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Radiation drying effects on biological characteristics of peel and leaves of "Maltaise demi-sanguine" oranges

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***Abstract*— Infrared and microwave drying changes in terms of chemical characteristics and antioxidant properties of "Maltaise demi-sanguine" orange peel and leaves extracts were studied.**

When comparing the dried samples with the fresh one, it was shown that both infrared and microwave treatments led to improvement of the leaves extracts chemical composition by increasing contents of all components (total phenols, chlorophylls a and carotenoids), except chlorophylls b which disappeared. In the case of the peel, both chlorophylls a and b were degraded after radioactive drying. However, an increase in total phenol and carotenoids content was registered at some temperatures and powers of treatment.

After radioactive drying, maximum of DPPH radical scavenging activity of peel and leaves extracts was reached respectively at 50 and 60 °C and at 450 and 180 W (an increase of respectively 8, 61, 69 and 53% with regard to the fresh state). The reducing power decreased considerably in leaves extracts. Concerning the ferrous ion-chelating ability of extracts, it was improved by infrared and microwave treatments especially at 60 °C for peel and at 50 °C and 300 W for leaves.

***Keywords*— Infrared and microwave drying, chemical characteristics, antioxidant properties, orange peel extracts, leaves extracts.**

I. Introduction

Citrus by-products have high contents of bioactive compounds such as flavonoids and terpenes which exhibit interesting antioxidant properties and some authors have claimed that certain parts of what is considered as dietary fiber might also exert antioxidant effects [1]. Due to their antioxidant properties, bioactive components obtained from *Citrus* by-products might decrease risk of cancer and cardiovascular diseases and prevent atherosclerosis and cataracts [2]. However, *Citrus* by-products (like peels and leaves), because of their high moisture content (1.509 kg water/kg db in leaves; 2.970 kg water/kg db in peels) [3], are highly perishable and so require reduction of their moisture content to a level at which microbial spoilage and deterioration reactions are minimized, thus increasing product shelf-life.

Dehydration has become a widely used food preservation process for the most agro-food products. There are several drying processes such as natural sun drying, convective hot air drying. However, high temperatures and long drying periods usually reduce the quality of the final product [4]. Microwave (MW) and infrared (IR) treatments have gained popularity as alternative drying methods for a variety of food products such as fruit, vegetable, snack food and dairy product. MW and IR drying is rapid, energy efficient and produces a high-quality end product compared to conventional methods ([5], [6]).

The aim of this work was to determine the influence of MW and IR drying on biological characteristics of "Maltaise demi-sanguine" orange peel and leaves in terms of chemical composition and antioxidant properties of their extracts.

II. Materials and Methods

A. Materials

Fresh oranges (*C. sinensis*) and leaves of the "Maltaise demi-sanguine" variety were picked from Manzel Bouzalfa (Nabeul, Tunisia) in an advanced stage of ripeness. The whole oranges and the leaves were stored at 0 – 4 °C until processing.

B. Methods

1) Radiation Drying: MW drying experiments of oranges peels and leaves were performed in a domestic microwave oven (TDS: Triple Distribution System, M 1714, Korea) at seven MW output powers (100 – 850 W). IR drying experiments were conducted by the means of an IR moisture analyser (Sartorius MA40) at different temperatures (40, 50, 60 and 70 °C). Drying was applied until obtaining a constant weight of the samples.

2) Chemical Characterisation: Dried and fresh samples were grinded and extracted by percolation with ethanol 95° at room temperature. All extracts were concentrated over a rotary vacuum evaporator until a solid extract sample was obtained. The resulting crude extract was freeze-dried.

Total phenol content (TPC) was determined by the Folin-Ciocalteau method [7]. Results were expressed as mg gallic acid equivalent (GAE) per gram of dry weight (DW) (mg GAE/g DW).

Carotenoids and chlorophylls (a and b) were determined according to the method described by [8]. Spectroscopic measurements of methanolic solution of each extract were performed at recommended wavelengths corresponding to maximal absorbance (A) of chlorophyll a, chlorophyll b and carotenoids (carotenes and xanthophylls). Respective concentrations of these pigments were given by the following equations:

$$C_a\,(\mu g/ml) = 16.72\ A_{665} - 9.16\ A_{652.4} \quad (1)$$

$$C_b\,(\mu g/ml) = 34.09\ A_{652.4} - 15.28\ A_{665.2} \quad (2)$$

$$C_{x+c}\,(\mu g/ml) = (1000\ A_{470} - 1.63\ C_a - 104.96\ C_b)/221 \quad (3)$$

3) Antioxidant Activity: The 1,1-diphenyl-2-picryl hydrazyl radical (DPPH) scavenging activity fresh and infrared dried orange peel and leaves extracts was measured using the method described by [9]. BHA was used as standard control. IC_{50} values denote the concentration of sample, which is required to scavenge 50% of DPPH free radicals.

The ferrous ion-chelating activity was carried out using [10] method. EDTA was used as positive control. EC_{50} value (µg/ml) is the concentration at which the chelating activity was 50%.

Reducing power was determined according to the method of described by [11]. The extract concentration providing 0.5 of absorbance (EC_{50}) was calculated from the graph of absorbance registrated at 700 nm against the correspondent extract concentration. BHA was used as standard control.

C. Statistical Analyses

All measurements were carried out in triplicate. ANOVA test was performed in order to examine the effect of radiation drying on chemical characteristics and antioxidant properties. The SPSS® version 11.0 (Statistical Package for Social Science) was used for statistical investigations. For all statistical analysis, the level of significance is fixed at 95%. Each factor having a p value < 0.05 was considered significant.

III. Results and Discussion

A. Effect of Infrared Drying on Biological Characteristics of Orange Peel and Leaves Extracts

1) Effect of Infrared Drying on Chemical Characteristics: Table 1 presents the effect of IR drying (40 – 70 °C) on total phenols, chlorophylls a and b and carotenoids in “Maltaise demi-sanguine” orange peel and leaves extracts. The applied IR temperatures affected significantly all chemical characteristics of both peel and leaves extracts ($p<0.05$).

TABLE I
EFFECT OF INFRARED DRYING (40 - 70 °C) ON TOTAL PHENOLS, CHLOROPHYLLS A AND B AND CAROTENOIDS IN “MALTAISE DEMI-SANGUINE” ORANGE PEEL AND LEAVES EXTRACTS.

	Total phenols (mg GAE/g DW)	**Chlorophylls a (mg/g DW)**	**Chlorophylls b (mg/g DW)**	**Carotenoids (mg/g DW)**
Peel				
FM	24.680 ± 0.792	0.080 ± 0.003	0.300 ± 0.011	0.136 ± 0.005
40 °C	24.700 ± 0.198	0	0	0.055 ± 0.002
50 °C	37.780 ± 0.877	0	0	0.053 ± 0.002
60 °C	22.120 ± 0.962	0	0	0.052 ± 0.002
70 °C	18.560 ± 0.453	0	0	0.099 ± 0.002
Leaves				
FM	32.370 ± 0.971	0	33.755 ± 1.350	0
40 °C	40.210 ± 1.598	14.185 ± 0.120	0.260 ± 0.010	1.545 ± 0.068
50 °C	47.320 ± 1.420	16.255 ± 0.629	0.115 ± 0.004	1.895 ± 0.021
60 °C	64.720 ± 2.150	18.865 ± 0.629	0	2.235 ± 0.021
70 °C	42.320 ± 1.270	11.135 ± 0.262	0	1.265 ± 0.056

All the given values are the means of three determinations ± standard deviation
FM: fresh matter; DW: dry weight; GAE: gallic acid equivalent

When comparing the IR-dried samples with the fresh one, it was shown that IR treatment led to improvement of the leaves extracts chemical composition by increasing the contents of all components, except the chlorophylls b which disappeared. Maximum values were obtained at 60 °C for total phenols (64.720 ± 2.150 mg GAE/g DW), carotenoids (2.235 ± 0.021 mg/g DW) and chlorophylls a (18.865 ± 0.629 mg/g DW). In the case of the peel, both chlorophylls a and b were degraded after IR drying and a reduction of 27 (at 70 °C) to 62% (60 °C) in carotenoids was noted. However, an increase of 53% in total phenols contents was registered respectively at 50 °C.

Improvement of the chemical characteristics after drying processes could be explained by damage of cell structures making easier extraction of antioxidant components from the plant material. [12] also dehydrated olive leaves (*Olea europaea* L.) by the same process and registered an increase of 9.6 % at 40 °C to 132.7 % at 70 °C in phenolic compounds, by comparison with the fresh state. Lee et al 2006 evaluated TPC in peanut hulls (*Arachis hypogaea* L.) after IR radiation at 150 °C and found an increase of about 94 % with regard to the fresh product. [13] showed previously that IR drying may have capability to cleave covalent bonds and liberate antioxidants such as flavonoids, carotene, tannin, ascorbate, flavoprotein or polyphenols. Furthermore, application of high temperatures could inactivate degradative enzymes (such as polyphenolxidases) and so avoid loss of phenolic compounds.

2) Effect of Infrared Drying on Antioxidant Properties: Table 2 presents the effect of IR drying (40 – 70 °C) on antioxidant activities of "Maltaise demi-sanguine" orange peel and leaves extracts. Statistical analyses showed that IR temperatures affected significantly all the activities of the extracts ($p<0.05$).

TABLE III
EFFECT OF INFRARED DRYING (40 - 70 °C) ON ANTIOXIDANT ACTIVITIES OF "MALTAISE DEMI-SANGUINE" ORANGE PEEL AND LEAVES EXTRACTS.

	IC_{50} values of DPPH RSA (µg/ml)	**EC_{50} values of RP (µg/ml)**	**EC_{50} values of FICA (µg/ml)**
Peel			
FM	819.630 ± 27.048	319.910 ± 10.557	-
40 °C	880.700 ± 34.347	988.400 ± 38.548	2365.790 ± 10.165
50 °C	751.200 ± 33.053	590.700 ± 25,991	2740.900 ± 32.891
60 °C	1094.400 ± 51.437	760.500 ± 35.744	1194.770 ± 26.285
70 °C	916.000 ± 32.976	441.900 ± 15.908	-
Leaves			
FM	326.420 ± 9.140	297.815 ± 8.339	677.670 ± 10.165
40 °C	430.900 ± 14.220	3882.500 ± 128.123	728.720 ± 10.931
50 °C	215.150 ± 8.391	1407.300 ± 54.885	465.459 ± 7.913
60 °C	128.300 ± 5.645	1692.500 ± 60.930	479.006 ± 9.101
70 °C	236.350 ± 11.108	873.850 ± 24.468	729.820 ± 8.758

FM: fresh matter; DW: dry weight; DPPH RSA: DPPH radical scavenging activity; RP: reducing power; FICA: ferrous ion-chelating ability

Compared with the peel, fresh leaves exhibited the strongest antioxidant potential. In fact, IC_{50} values of DPPH radical scavenging activity, EC_{50} values of reducing power and EC_{50} values of ferrous ion-chelating ability were revealed lower than those obtained with fresh peel extracts (326.420 ± 9.140 µg/ml, 297.815 ± 8.339 µg/ml and 685.000 ± 14.385 µg/ml respectively for leaves extracts, against 819.630 ± 36.064 µg/ml, 351.500 ± 15.466 µg/ml and 0 respectively for peel extracts).

After drying, maximum of DPPH radical scavenging activity of peel and leaves extracts was reached respectively at 50 and 60 °C (an increase of respectively 8 and 61% with regard to the fresh state): the respective IC_{50} values calculated were 751.200 ± 33.053 and 128.300 ± 5.645 µg/ml. The reducing power decreased considerably after IR treatment in extracts of both peel and leaves. The lowest EC_{50} values were obtained at 70 °C (441.900 ± 15.908 µg/ml for peel; 873.850 ± 24.468 µg/ml for leaves). Concerning the ferrous ion-chelating ability of extracts, it was improved by IR drying especially at 60 °C for peel and 50 °C for leaves.

The increase of antioxidant activities of peel and leaves extracts at certain applied IR temperatures may be explained by the formation, during drying process, of new compounds with antioxidant activity. [12] and [14] also reported an enhancement of the antioxidant activity of IR dried olive oil and peanut hulls. According to [15], it is likely that the drying favour the non-enzymatic browning or "Maillard reactions". These reactions provided high antioxidant capacity generally associated to the formation of brown melanoidins [16].

The relationship between chemical composition and antioxidant activities was statistically investigated. The correlation coefficient was found very variable indicating that antioxidant capacities was provided not only by the determined components, but also by different generated antioxidant compounds having varying degree of antioxidant activity developing antagonistic, synergic or additional effects with themselves or with the other constituents of peel and leaves extracts [17].

B. Effect of Microwave Drying on Biological Characteristics of Orange Peel and Leaves Extracts

1) Effect of Microwave Drying on Chemical Characteristics: Table 3 presents the influence of MW drying (100 – 850 W) on total phenols, chlorophylls a and b and carotenoids contained in "Maltaise demi-sanguine" orange peel and leaves extracts. All chemical characteristics of both peel and leaves extracts were found significantly affected by the applied MW powers ($p<0.05$).

When comparing the MW dried samples with the fresh one, it was shown that MW treatment led to improvement of the leaves extracts chemical composition by increasing the contents of all components, except the chlorophylls b which disappeared. Maximum values were obtained at 180 W for total phenols (137.040 ± 6.222 mg GAE/g DW) and chlorophylls a (21.095 ± 0.290 mg/g DW) and at 600 W for carotenoids (2.010 ± 0.090 mg/g DW). In the case of the peel, both chlorophylls a and b were degraded after MW drying. However, a maximum increase of 57% in total phenol content and of 360% in carotenoids was registered respectively at 700 W and 100 W.

Drying process would generally result in a depletion of naturally occurring antioxidants in raw materials from plants. But in some cases, processing causes little or no change, significant losses, or enhancement to the content of certain components. [12] showed and confirmed the increase of TPC in olive leaves (*Olea europaea* L.) extracts after MW drying. In fact, compared to the fresh state, improvement percentage of TPC in dehydrated leaves was found of about 17% at 100 W and 92% at 300 W. MW heating, brought about by absorption of MW energy by water molecules, could inactivate oxidative enzymes (such as polyphenolxidases) and so prevent the degradation of phenolic compounds [18]. Increase in antioxidants content following MW treatment could also be attributed to the release of bound phenolic compounds brought about by the breakdown of cellular constituents [19].

TABLE IIIII

EFFECT OF MICROWAVE DRYING (100 - 850 W) ON TOTAL PHENOLS, CHLOROPHYLLS A AND B AND CAROTENOIDS IN "MALTAISE DEMI-SANGUINE" ORANGE PEEL AND LEAVES EXTRACTS.

	Total phenols (mg GAE/g DW)	**Chlorophylls a (mg/g DW)**	**Chlorophylls b (mg/g DW)**	**Carotenoids (mg/g DW)**
Peel				
FM	*24.680 ± 0.792*	*0.080 ± 0.003*	*0.300 ± 0.011*	*0.136 ± 0.005*
100 W	*14.170 ± 0.382*	*0.080 ± 0.003*	*0.300 ± 0.011*	*0.136 ± 0.005*
180 W	*19.215 ± 0.576*	*0*	*0*	*0.625 ± 0.028*
300 W	*22.870 ± 0.686*	*0*	*0*	*0.226 ± 0.010*
450 W	*36.240 ± 0.453*	*0*	*0*	*0.170 ± 0.007*
600 W	*35.040 ± 0.113*	*0*	*0*	*0.300 ± 0.011*
700 W	*38.640 ± 0.792*	*0*	*0*	*0.126 ± 0.006*
850 W	*22.480 ± 1.018*	*0*	*0*	*0.248 ± 0.011*
Leaves				
FM	*32.370 ± 0.971*	*0*	*33.755 ± 1.350*	*0*
100 W	*124.720 ± 2.828*	*14.995 ± 0.488*	*8.000 ± 0.297*	*0*
180 W	*137.040 ± 6.222*	*21.095 ± 0.290*	*0*	*1.795 ± 0.021*
300 W	*129.440 ± 5.431*	*13.880 ± 0.625*	*0*	*1.625 ± 0.073*
450 W	*98.720 ± 1.131*	*14.970 ± 0.198*	*0*	*1.190 ± 0.028*
600 W	*94.475 ± 1.237*	*11.085 ± 0.332*	*0*	*2.010 ± 0.090*
700 W	*94.745 ± 1.167*	*17.160 ± 0.772*	*0*	*0.750 ± 0.014*
850 W	*78.760 ± 3.267*	*12.825 ± 0.544*	*0*	*1.895 ± 0.064*

All the given values are the means of three determinations ± standard deviation

FM: fresh matter; DW: dry weight; GAE: gallic acid equivalent

2) Effect of Microwave Drying on Antioxidant Properties: Table 4 presents the effect of MW drying on antioxidant activities of "Maltaise demi-sanguine" orange peel and leaves extracts. Statistical analyses showed that MW powers affected significantly all the activities of the extracts ($p<0.05$).

Compared with the peel, fresh leaves exhibited the strongest antioxidant potential. In fact, IC_{50} values of DPPH radical scavenging activity, EC_{50} values of reducing power and EC_{50} values of ferrous ion-chelating ability were revealed lower than those obtained with fresh peel extracts (326.42 ± 9.140 µg/ml, 297.815 ± 8.339 µg/ml and 685.000 ± 14.385 µg/ml respectively for leaves extracts, against 819.630 ± 36.064 µg/ml, 351.500 ± 15.466 µg/ml and 0 respectively for peel extracts).

After drying, maximum of DPPH radical scavenging activity of peel and leaves extracts was reached respectively at 450 and 180 W (an increase of respectively 69 and 53% with regard to the fresh state): the respective IC_{50} values calculated were 253.190 ± 9.115 and 152.750 ± 5.499 µg/ml. The reducing power of leaves extracts decreased considerably after MW treatment when peel extracts revealed their highest activity at 700 W: the lowest EC_{50} value was 139.210 ± 4.594 µg/ml. MW drying also improved the ferrous ion-chelating ability of leaves extracts especially at 300 W (the correspondent EC_{50} was 437.300 ± 6.560 µg/ml). For the peel, the EC_{50} values of the ferrous ion-chelating ability were calculated only at 300, 450, 700 and 850 W with a maximum of 494.220 ± 9.390 µg/ml at 700 W.

The increase of antioxidant activities of peel and leaves extracts at certain applied MW powers may be explained by the formation, during drying process, of new compounds with antioxidant activity. [20] noticed an enhancement of the antioxidant activity after MW drying of grapes. According to these authors, it is likely that the drying favour the non-enzymatic browning or "Maillard reactions". These reactions provided high antioxidant capacity generally associated to the formation of brown melanoidins [16].

The relationship between chemical composition and antioxidant activities was statistically investigated. The correlation coefficient was found very variable indicating that antioxidant capacities was provided not only by the determined components, but also by different generated antioxidant compounds having varying degree of antioxidant activity developing antagonistic, synergic or additional effects with themselves or with the other constituents of peel and leaves extracts [17].

TABLE IVV

EFFECT OF MICROWAVE DRYING (100 - 850 W) ON ANTIOXIDANT ACTIVITIES OF "MALTAISE DEMI-SANGUINE" ORANGE PEEL AND LEAVES EXTRACTS.

	IC_{50} values of DPPH RSA (µg/ml)	EC_{50} values of RP (µg/ml)	EC_{50} values of FICA (µg/ml)
Peel			
FM	819.630 ± 27.048	319.910 ± 10.557	-
100 W	1257.700 ± 49.050	436.420 ± 17.020	-
180 W	786.700 ± 34.615	370.520 ± 16.303	-
300 W	342.500 ± 16.098	218.540 ± 10.271	4512.800 ± 54.154
450 W	253.190 ± 9.115	191.440 ± 6.892	3560.600 ± 60.53
600 W	343.500 ± 9.618	235.930 ± 6.606	-
700 W	296.600 ± 9.788	139.210 ± 4.594	494.220 ± 9.390
850 W	900.500 ± 35.120	587.800 ± 22.924	1775.900 ± 37.294
Leaves			
FM	326.420 ± 9.140	297.815 ± 8.339	677.670 ± 10.165
100 W	199.600 ± 9.381	971.100 ± 45.6417	612.750 ± 7.353
180 W	152.750 ± 5.499	1411.400 ± 50.810	1226.400 ± 26.981
300 W	197.100 ± 5.519	980.500 ± 27.454	437.300 ± 6.560
450 W	219.100 ± 7.230	1712.000 ± 56.496	440.400 ± 7.487
600 W	275.850 ± 10.758	605.000 ± 23.595	441.100 ± 9.263
700 W	181.500 ± 7.986	1095.300 ± 48.193	445.400 ± 10.165
850 W	200.800 ± 9.438	712.500 ± 33.488	439.400 ± 5.273

FM: fresh matter; DW: dry weight; DPPH RSA: DPPH radical scavenging activity; RP: reducing power; FICA: ferrous ion-chelating ability

IV. CONCLUSIONS

The multiple antioxidant activities of "Maltaise demi-sanguine" orange peel and leaves extracts demonstrated in this study clearly indicates the potential application value of these by-products. Further studies are needed on the isolation and characterization of individual compounds to elucidate their different antioxidant mechanisms and the existence of possible synergism, if any, among the compounds.

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REFERENCES

[1] Y. Lario, E. Sendra, J. García-Pérez, C. Fuentes, E. Sayas-Barberá, J. Fernández-López and J.A. Pérez-Alvarez, "Preparation of high dietary fiber powder from lemon juice by-products", Innovative Food Science and Emerging Technologies, vol. 5, pp. 113-117, 2004.

[2] Y.-C. Wang, Y.-C. Chuang and Y.-H. Ku, "Quantitation of bioactive compounds in citrus fruits cultivated in Taiwan", Food Chemistry, vol. 102, pp. 1163-1171, 2007.

[3] A. Kammoun Bejar, N. Boudhrioua Mihoubi and N. Kechaou, "Moisture sorption isotherms-experimental and mathematical investigations of orange (*Citrus sinensis*) peel and leaves", Food Chemistry, vol. 132, pp. 1728-1735, 2012.

[4] I.M.L.B. Avila and C.L.M. Silva, "Modeling kinetics of thermal degradation of color in peach puree", Journal of Food Engineering, vol. 39, pp. 161-166, 1999.

[5] D. Nowak and P.P. Lewicki, "Infrared drying of apple slices", Innovative Food Science and Emerging Technologies, vol. 5, pp. 353-360, 2004.

[6] K. Zhu, J. Zou, Z. Chu and X. Li, "Heat and mass transfer of seed drying in a two pass infrared radiation vibrated bed", Heat Transfer-Asian Research, vol. 31(2), pp. 141-147, 2002.

[7] N. Cicco, M. Lanorte, M. Paraggio and M. Viggiano, "A reproducible, rapid and inexpensive Folin-Ciocalteu micro-method in determining phenolics of plant methanol extracts", Microchemical Journal, vol. 91, pp. 107-110, 2009.

[8] H.K. Lichtenthaler and C. Buschmann, "Chlorophylls and Carotenoids: Measurement and Characterization by UV-VIS Spectroscopy", Current Protocols in Food Analytical Chemistry. F4.3.1-F4.3.8, 2001.

[9] A.J. Kirby and R.J. Schmidt, "The antioxidant activity of Chinese herbs for eczema and of placebo herbs–I", Journal of Ethnopharmacology, vol. 56, pp. 103–108, 1997.

[10] P. Carter, "Spectrophotometric determination of serum iron at the submicrogram level with a new reagent (ferrozine)", Analytical Biochemistry, vol. 40, pp. 450-458, 1971.

[11] A. Yildirim, M. Oktay and V. Bülaloğlu, "The Antioxidant Activity of the Leaves of *Cydonia vulgaris"*, Turkish Journal of Medical Sciences, vol. 31, pp. 23-27, 2001.

[12] N. Bahloul, « Caractérisation physico-chimique, biologique et thermodynamique de quatre variétés de feuilles d'olivier (*Olea europeae* L.) et étude expérimentale et théorique du séchage en vue de leur valorisation ». Thèse de doctorat, Tunisie, 2011.

[13] S.C. Lee, J.H. Kim, S.M. Jeong, D.R. Kim, J.U. Ha and K.C. Nam, "Effect of far-infrared radiation on the antioxidant activity of rice hulls", Journal of Agricultural and Food Chemistry, vol. 51, pp. 4400-4403, 2003.

[14] S.C. Lee, S.M. Jeong, S.Y. Kim, H.R. Park K.C. Nam and D.U. Ahn, "Effect of far infrared radiation and heat treatment on the antioxidant activity of water extracts from peanut hulls", Food Chemistry, vol. 94, pp. 489-493, 2006.

[15] L. Manzocco, S. Calligaris, D. Mastrocola, M.C. Nicoli and C.R. Lerici, "Review of non-enzymatic browning and antioxidant capacity in processed foods", Trends in Food Science and Technology, vol. 11, pp. 340-346, 2001.

[16] S. Cheriot, « Role des produits de la reaction de Maillard dans l'inhibition de l'oxydation enzymatique des phenols et des lipides ». Thèse de doctorat, France, 2007.

[17] H. Zielisnki and H. Koslowska, "Antioxidant activity and total phenolics in selected cereal grains and their different morphological fractions", Journal of Agricultural and Food Chemistry, vol. 48, pp. 2008-2016, 2000.

[18] Y.Y. Lim and J. Murtijaya, "Antioxidant properties of Phyllanthus amarus extracts as affected by different drying methods", Lebensmittel Wissenschaft und Technologie, vol. 40pp. 1664-1669, 2007.

[19] E.W.C. Chan Y.Y. Lim and Y.L. Chew, "Antioxidant activity of *Camellia sinensis* leaves and tea from a lowland plantation in Malaysia", Food Chemistry, vol. 102 pp. 1214-1222, 2006.

[20] J. Moreno, J. Peinado and R.A. Peinado, "Antioxidant activity of musts from Pedro Ximenez grapes subjected to off-vine drying process", Food Chemistry, vol. 104, pp. 224-228, 2007.