unsaturated fats by acting on photosensitive agents such as carotenoids. Containers of polyethylene naphtalate (PEN) or polyethylene terephtalate (PET)/PEN offered better protection than PET by protecting lipidic substances with respect to UV, but the same containers did not absorb blue light. According to Sattar and others (1976a, 1976b), b-carotene acts as a light filter by extending the induction period for light-induced oxidation. Photodegradation of pigments such as carotenes and lycopene was well correlated with both a decrease in yellowness and a slight increase in lightness in lipid sample containing them (Pesek and Warthesen 1987). a- and b-carotenes were more sensitive to photobleaching than lycopene. The oxidation rate was independent of oxygen concentration at high oxygen partial pressure, whereas it was independent of substrate concentration at low oxygen partial pressure (Labuza 1971; Karel 1992). Tawfik and Huyghebaert (1999) studied the effects of packaging on the stability of olive, sunflower, and palm oil during storage. Oxygen stability was best for glass, followed by polyvinylchloride (PVC), PET, polypropylene (PP), and PS polystyrene (PS).

Photodegradation of lycopene in tomato sauce causes both reduction of red color and reduction in nutritive value. Lycopene, a fat-soluble carotenoid, is a precursor of b-carotene (Sandmann 1994) and has at least twice the antioxidant capacity of b-carotene (Di Mascio and others 1989). Furthermore, epidemiological studies have indicated positive health benefits from consumption of a diet

high in lycopene, in particular to reduce cancer incidence (Gerster 1997; Rao and Agarwal 1998; Giovannucci 1999). Zanotti and others (2001) studied the influence of packaging material on the maintenance of lycopene content and color in strained tomatoes under different experimental conditions (room temperature or 36 °C to 38 °C, in the presence or absence of light) for a 165-d storage. They found that all the packaging materials used (glass bottles, multilayer cartons, transparent pouches, plain tinplate cans, multilayer plastic pouches having an intermediate aluminum foil) were suitable for retaining lycopene in strained tomatoes, and explained that it was due to the strong chemical inertia of lycopene in products free from lipidic components.

The purpose of this work was to observe the influence of various polymeric containers compared with glass on shelf life of semi-preserved emulsified tomato sauce.

Materials and Methods

Production of the tomato sauce

Tomato sauce was produced by using the following ingredients (expressed as % weight): commercial bottled strained tomato (78.84%); commercial olive oil (9.21%) whose acidity, peroxide value, K232, K270, and DK were below the European legal limits (1.5%, 15mEq O_2/kg of oil, 3.40%, 1.00%, and 0.13%, respectively, EEC Regulation 2568/91); stoned green olives preserved in a sodium chloride solution (10.24%); salt (1.71%).

Ingredients were mixed together before the heat treatment at 75 °C for 15 min.

Plastic container production

Plastic containers were produced by means of a single-step injection stretching blow molding machine (CIB LAB 01/92, SIPA, Vittorio Veneto, Italy). AMOSORB (grade 4020, British Petroleum, Naperville, Ill., U.S.A.; Colormatrix, Eindhoven, Holland) was used as the oxygen scavenger in this investigation. AMOSORB were added to PET before injection.

Packaging

Tomato sauce was aseptically filled in glass jars or in polymeric ones (Sipa S.p.A., Plastic Packaging Systems, Vittorio Veneto, Italy) having the characteristics reported in Table 1 and a weight of about 29 g. Containers were filled completely, leaving little to no headspace. The glass jars were previously sterilized at 121 °C for 15 min, whereas the polymeric bottles were irradiated with Cobalt-60 γ-rays at 12.50 kGy. After the jars were filled, they were hermetically closed.

Oxygen transmission rate measurements

Oxygen transmission rate for the plastic containers was measured using a Mocon Oxtran 2/20 (Minneapolis, Minn., U.S.A.) according to the F 1927–98 Standard Method (ASTM 2004). At least 10 measurements were made for each container. Conditioning time was considered sufficient when 2 sequential readings of permeability give a difference in value less than 2%.

Storage

Samples were stored at 5 °C in the dark for 4 mo and every 2 weeks, 3 containers of each type were withdrawn and opened for the analyses. Analyses were also performed at the zero time.

Analyses of the tomato sauce

pH. Measurements of pH were conducted using a Basic 20 pH meter (Crison Instruments S.A., Barcelona, Spain).

Colorimetric measurements. Colorimetric measurements were performed through a tristimulus colorimeter (Chromameter-400, Minolta, Osaka, Japan) to evaluate the visual color changes associated with browning or pigment degradation during storage. Color was expressed as L^*, a^*, and b^* (luminosity, red value, and yellow value, respectively, on the Hunter scale). The colorimeter was calibrated on a standard white tile ($L^* = 93.5$, $a^* = -1.0$, $b^* = 0.8$) before each series of measurements.

Lycopene assay. The lycopene assay was performed according to the "low volume hexane extraction method" as in Fish and others (2002). After extraction, the lycopene content of each sample was estimated using the absorbance at 503 nm (UV/VIS Beckman spectrophotometer mod. DU 640, Fullerton, Calif., U.S.A.) versus a blank of hexane solvent and the sample weight according to the following relation:

$$lycopene\left(mg/kg\right) = \frac{A_{503}x0.0312}{kgsample}$$

The absorbance peak at 503 nm was used to minimize interference from other carotenoids. For example, constituent carotenoids other than lycopene contribute to the absorbance at 503 nm <4% for fresh red tomatoes.

The fat fraction. The fat fraction was separated from the tomato sauce by centrifugation (mod. PK121R, ALC Intl. S.r.l., Cologno Monzese, Italy) at 10000 rpm for 10 min at 20 °C, recovered, and filtered on anhydrous sodium sulfate to remove water traces. The obtained oil was then redissolved in a small volume of hexane, and charcoal was added to remove fat-soluble pigments. After filtration through Whatman nr 1 papers, the solvent was evaporated using a Rotavapor model R114 (Büchi, Switzerland). The remaining traces of solvent were removed under nitrogen flow. The extracted oil was submitted to the following analyses:

(1) Acidity was determined by titration with 0.1 *N* NaOH in the presence of phenolphtalein to evaluate the free fatty acids; acidity was expressed as grams of oleic acid per 100 g of oil (EEC 1991).

(2) Peroxide value was determined by titration with 0.01 *N* sodium thiosulphate in the presence of potassium iodide to evaluate the hydroperoxide formation (primary oxidation); peroxide value was expressed as milliequivalents (mEq) of active oxygen per kilogram of oil (EEC 1991).

(3) Spectrophotometric indexes (K_{232}, K_{270}, and ΔK) (EEC 1991) were measured with a UV/VIS Beckman spectrophotometer model DU 640 (Fullerton, Calif., U.S.A.) to evaluate the formation of double and triple conjugated bounds; determinations were made by dissolving the oil samples in 2,2,4-trimethylpentane and reading the absorbance at 232, 266, 270, and 274 nm versus a blank of 2,2,4-trimethylpentane.

(4) p-Anisidine value (p-A.V.), was measuerd according to the AOCS Official Methods (AOCS 1993), in order to evaluate the secondary oxidation (hydroperoxide decomposition); measurements were made by dissolving the oil samples in 2,2,4-trimethylpentane and reading the absorbance at 350 nm before and after the addition of the p-anisidine reagent.

Statistical analyses

Analyses were carried out in triplicate except for both the colorimetric analyses, for which at least 20 determinations were performed, and pH measurements (6 determinations for each sample).

The average and standard deviation were calculated. In fact, the data shown in the figures are the average of all repetitions, whereas the error bars are the standard deviation.

The confidence intervals of model's parameters were evaluated as follows: 1st, a fit was run with the original data; then, using the data points standard deviation 500 additional fits were run on artificial data sets, which were generated by randomly varying the data around the fitted function. From these additional fits, a distribution of values for each parameter was obtained. The sets of data obtained for each parameter was statistically treated to obtain the 95% confidence interval.

Results and Discussion

Oxygen transmission rate

Results are reported in Table 1. The oxygen transmission rate was in an increasing order: PP > PET > PET+ 5% oxygen scavenger. It is worth noting that permeability tests were conducted at 23 °C instead of 5 °C (the temperature at which the storage was performed). Therefore, the oxygen transmission rate values can be considered only for comparative purposes. Of course, glass offered a total barrier property.

As reported previously, the quality of the investigated food product depends on several quality sub-indices, which can be clustered into 3 main groups: physical (pH and color), nutritional (lycopene content), and chemical (free fatty acids, peroxide value, p-anisidine value, and spectrophotometric constants). To determine the influence of using containers made of different materials on the quality decay kinetics of a semi-preserved sauce, the above quality sub-indices were monitored during storage. The results obtained will be discussed separately.

Physical descriptors

pH. The function

$$pH = \cos t \tag{1}$$

represents the best fit equation to the experimental data. In fact, pH did not substantially change during storage at 5 °C (being about 4.2 for sauce in glass containers and about 4.0 for sauce in polymeric containers). This could indicate that neither undesirable fermentations nor microbiological growth occurred; lack of change of pH cannot, however, rule out the possibility of microbial growth during storage. The superposition of the 95% confidence intervals (data not shown) indicate the absence of statistically significant differences among the sauce packed in the polymeric containers used in this experiment. Sauce packaged in the glass jars exhibited highest pH values, probably due to the reduced O_2 partial pressure.

Colorimetric measurements. The results obtained show that sauce brightness (L^*) remained almost constant during the considered period of storage. The parameters reported in Table 2 have been obtained by fitting the function

$$L^* = \cos t \tag{2}$$

to the experimental data. The superposition of the 95% confidence intervals indicates the absence of statistically significant differences among the different containers.

Concerning the red index (a^*), a decrease during the storage was detected in all the considered samples (Figure 1). To quantitatively determine these changes, a 1st-order kinetic was fitted to the data shown in Figure 1:

$$a^* = a^*_\infty + \left(a^*_0 - a^*_\infty\right)\exp(-k \cdot t) \tag{3}$$

Table 1—Characteristics of the containers used in the experiments

Type of containers	Capacity (mL)	Oxygen transmission rate (cc/package * d)[a]
Glass	212	—
PET[b]	490	0.0259 ± 0.0011
PET+5% ox. scaveng.	490	0.0011 ± 0.00002
PP[c]	490	0.7389 ± 0.0111

[a]Measurement conditions: 23 ºC, 44% RH, under air.
[b]PET = polyethylene terephtalate.
[c]PP = polypropylene.

where a^* is the a^* value at time t, a^*_∞ is the a^* value at the infinite time, a^*_0 is the initial a^* value, k is the kinetic constant, and t is the time. As can be inferred from the data shown in Figure 1, a 1st-order equation satisfactorily fits the data. The values of the parameters appearing in Eq. 3 are listed in Table 2. They show the continual decrease in the red component of the color (without the attainment of an equilibrium value) and that the type of container did not affect the kinetic constant.

The yellow index (b^*) did not exhibit substantial changes during storage and, for this reason, the function

$$b^* = \cos t \tag{4}$$

was successfully fitted to the experimental data. The results of the fitting are reported in Table 2 and indicate that there were not statistically significant differences due to the type of container.

Nutritional descriptors

Lycopene content. A substantial decrease in the lycopene content for all the samples was monitored during storage (Figure 2). To quantitatively determine these changes, a 1st-order kinetic was fitted to the data shown in the Figure 2:

$$C_{lyc} = C^\infty_{lyc} + \left(C^0_{lyc} - C^\infty_{lyc}\right)\exp(-k \cdot t) \tag{5}$$

where: C_{lyc} is the lycopene content (mg/kg) at the time t, C^∞_{lyc} is the lycopene content at the equilibrium (infinite time), C^0_{lyc} is the initial lycopene content, k is the kinetic constant, and t is the time. Results

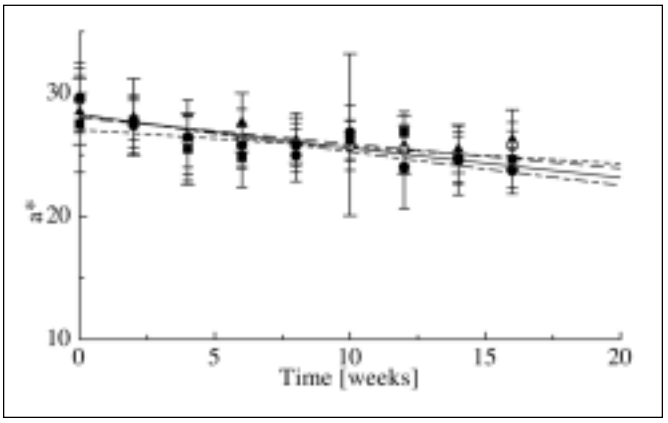

Figure 1—a^* plotted as a function of storage time. ▲ = glass; ○ = polyethylene terephtalate (PET); ■ = PET + 5% ox. scav.; ● = polypropylene (PP). The curves shown in the figure were obtained by fitting Eq. 3 to the experimental data: (— — —) glass; (— —) PET; (– – – –) PET + 5% ox. scav.; (– — –) PP.

Table 2—Values of the Eq. 2, 3, and 4 parameters obtained by fitting the *L, *a**, and *b** data, respectively[a]**

Types containers	*L** values	*a**			*b**
		k_{a^*}	*a** initial values	*a** asymptotic values	
Glass	30.1622	9.8994×10^{-3}	28.2229	0.0000	30.0291
	[27.7939, 32.3627]	[0.0000, 0.3742]	[24.8991, 33.3945]	[0.0000, 25.5425]	[26.9145, 33.3141]
PET	31.2993	7.9220×10^{-3}	28.0208	0.0000	28.6536
	[28.7432, 33.5978]	[0.0000, 0.2501]	[25.5630, 31.2854]	[0.0000, 4.9054]	[25.4578, 31.7392]
PET + 5% ox. scav.	30.7088	5.3729×10^{-3}	27.0386	0.0000	28.6664
	[28.5299, 33.2417]	[0.0000, 0.1363]	[24.9161, 29.8474]	[0.0000, 2.6156e-7]	[25.8418, 31.5863]
PP	30.6132	1.1398×10^{-2}	28.2975	0.0000	29.8979
	[27.9959, 33.3138]	[1.3636e-17, 0.3580]	[25.0385, 32.8373]	[0.0000, 24.2325]	[26.2779, 33.8103]

[a]Values in the square brackets are upper and lower limits of the 95% confidence interval. PET = polyethylene terephtalate; PP = polypropylene.

Table 3—Values of the Eq. 5 parameters obtained by fitting the lycopene content data[a]

Type of containers	K_{lyc}	Lycopene (mg/kg)	Lycopene asymptotic values (mg/kg)
Glass	9.8837×10^{-3}	132.5662	0.0000
	[7.2559×10^{-3}, 1.2482×10^{-2}]	[129.2730, 135.9436]	[0.0000, 0.0000]
PET	1.5241×10^{-2}	138.8617	0.0000
	[1.2699×10^{-2}, 1.7881×10^{-2}]	[135.5313, 142.2061]	[0.0000, 0.0000]
PET + 5% ox. scav.	3.5375×10^{-3}	125.6289	0.0000
	[2.4496×10^{-3}, 4.7690×10^{-3}]	[124.1417, 127.1498]	[0.0000, 0.0000]
PP	1.6461×10^{-2}	123.7209	0.0000
	[1.5244×10^{-2}, 1.7686×10^{-2}]	[122.2280, 125.1566]	[0.0000, 0.0000]

[a]The values in the square brackets are upper and lower limits of the 95% confidence interval. PET = polyethylene terephtalate; PP = polypropylene.

from fitting, listed in Table 3, indicate that the degradation kinetic constant for glass and PET added of oxygen scavenger was lower than those obtained for PET and PP. The decrease in lycopene content appears well correlated with the decrease in the red index (to which the lycopene contributes): the relative kinetic constants (Table 2 and 3) have the same order of magnitude at a parity of the type of container. As explained subsequently, the decrease in lycopene content could be put into relation with the behavior of the sauce with respect to the oxidative degradation of the fat fraction.

Chemical descriptors

Hydrolytic degradation of the fat fraction: oil acidity. In this case, a constant function,

$$Ac.\% = \cos t \tag{6}$$

was successfully fitted to the experimental data. The content of free fatty acids remained almost constant during storage and ranged between 0.21% and 0.34%. The superposition of the 95% confidence intervals (data not shown) demonstrates that the hydrolytic degradation of the fat fraction was not affected by the type of container.

Oxidative degradation of the fat fraction: primary oxidation. A slight increase in the peroxide value was observed during storage in glass, PET containing the oxygen scavenger, and PP containers (Figure 3). A 1st-order kinetic was fitted to the experimental data:

$$N.P. = (N.P.^{\circ}) \exp(k \cdot t) \tag{7}$$

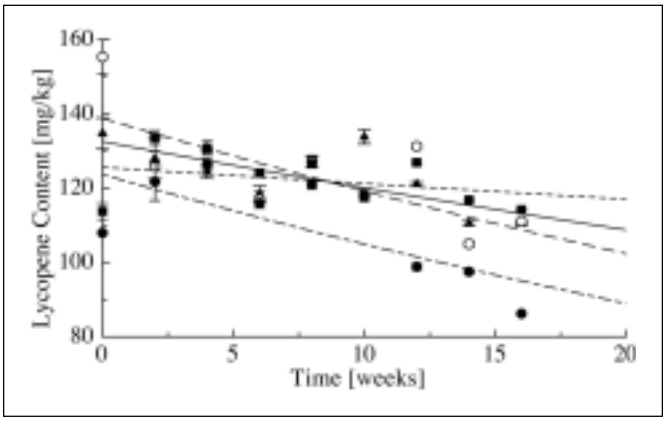

Figure 2—The evolution of the lycopene content during storage. ▲ = glass; s = polyethylene terephtalate (PET); ■ = PET + 5% ox. scav.; ● = polypropylene (PP). The curves shown in the figure were obtained by fitting Eq. 5 to the experimental data: (— — —) glass; (— —) PET; (– – – –) PET + 5% ox. scav.; (– — – ·) PP.

where *N.P.* represents the peroxide value at the time t, *N.P.*° is the initial peroxide value, *k* is the kinetic constant, and *t* is the time. The results of the fitting are reported in Table 4. The rate of hydroperoxide formation was very low in the cases of glass and PET added with oxygen scavenger and higher in PET and PP containers. These data are well correlated with those of oxygen permeability (Table 1); in fact, the hydroperoxide formation could not occur in the absence of oxygen. However, the confidence interval referred to the kinetic constant in PET containers is superposed to the others due to an imperfect adaptation of the function to the experimental data. Probably, the primary oxidation extension was limited by the action of lycopene. This molecule is known for its antioxidant properties; in fact, it is oxidized by oxygen before oxidation of other susceptible substances occurs. In a fat-free food system, lycopene has a strong chemical inertia (that is, it does not react with other molecules), independently of the packaging material used (Zanotti and others 2001).

The evolution of K_{232} considered as an index of primary oxidation is less significant than those of the peroxide value because it does

Table 4—Values of the Eq. 7 and 8 parameters obtained by fitting the peroxide value and the K_{232} data, respectively[a]

	Peroxide values		
Type of containers	K	Initial values (mEq O_2/kg fat fraction)	K_{232} values
Glass	6.5938×10^{-18}	5.8830	1.8372
	[4.8251×10^{-18}, 8.8617×10^{-18}]	[5.4707, 6.3322]	[1.7814, 1.8980]
PET	3.4530×10^{-3}	5.4348	1.9583
	[0.0000, 1.7255×10^{-2}]	[4.7580, 5.9053]	[1.8500, 2.0612]
PET+5% ox. scav.	1.4825×10^{-19}	6.7453	1.8631
	[1.0662×10^{-19}, 1.8579×10^{-19}]	[6.4087, 7.1362]	[1.7862, 1.9389]
PP	1.3999×10^{-2}	5.3159	1.9236
	[3.1134×10^{-3}, 2.3835×10^{-2}]	[4.7809, 5.8692]	[1.8158, 2.0236]

[a]The values in the square brackets are upper and lower limits of the 95% confidence interval. PET = polyethylene terephtalate; PP = polypropylene.

Table 5—Values of the Eq. 9, 10, and 11 parameters obtained by fitting the p-anisidine value, the K_{270}, and the DK data, respectively[a]

	p-Anisidine values			
Type of containers	K	Initial values	K_{270} values	DK values
Glass	3.2696×10^{-2}	1.2998	0.4322	3.2878×10^{-2}
	[0.0000, 7.5350×10^{-2}]	[0.7874, 1.8469]	[0.4156, 0.4474]	[3.1543×10^{-2}, 3.4145×10^{-2}]
PET	1.5065×10^{-2}	2.1383	0.4764	3.4656×10^{-2}
	[0.0000, 3.6193×10^{-2}]	[1.7082, 2.4982]	[0.4511, 0.4994]	[3.2449×10^{-2}, 3.6914×10^{-2}]
PET+5% ox. scav.	3.1603×10^{-3}	1.8798	0.4525	3.2835×10^{-2}
	[0.0000, 1.9977×10^{-2}]	[1.6167, 2.0479]	[0.4349, 0.4702]	[3.1507×10^{-2}, 3.4475×10^{-2}]
PP	3.5860×10^{-2}	0.9244	0.4408	2.9028×10^{-2}
	[5.5225×10^{-3}, 6.7043×10^{-2}]	[0.6545, 1.1995]	[0.4211, 0.4611]	[2.7947×10^{-2}, 3.0165×10^{-2}]

[a]The values in the square brackets are upper and lower limits of the 95% confidence interval. PET = polyethylene terephtalate; PP = polypropylene.

not show the differences due to the packaging material. They were constant during the storage time

$$K_{232} = \cos t \tag{8}$$

and showed a perfectly superimposed confidence intervals.

Oxidative degradation of the fat fraction: secondary oxidation. The decomposition of hydroperoxides in volatile compounds measured by the p-anisidine value was very low in all the considered samples (Figure 4), probably due to the presence of lycopene. This means that, at least during the 1st 4 mo of storage, off-flavors evidently did not develop. The experimental data were fitted according to a 1st-order kinetic:

$$N.p.A. = \left(N.p.A.^{0}\right) \exp(k \cdot t) \tag{9}$$

where *N.P.A.* is the p-anisidine value at time t, *N.P.A.*° is the initial p-anisidine value, *k* is the kinetic constant, and *t* is the time. As can be inferred from the results of the fitting listed in Table 5, the type of container used to package the sauce did not influence the evolution of this chemical index.

The K_{270} and DK parameters are indices of secondary oxidation,

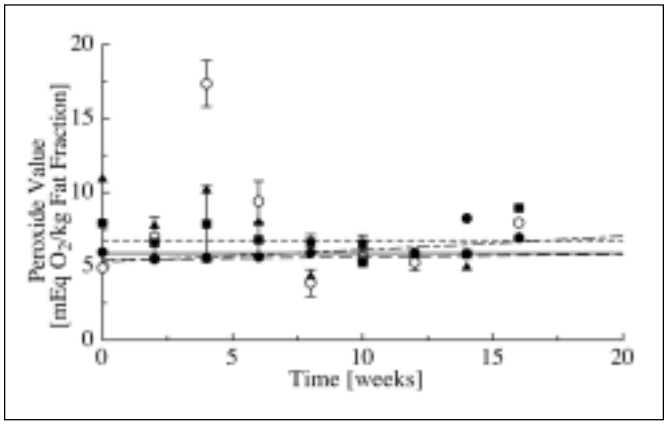

Figure 3—Peroxide values plotted as a function of storage time. ▲ = glass; ○ = polyethylene terephtalate (PET); ■ = PET + 5% ox. scav.; ● = polypropylene (PP). The curves shown in the figure were obtained by fitting Eq. 7 to the experimental data: (— — —) glass; (— —) PET; (– – – –) PET + 5% ox. scav.; (– — – ·) PP.

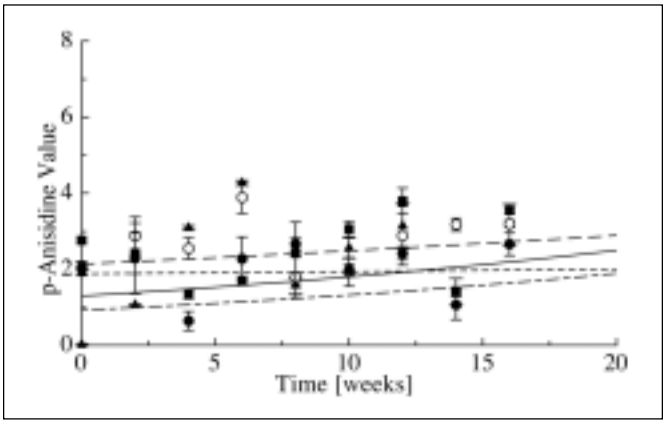

Figure 4—p-Anisidine values plotted as a function of storage time. ▲ = glass; ○ = polyethylene terephtalate (PET); ■ = PET + 5% ox. scav.; ● = polypropylene (PP). The curves shown in the figure were obtained by fitting Eq. 9 to the experimental data: (— — —) glass; (— —) PET; (– – – –) PET + 5% ox. scav.; (– — – ·) PP.

being a measure of triple conjugated bonds. They were almost constant during storage—

$$K_{270} = \cos t \tag{10}$$

and

$$\Delta K = \cos t \tag{11}$$

—and the confidence interval superposition indicates the absence of statistical significant differences due to the type of container.

Conclusions

This research concerns the study of the effects of different kinds of packages (glass, PET, PET containing the oxygen scavengers, PP) on the quality decay kinetics of a semi-preserved sauce stored at 5 °C for 4 mo. The obtained results demonstrate that most of the degradation reactions (decrease in a^* and lycopene content and increase in peroxide value and p-anisidine value) followed a 1st-order kinetic. Furthermore, the packages described in these experiments can be used interchangeably because of the scant influence of the packaging materials on most of the quality indices. The exception was represented by the lycopene content (whose decrease was faster in PET and PP than in glass and PET containing oxygen scavenger). As a consequence, doubling the storage time from 2 mo generally fixed for this type of product to 4 mo did not negatively affect measured product quality, at least in the experimental conditions chosen.

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