

## Research Article

# Micronized natural talc with a low particle size and a high carbonate rate is more effective at breaking down oil-in-water emulsion

Abir Sadkaoui<sup>1</sup>, Antonio Jiménez<sup>1</sup>, Rafael Pacheco<sup>2</sup> and Gabriel Beltrán<sup>1</sup>

<sup>1</sup> IFAPA Centro “Venta del Llano”, Junta de Andalucía, Mengíbar, Jaén, Spain

<sup>2</sup> Departamento de Ingeniería Química, Ambiental y de los Materiales, Universidad de Jaén, Jaén, Spain

Micronized natural talc (MNT) has demonstrated to be very useful to break down emulsions formed during the virgin olive oil extraction process, improving the oil yield. This study was aimed to obtain more insights into the mechanisms of MNT to break down oil-in-water emulsions. For this purpose, laboratory scale experiments were performed in order to evaluate the effect of different pectin concentrations (0.5, 1, 1.5, and 2%), used as an emulsifier agent, on the behavior of an oil-in-water interface. Afterward, to evaluate the effect of MNT dosage as well as its physicochemical characteristics on breaking o-reducing emulsions, four MNTs differing in their particle size (D50) and carbonate rate were assayed at doses ranging from 0 to 1%. Increasing pectin concentration gave a rise in the emulsifying activity (EA). The emulsifier effect of pectins was weakened by the addition of increasing MNT dose. MNT physicochemical characteristics markedly affected the breaking of oil-in-water emulsions. Nonetheless, its effect depends on the dose of MNT applied to the emulsion. The highest decrease in EA was observed for MNT with the lowest D50 (2.4  $\mu\text{m}$ ) and the highest carbonate rate (4%) at 0.5%. In general, MNT containing lower D50 and high rate of carbonate showed better capacity for breaking oil-in-water emulsion.

**Practical applications:** So far as can be ascertained, no quantitative study has been made, in vitro, on the relative merits of MNT addition as a technological aid in breaking down oil-in-water emulsions. This study provides deeper insights into the clarification of the effect of pectins as emulsifier agents, on aqueous emulsions of Hojiblanca virgin olive oil and how the addition of different doses of MNT, with different physicochemical characteristics, carried out the breaking of the oil-in-water emulsions.

**Keywords:** Carbonate rate / Emulsifying activity / Micronized natural talc / Oil-in-water emulsion / Particle size / Pectins / Virgin olive oil

Received: March 8, 2015 / Revised: April 30, 2015 / Accepted: May 15, 2015

DOI: 10.1002/ejlt.201500112

## 1 Introduction

Virgin olive oil production, unlike that of other vegetable oils, is a mechanical process that consists of crushing, malaxation,

and oil separation [1–3]. Several studies showed that the most fundamental phase of the extraction process is the olive paste malaxation since it can increase the oil yield. During this mechanical step, oil remains inside the unaltered cells or is left in the colloidal system of the olive paste (microgels) and some is bound in an emulsion with the vegetable water [4]. The difficulty of releasing this bound oil can be explained because the droplets of dispersed or emulsified oil are surrounded by a lipoprotein membrane (phospholipids and proteins) [5]. Furthermore, an important potential factor in determining extractability of olive paste is the high molar mass of polymeric substances derived from cell wall polysaccharides during processing. These substances are natural emulsifier agents present in olives. They promote

**Correspondence:** Dr. Gabriel Beltrán Maza, IFAPA Centro “Venta del Llano,” Junta de Andalucía, P.O. Box 50, Mengíbar, Jaén E-23620, Spain  
**E-mail:** gabriel.beltran@juntadeandalucia.es  
**Fax:** +34 953366380

**Abbreviations:** ANOVA, analysis of variance; D50, particle size; EA, emulsifying activity; ELV, emulsified layer; HSD, honest significant difference; MNT, micronized natural talc; PGA, polygalacturonic acid; PSD, particle size distribution; SD, standard deviation; w/v, weight/volume; W<sub>v</sub>, whole volume of the solution

emulsion formation and short-term stabilization by interfacial action [6]. This effect is more important when the fruits are harvested at the first stage of ripening and have high moisture content, usually above 55% [7].

Some olive varieties, such as Hojiblanca, achieve their highest content of pectic substances during veraison stage [8] which represents the usual picking period. Harvesting at this stage may produce emulsions during malaxation due to the presence of cell wall pectic polysaccharides with emulsifying activity. These emulsions lead to the formation of the so-called difficult pastes which lessen substantially the oil yield. To break down these emulsions, some technological co-adjuvants have been successfully developed. A combination of pectolytic, cellulolytic, and hemicellulolytic plant enzymes have been used to break emulsions improving not only the oil yield but also the nutritional quality of the oil [9, 10]. Nevertheless, the use of technological coadjuvants with chemical or biochemical activity is forbidden by European regulations on virgin olive oil production [11].

The use of common salt (NaCl) could represent a feasible mean for the improvement of oil extraction [12, 13]. Its action, which is exclusively physical, is based on the repulsion between the oil and the hydrophilic phases due to the increased ionic charge as well as its density [13]. Koprivnjak et al. [14] found that a significantly higher extractability of oil from 25 to 29% compared to the control,  $p < 0.05$ , was obtained by adding 3% of NaCl. Furthermore, in a research study describing the effect of salt addition on the solubility of phenolic compounds in olive mill waste water, Noubigh et al. [15] found that as the concentration of the NaCl increases, more and more water is bound up in hydration shells depending on the salt ability to coordinate water.

Another powerful emulsion breaker authorized by European Union regulations (CE Directive 30/2001) is the calcium carbonate (E170) [4]. This aid does not react with oils because of its crystalline structure and it is easily removed by centrifugation together with olive pomace due to its high density ( $2.72 \text{ g/cm}^3$ ) and water affinity [4]. A recent research study conducted by Ben Brahim et al. [16] revealed that adding a ratio of 1.6% of calcium carbonate to the olive paste at a malaxing temperature of  $31^\circ\text{C}$  during 20 min has important advantages. Indeed, it increases oil yield by 2% phenol and pigments contents without affecting the oil quality, as well as improves the antioxidant activity.

Currently, micronized natural talc (hydrated magnesium silicate) is the most widely used co-adjuvant for oil extraction [17, 18] due to its exclusively physical action [4]. The use of talc as co-adjuvant during malaxation has been proved to improve the extractability [7, 13], but it has not a marked effect on the quality parameters of olive oil [10, 19]. The same was observed by Carrapiso et al. [17] for laboratory trials used on Carrasqueña and Picual cultivars. In general, the amount of talc used ranges from 0.3 to 1% of fresh weight [20] although an over dose can reduce the process yield.

The hydrophobicity of talc has been thoroughly studied; its breakage during milling forms two surfaces [21, 22]. One surface results from the easy breaking of the Van der Waals bonds of a surface from its neighbor [23] which forms a basal face that is hydrophobic. The other surface is generated from the ionic/covalent bonds within the layers and form edges that are hydrophilic in nature [21, 22, 24].

From the chemical point of view, the hydrophilic or ionic face would be in an unstable state immediately after the bond breakdown and would seek to react with ions of the opposite charge in order to return to their stable state. Furthermore, micronized natural talc (MNT) physicochemical characteristics vary from deposit to other. Among the most studied MNT characteristics, particles size and carbonate rate may affect substantially the break of oil-in-water emulsions and thus industrial oil yield [25, 26, 5].

The purpose of this study was to determine the effect of pectin addition, as an emulsifier agent, on aqueous emulsions of Hojiblanca virgin olive oil and how the addition of different doses of MNT with different physicochemical characteristics affects the breakdown of oil-in-water emulsions.

## 2 Materials and methods

### 2.1 Methods

For this work, olive trees (*Olea europaea* L.) of Hojiblanca cultivar with uniform characteristics were selected. The trees were spaced  $7 \times 7 \text{ m}$  and grown in the experimental orchard of Center IFAPA “Venta Del Llano”—Mengibar, Jaén (Spain) using standard growing techniques. This work was performed during the crop year 2012–2013.

Fruit samples were harvested by hand at the ripening index 4.53, according to the fruit classification based on skin and flesh color described in the ripening index method [27].

The virgin olive oil was extracted in the pilot oil mill of IFAPA Venta Del Llano equipped with a continuous extraction system (Pieralisi, Spain) working at two phases way.

In this experiment, has been determined the effect of the physicochemical properties of the MNT on the emulsifying activity (EA) of an oil-in-water system prepared with different pectin amounts. Four commercial MNTs have been used; their main physical and chemical characteristics are shown in Table 1. In the experiment, a factorial design was selected considering three variables: type of MNT (MNT1, MNT2, MNT3, and MNT4); MNT dose added to the emulsion (0, 0.25, 0.5, and 1%); and the concentration of pectin added to the emulsion (0, 0.5, 1, 1.5, and 2%). The assay was carried out by triplicate.

Emulsifying activity was assessed using the Dalev and Simeonova procedure [28]. In graduated tubes, emulsions were prepared by adding 1 mL of virgin olive oil to 2.5 mL of polygalacturonic acid (PGA) aqueous solution (0.5%, w/v),

**Table 1.** Basic data of the used micronized natural talc (MNT) used in the experiment

Coadjuvant	Carbonate (%)	Medium particle size D50 (μm)	Density (g/cm <sup>3</sup> )	Specific surface B.E.T (m <sup>2</sup> /g)
MNT 1	4	2.4	2.77	7
MNT 2	0.8	7.1	2.78	9
MNT 3	0.5	13	2.77	7
MNT 4	1.1	16.3	2.78	6

as a source of pectin. The mixture was homogenized at room temperature in a vortex mixer at maximum speed, for 3 min. Samples were centrifuged at 527 g, for 5 min, at 23°C then the whole volume of the solution ( $W_v$ ) and the emulsified layer volume were measured ( $EL_v$ ). EA was calculated using Equation (1):

$$EA = \frac{EL_v}{W_v} \times 100 \quad (1)$$

## 2.2 Statistical analysis

In the tables, results are expressed as mean values  $\pm$  standard deviation (SD). Analysis of variance (ANOVA) was applied. Tukey's HSD test was used to determine significant differences between means ( $p \leq 0.05$ ). These determinations were carried out using the software Statistix, Version 9.0.

## 3 Results and discussion

Changes in the emulsions were tested by measuring their EA. Among the factors studied, pectin amount used for oil-in-water emulsion (either with or without use of the MNT) was the main factor affecting the EA, since it represents around 86% of variability observed in the ANOVA (Table 2). Both, talc type and its dose showed a highly significant effect too, although explained a lower variability percent.

### 3.1 Effect of pectin concentration on emulsifying activity

Figure 1 shows the changes in EA with increasing pectin concentrations. EA increased with pectin percent, achieving significant differences between the higher pectins concentrations (1.5 and 2%) and the rest. However, pectin content higher than 1.5% did not produce significant raise.

For the control, without pectin addition, EA was not detected although a thin emulsion was formed after mixing. This emulsion may be due to virgin olive oil phospholipidic components that show amphiphilic character [29]. However, these emulsions were unstable and could be separated into

**Table 2.** Partial mean squares from analysis for the effect of pectin concentration and talc physicochemical characteristics and dosage on the emulsifying activity (EA)

Factor	DF <sup>a</sup>	MS <sup>b</sup>	SST <sup>c</sup>	$p^d$
Total	239			
Talc (A)	3	162.46	1.43***	0.0000
%Talc (B)	3	426.73	3.75***	0.0000
Pectins (C)	4	7336.23	86.01***	0.0000
A $\times$ B	9	23.70	0.63*	0.0245
A $\times$ C	12	17.89	0.63 <sup>ns</sup>	0.0799
B $\times$ C	12	37.35	1.31***	0.0001
A $\times$ B $\times$ C	36	11.28	1.19 <sup>ns</sup>	0.4069
Error	160	10.77	5.05	

ns: no significance.

\*Significance level  $p$ , 0.05; \*\*\*Significance level  $p$ , 0.001.

<sup>a</sup>Degree of freedom.

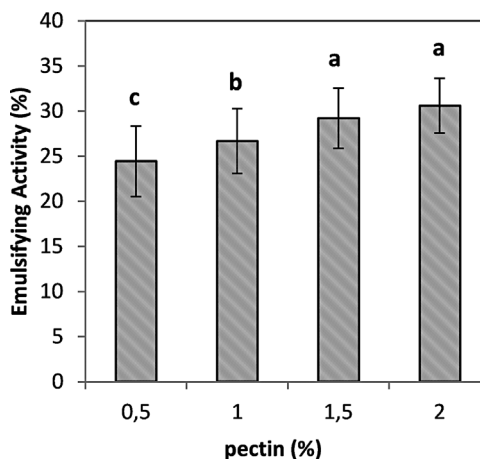
<sup>b</sup>Mean squares.

<sup>c</sup>Partial mean square for the effect expressed as percentage of the total corrected sum of square.

<sup>d</sup>Statistical significance.

two layers after centrifugation. This short-term stability can be explained by the fact that emulsions formed between oil and water are thermodynamically unstable systems that break down over time.

Pinoti et al. [30] proposed that pectin molecules adsorbed to the surface of the oil droplets of emulsion could act as polymer bridges holding the droplets together. Once pectins are strongly adsorbed to the oil-in-water interface, they can stabilize emulsions for long periods probably enhancing the electrostatic repulsion among the emulsified droplets [6]. Therefore, pectin may be considered the main responsible of the oil emulsified during processing olive difficult pastes.

**Figure 1.** Effect of pectin concentration on the EA considering the four types and doses of MNT. Different letters means significant differences at  $p$ , 0.05.

**Table 3.** Partial means squares from analysis for the effect of MNT physicochemical characteristics and dosage on the EA for each of the percentages of pectin (0.5, 1, 1.5, and 2%)

Pectin dose (%)	DF <sup>a</sup>	Total 47	MNT (%) (A) 3	MNT type (B) 3	A × B 9	Error 32
0.5	MS <sup>b</sup>	215.747	171.077***	36.234***	6.925***	1.511
	SST <sub>0</sub> <sup>c</sup>		70.06	14.84	8.51	6.60
1	MS <sup>b</sup>	196.036	156.167	32.184	6.095	1.590
	SST <sub>0</sub> <sup>c</sup>		69.84***	14.39***	8.18***	7.58
1.5	MS <sup>b</sup>	155.5227	85.8794***	62.7089***	5.5870**	1.3474
	SST <sub>0</sub> <sup>c</sup>		47.78	34.89	9.33	8.00
2	MS <sup>b</sup>	128.6811	76.9103***	46.767***	4.4200***	0.8741
	SST <sub>0</sub> <sup>c</sup>		52.69	31.84	9.08	6.39

\*\*Significance level  $p$ , 0.01; \*\*\*Significance level  $p$ , 0.001.

<sup>a</sup>Degree of freedom.

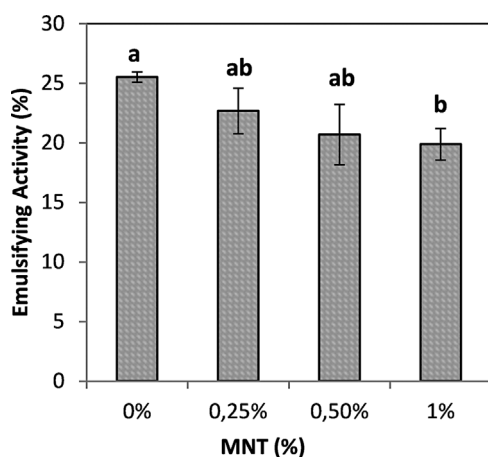
<sup>b</sup>Mean squares.

<sup>c</sup>Partial mean square for the effect, expressed as percentage, of the total corrected sum of square.

### 3.2 Effect of MNT dose on the emulsifying activity

Other significant factor affecting the EA is the MNT dose added to the emulsion. Because pectin concentration was the main responsible of EA variability and its interaction between MNT dosage and MNT type was significant, a separated ANOVA analysis for each pectin concentration was established (Table 3) in order to clarify the results discussion.

As can be seen, independently of the pectin concentration, the physicochemical characteristics of MNT used as well as its dose affected significantly ( $p \leq 0.001$ ) to the EA. Moreover, the main factor explaining the variability of EA values for all the tested pectin concentrations was the MNT dose. Considering the pool of MNT and pectin concentrations, the addition of MNT at doses between 0.25 and 1% reduced the emulsifying effect of the pectins (Fig. 2) although



**Figure 2.** Effect of MNT dosage on the EA considering the four co-adjuvant and the five pectins concentrations. Different letters means significant differences at  $p$ , 0.05.

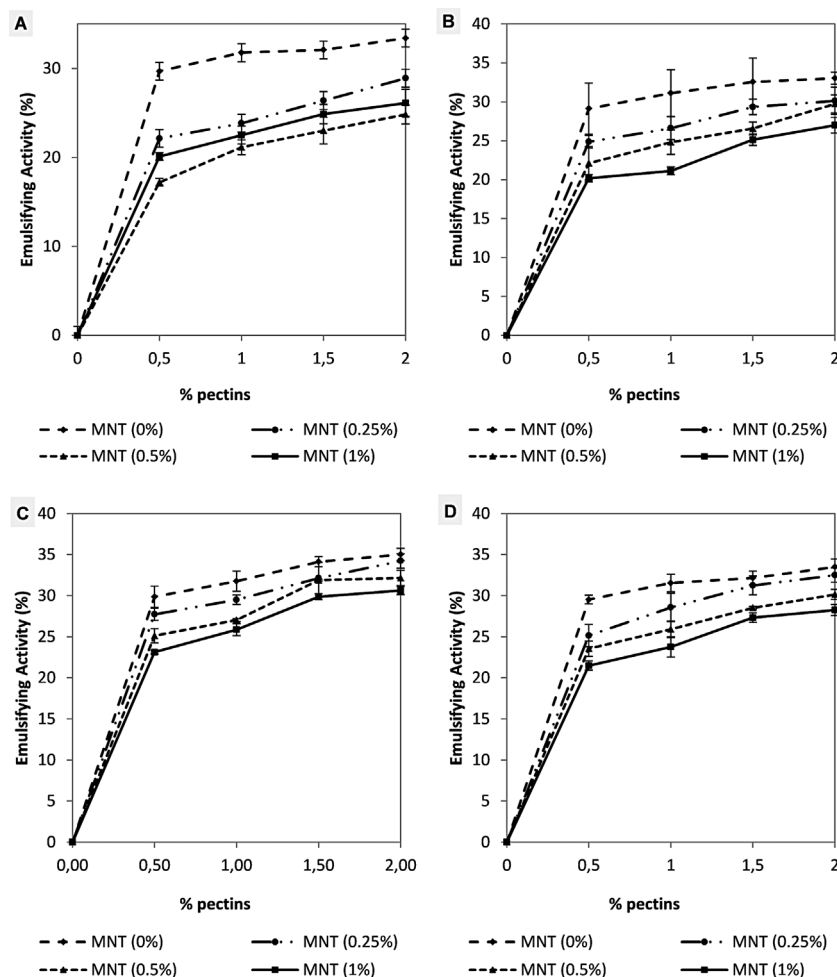
in general, significant differences could be detected only for the highest MNT dose.

In Fig. 3 can be observed how the four MNTs, at different doses, affect EA for each pectin percent. MNT1 produced the most important decrease in EA even at low doses; the best reduction was achieved at 0.5%. MNT3 showed lesser EA reduction even for the greatest dose. The effectiveness of the MNTs was lowered as pectin percent was increased in the emulsion.

The capacity of MNT to break the oil-in-water emulsions could be explained by its hydrophobic character which is responsible for the surface activity of pectin substances. In fact, the hydrophobic or ionic face of the talc would be in an unstable state and would seek to react with ions of the opposite charge in order to return to their stable state. As pectins are anionic hydrocolloid emulsifiers [31], they represent a negative charge, acting as a strong anchor point at the oil-in-water interface; therefore, producing the attraction of the positive face of talc particle and the formation of pectin–talc complex [32]. Therefore, the addition of MNT to the oil-in-water emulsions may generate electrostatic interactions between the co-adjuvant and pectins because they are two oppositely-charged components.

As can be observed in Fig. 4, the emulsified layer decreases when MNT was added. This suggests that there was enough talc present with positive charge to completely compensate the negative charge of the pectin. It can lead to a macroscopic phase separation and formation of pectin/talc complex that sediments after centrifugation. The pectin molecules adsorbed to the surface of the oil-in-water system are lowered, giving the breaking of the emulsions and the decrease of the EA caused by pectins. It depends on the MNT dose and its physicochemical characteristics.

These results are in agreement with previous works [33] that described when the amount of positive charge on the talc and negative charge on the pectin are equal, the full charge compensation could lead to aggregation of the soluble



**Figure 3.** Effect of the physicochemical talc characteristics (used at different doses) and pectin concentration on the emulsifying activity of Hojiblanca virgin olive oil. (A) MNT1, (4% (CaCO<sub>3</sub>); 2.4 μm); (B) MNT2, (0.8% (CaCO<sub>3</sub>); 7.1 μm); (C) MNT3, (0.5% (CaCO<sub>3</sub>); 13 μm); (D) MNT4, (1.1% (CaCO<sub>3</sub>); 16.3 μm).

complexes and, finally, to complex coacervation/precipitation.

Pectin-MNT complexation may affect the pectin adsorption rate at oil-in-water interfaces. Various factors may contribute to this: (i) due to complexation, the positive talc particles are partitioning over polysaccharide bound and the free state, implying that less talc is available for direct adsorption; (ii) the bound state diffuses much more slowly than the free state, because of the larger hydrodynamic radius of the pectin carrier; and (iii) the attachment of the bound talc to the oil-in-water interface may be hindered by the presence of the surrounding pectins [34].

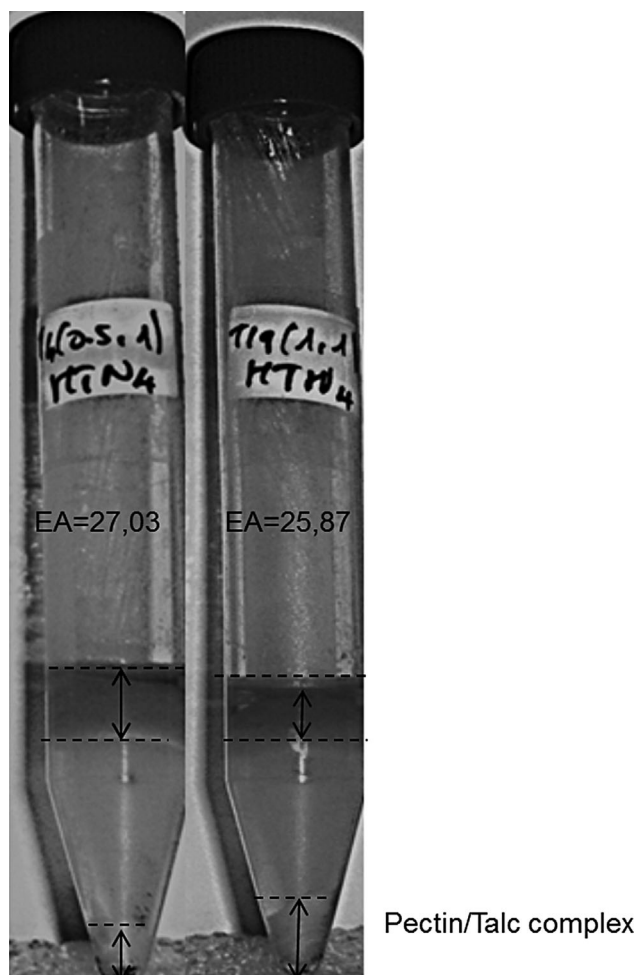
### 3.3 Effect of MNT physicochemical characteristics on emulsifying activity

When the MNTs assayed were compared, considering the pool of MNT and pectin doses, (Fig. 5) significant differences were not found between them. The highest value of EA was obtained using MNT4, characterized by the highest particle size (D50, 16.3 μm) and a carbonate rate relatively

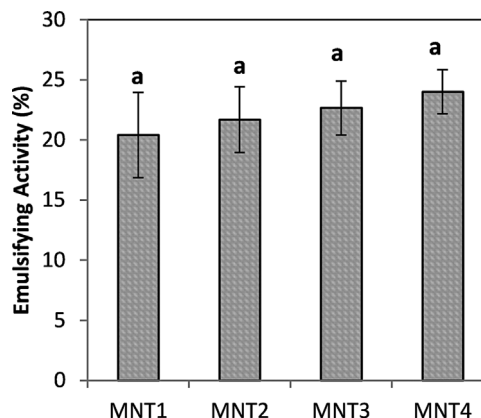
low (1.1%). The lowest EA value was obtained using MNT1 characterized by the highest carbonate rate (4%) and the lowest particle size (2.4 μm). These findings confirm the results found by other authors [25, 26] reporting as MNT physicochemical characteristics play an important role in breaking oil-in water emulsions and then, on oil yield. Therefore, the efficiency of talc to break down emulsions is not only affected by the dose applied to the emulsion but also by its mineralogical composition, morphology, and particle size distribution (PSD).

The excellent effectiveness of MNT1 was due to its fine particle size and its high carbonate content. MNT1 had the lowest D50 and thus the greatest active surface area which let to adsorb a great amount of pectin and water molecules. Furthermore, this talc (MNT1) had the highest rate of carbonate enhancing the breaking of oil-in-water emulsion by releasing oil droplets that merge into larger drops.

In order to confirm these results and explore the influence of physical and chemical characteristics of the MNT on the EA, the effect of these two parameters on emulsions has been analyzed.



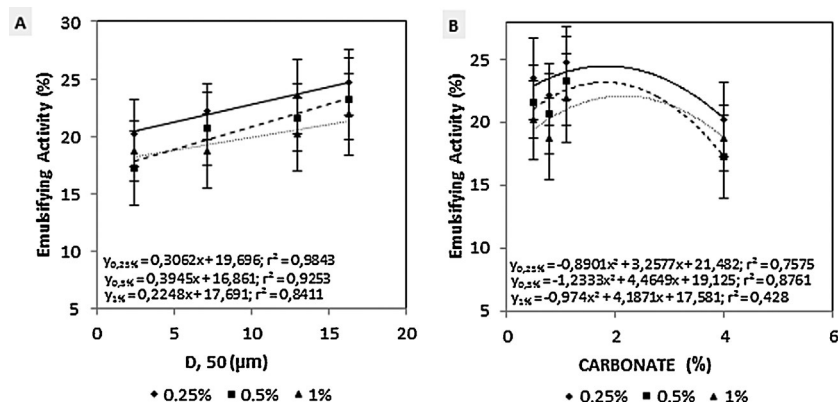
**Figure 4.** Visual observation of 1% pectin oil-in-water emulsion with addition of MNT at dose of 0.5 (T1) and 1% (T2) MNT.



**Figure 5.** Effect of MNT physicochemical characteristics on the EA considering the four MNT doses and the five pectins concentrations. Different letters means significant differences at  $p$ , 0.05.

Increased particle size seems to have a greater negative effect on EA and thus on oil extraction. For each MNT dose, EA showed a rising trend as particle size increased (Fig. 6A). The surface hydrophobicity of MNT increases as particle size was smaller due to an increase in the value of contact angles [35]. Therefore, the high hydrophobicity of MNT1 was predominantly due to the high surface area generated by its smaller particle size.

MNT for oil mill contains significant amounts of by-minerals such as carbonate. Several studies have showed that this component plays a major role in breaking down emulsions during olive paste kneading step [4]. In Fig. 6B, is shown, the use of different MNT doses induced an increase in the EA as the MNT carbonate rate increased in the range 0.5–1.1%. For higher carbonate content (4%) a marked EA decrease was obtained. Therefore, MNT containing high carbonate content showed a better capacity to break oil-in-water emulsions. Carbonate is a rich-calcium



**Figure 6.** Correlation between EA and MNT physicochemical characteristics applied at different doses. (A) Particle size, D50; (B) carbonate rate.

component and therefore, can enhance the formation of electrostatic complexes between the anionic pectic and calcium anions [36].

## 4 Conclusions

Results showed the effect of pectins on the oil-in-water interface giving an increase of the EA. It can confirm the role of pectins making oil-in-water emulsion during processing difficult olive pastes. However, this emulsifying effect of pectins can be weakened by the addition of MNT.

The capacity of MNT to break the oil-in-water emulsions could be explained by its hydrophobic character which is responsible for the surface activity of the pectin substances. The addition of MNT to the oil-in-water emulsions generated electrostatic interactions between the co-adjuvant and pectins due to their opposite charges. After olive paste centrifugation, the formed complex is sedimented, leading to a reduction of the pectin molecules adsorbed in the surface of the oil-in-water system; thus generating the break of the emulsions and the decrease of EA caused by the pectic polysaccharides.

The effectiveness of MNT to breaking emulsions depended not only on the dose but also on its physicochemical characteristics. The most efficient MNT was characterized by the highest carbonate rate and the lowest particle size achieving the lowest EA for a dose of 0.5%. Likewise, the effect of MNT physicochemical characteristics depended on the dose applied to the oil-in-water emulsion. Therefore, a higher efficiency for other MNTs with lower carbonate rate and larger particle size can be achieved by applying higher MNT doses.

*This work has been supported by a MAEC-MAEC grant (Cultural and Scientific Relations Office of the Spanish Agency for International Cooperation), the research-projects: FEDER P10-AGR-6690 (Junta de Andalucía) and FEDER-INIA RTA2008-00066-C03-01. The authors gratefully acknowledge their financial support.*

*The authors have declared no conflicts of interest.*

## References

- [1] Angerosa, F., Mostallino, R., Basti, C., Vito, R., Influence of malaxation temperature and time on the quality of virgin olive oil. *Food Chem.* 2001, 72, 19–28.
- [2] Di Giovacchino, L., Costantini, N., Ferrante, M., Serraiocco, A., Influence of malaxation time of oil extraction yields and chemical and organoleptic characteristics of virgin olive oil obtained by a centrifugal decanter at water saving. *Grasas y Aceites* 2002, 53, 179–186.
- [3] Clodoveo, M. L., Dipalmo, T., Schiano, C., La Notte, D., What's now, what's new and what's next in virgin olive oil elaboration system? A perspective on current knowledge and future trends. *J. Agri. Eng.* 2014, 14, 49–59.
- [4] Espínola, F., Moya, M., Fernández, D., Castro, E., Improved extraction of virgin olive oil using calcium carbonate as coadjuvant extractant. *J. Food Eng.* 2009, 92, 112–118.
- [5] Moya, M., Espínola, F., Fernández, D., De Torres, A., et al., Industrial trials on coadjuvants for olive oil extraction. *J. Food Eng.* 2010, 97, 57–63.
- [6] Dickinson, E., Hydrocolloids at interfaces and the influence on the properties of dispersed systems. *Food Hydrocolloid.* 2003, 17, 25–39.
- [7] Aguilera, MP., Beltrán, M., Sánchez, S., Uceda, M., Jiménez, A., Kneading olive paste from 'Picual' fruits: I. Effect on oil process yield. *J. Food. Eng.* 2010, 97, 533–538.
- [8] Mínguez-Mosquera, I., Galarido, L., Roca, M., Pectinesterase and Polygalacturonase in changes of pectic Matter in Olives (cv. Hojiblanca) intended for mill. *J. Am. Oil Chem. Soc.* 2002, 79, 93–99.
- [9] Ranalli, A., Pollastri, L., Contento, S., Iannucci, E., Lucera, L., Effect of olive paste kneading process time on the overall quality of virgin olive oil. *Eur. J. Lipid Sci. Technol.* 2003, 105, 57–67.
- [10] Cert, A., Alba, J., León-Camacho, M., Moreda, W., Pérez-Camino, M. C., Effects of talc addition and operating mode on the quality and oxidative stability of virgin oils obtained by centrifugation. *J. Agric. Food. Chem.* 1996, 44, 3930–3934.
- [11] Regulation EEC 1513/2001 as regards the extension of the period of validity of the aid scheme and the quality strategy for olive oil. European Union Commission. *Off. J. Eur. Commun.* 2001, 201.
- [12] Cruz, S., Yousfi, K., Pérez, A. G., Mariscal, C., García, J. M., Salt improves physical extraction of olive oil. *Eur. Food. Res. Tech.* 2007, 225, 359–365.
- [13] Pérez, A. G., Romero, C., Yousfi, K., García, J. M., Modulation of olive oil quality using NaCl as extraction coadjuvant. *J. Am. Oil Chem. Soc.* 2008, 85, 685–691.
- [14] Koprivnjak, O., Bubola, K. B., Kosić, U., Sodium chloride compared to talc as processing aid has similar impact on volatile compounds but more favourable on ortho-diphenols in virgin olive oil. *Eur. J. Lipid. Sci. Technol.* 2015, 117, DOI: 10.1002/ejlt.201500014
- [15] Noubigh, A., Abderrabba, M., Provost, E., Temperature and salt addition effects on the solubility behaviour of some phenolic compounds in water. *J. Chem. Thermodynamics.* 2006, 39, 297–303.
- [16] Ben Bahim, S., Marrakchi, F., Gargouri, B., Bouaziz, M., Optimization of malaxing conditions using CaCO<sub>3</sub> as a coadjuvant: A method to increase yield and quality of extra virgin olive oil cv. Chemlali. *LWT- Food. Sci. Technol.* 2015, 1–10.
- [17] Carrapiso, A. I., García, A., Petró, J., Martín, L., Effect of talc and water addition on olive oil quality and antioxidants. *Eur. J. Lipid. Sci. Technol.* 2013, 115, 583–588.
- [18] Hermoso, M., González, J., Uceda, M., García-Ortiz, A., et al., Elaboración de aceite de oliva de calidad. Obtención por el sistema de dos fases. Informaciones técnicas, 1998, Direc. Gral. de Investigación y formación agraria Junta de Andalucía.
- [19] Ben-David, E., Kerem, Z., Zipori, I., Weissbein, S., et al., Optimization of the Abencor system to extract olive oil from

- irrigated orchards. *Eur. J. Lipid. Sci. Technol.* 2010, 112, 1158–1165.
- [20] Clodoveo, M. L., Malaxation influence on virgin olive oil quality. Past, present and future. An overview. *Trends. Food. Sci. Tech.* 2012, 25, 13–23.
- [21] Jenkins, P., Ralston, J., The adsorption of polysaccharide at the talc-aqueous solution. *Colloids Surf. A.* 1998, 139, 27–40.
- [22] Morris, G. E., Fomasiero, D., Ralston, J., Polymer depressant at the talc-water interface: Adsorption isotherm, microflotation and electrokinetic studies. *Int. J. Miner. Process.* 2002, 30, 1–17.
- [23] Moore, D. M., Reynolds, R. C. J., *X-Ray Diffraction and the Identification of Clay Minerals*. Oxford University Press, Inc, Oxford, New York 1989.
- [24] Yahia, A., Al-Wakeel, M. L., *Technical Note Talc Separation From Talc-Carbonate Ore to Be Suitable for Different Industrial Applications*. *Miner. Eng.* 2000, 13, 11–116.
- [25] Sánchez, S., Pacheco, R., La Rubia, M. D., Sánchez A., Pereira M. G., Aplicación de distintos talcos naturales, como coadyuvantes tecnológicos, en los procesos de extracción de aceites de oliva. En: Acta del Oliva. Fundación para la promoción, el desarrollo del olivar y del aceite de oliva (Ed.), *Simposium Científico-Técnico. Expoliva*, Jaén (Spain) 2007, pp 497–502.
- [26] Alba, J., Moyano, J., Martínez, F., Hidalgo, F., Influencia de la granulometría y del contenido de carbonatos del talco sobre el rendimiento en aceite de oliva virgen. *XII Simposium Científico-Técnico. Expoliva*, Jaén (Spain) 2005.
- [27] Uceda, M., Frías, L., Épocas de recolección. Evolución del contenido graso y de la composición y la calidad del aceite. *Proceeding II Seminario Oleícola Internacional*, Córdoba 1975.
- [28] Dalev, P. G., Simeonova, L. S., Emulsifying properties of protein-pectin complexes and their use in oil contain foodstuffs. *J. Sci. Food. Agric.* 1995, 68, 203–206.
- [29] Pichot, R., Watson, R. L., Norton, I. T., Phospholipids at the interface: Current trends and challenges. *Int. J. Mol. Sci.* 2013, 14, 11767–11794.
- [30] Pinotti, A., Belvilacqua, A., Zaritzki, N., Optimization of the flocculation stage in a model system of food emulsion waste using chitosan as a polyelectrolyte. *J. Food. Eng.* 1997, 32, 69–89.
- [31] Moreau, L., Kim, H. J., McClement, D. J., Production and characterization of oil-in-water emulsions containing droplets stabilized by beta-lactoglobulin-pectin membranes. *J. Agric. Food Chem.* 2003, 51, 6612–6617.
- [32] Weinbreek, F., Nieuwenhuijse, H., Robijn, G. W., De Kruif, C. G., Complex formation of whey proteins: Exocellular saccharide EPS B40. *Langmuir* 2003, 9, 9404–9410.
- [33] Ganzevles, R. A., Martien, A., Stuart, C., Van Vilet, T., Jongh, H. H. J., Use of polysaccharides to control protein adsorption to the air-water interface. *Food Hydrocolloid.* 2006, 20, 872–878.
- [34] Ganzevles, R. A., Polysaccharide charge density regulating protein adsorption to air/water interfaces by protein/polysaccharide complex formation. *J. Phys. Chem. B.* 2007, 111, 12969–12976.
- [35] Öksüz, M., Eroglu, M., Yildirim, H., Effect of talc on the properties of polypropylene/ethylene/diene terpolymer blends. *J. Appl. Polym. Sci.* 2006, 101, 3033–3039.
- [36] Nguyen, H. V., Savage, G. P., The effect of temperature and pH on the extraction of oxalate and pectin from green kiwifruit (*Actinidia deliciosa* L.), golden kiwifruit (*Actinidia chinensis* L.), kiwiberry (*Actinidia arguta*) and persimmon (*Diospyros kaki*). *Int. J. Food. Sci. Tech.* 2012, 48, 794–800.