Asian Journal of Chemistry; Vol. 26, No. 9 (2014), 2629-2631

ASIAN JOURNAL OF CHEMISTRY

http://dx.doi.org/10.14233/ajchem.2014.15770

# Zeta Potential as Criterion of Electrocoagulation Process Control in Acid Whey

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*Received*: 14 May 2013; *Accepted*: 11 September 2013; *Published online*: 28 April 2014; AJC-15084

The electrocoagulation (EC) is a technique used for treatment of various waste waters. In this process, contaminants are removed suspended, emulsified or dissolved in the aqueous medium, inducing electric current through metal plates. The zeta potential (ζ) is an important parameter for electrostatic particles suspended in an aqueous medium as an index of evaluating the stability of colloidal dispersions with respect to the aggregation of particles. The aim of this work was to study the application of electrocoagulation process under conditions previously optimized for the treatment of organic load removal (COD), color and turbidity in a batch type electrochemical reactor. The results showed that it is possible to achieve optimum process performance while electrocoagulation sedimentation and reduction of the organic load present in the acid whey, carrying out measurements in the liquid phase zeta potential whey as an indicator of effectiveness electrocoagulated destabilization particles. The zeta potential positively correlated with pH and effective initial direct correlation with the color (measured as absorbance of purified liquid) and turbidity.

**Keywords: Acid whey, Zeta potential, Turbidity, Electrocogulation, Correlation.**

## INTRODUCTION

Whey is defined as liquid substance obtained by removal of clot milk in cheese making[1-5]. It is a translucent liquid yellowish green, milk obtained after precipitation of the protein (casein)[5]. The whey is released, corresponding to about 83 % of the volume of milk used as raw material. This residue corresponds to the effluent that causes more pollution in the dairies, as it contains large amount of lactose and proteins. It is therefore advisable that these sera is not dumped directly into the channel or sewage, as would cause a huge increase in BOD and COD.

Chemical coagulation is the most important step to determine the removal efficiency in coagulation/flocculation/clarification of aqueous waste and its associated costs. It is therefore important that these processes are optimized and controlled removal[6]. Coagulation is a process related to the surface charges of the suspended particles, therefore, the addition of chemicals reduces the negative surface charge of the suspended particles, so that it becomes unstable and promotes agglomeration and subsequent formation of aggregate[7].

For some years, in countries like the former Soviet Union, United States of America, Canada, Germany, Brazil and Mexico, are investigating and applying an unconventional system to remove contaminants from industrial wastewater and domestic Electrochemical Wastewater Treatment (EWT). The electrocoagulation (EC) is a technique used for the treatment of various waste waters. The treatment consists of passing a direct current through two electrodes which can be aluminum, copper, iron, titanium, graphite, steel, platinum, among others, immersed in the effluent to be treated[8,9].

In this process the removal of are either by contaminants suspended, emulsified or dissolved in the aqueous medium inducing electric current in the aqueous phase through the metal plates. In this case, the function of removing contaminants is performed by the electric current applied to the contaminated medium[10] and makes use of a chemical coagulant.

The zeta potential (ζ) for its part, is an important parameter for electrostatic particles suspended in an aqueous medium as an index of evaluating the stability of the colloidal dispersions suspended with respect to the aggregation of particles and the subsequent understanding of the physical operations such as flocculation, flotation and sedimentation of these suspensions[11]. The zeta potential is defined as the shear in the plane of the electrical double layer is frequently used in discussions of colloid stability and its value is considered useful in connection with the electrical double layer[12]. The double layer portion is divided into a compact adjacent to the surface and a diffuse part. In the mobile ions are diffused obey laws and statistical mechanics, the counterions are drawn through the surface and are repelled coiones[13]. There is evidence that the electric double layer model is simplified although in many respects, is sufficient to encompass the essential characteristics of reality[14]. The zeta is located close to the cutting plane, at the boundary of the diffuse layer and represents the actual location of the solid-liquid interface[15].

Electrokinetic phenomena are used to obtain information about the electrical state of the solid-liquid interface. In particular the concept zeta potential is a transcendental to relate measurable macroscopic quantities with microscopic parameters characterizing the state of colloids[16].

There are a number of techniques to measure the ζ, one of which is electrophoresis. This method determines the potential placing fine particles in an electric field and measuring their mobility. The mobility is related to the ζ using the Smoluchowski equation[17].

Other techniques for measuring the electroacoustic ζ as useful tools for measuring the potential in aqueous suspension concentrates, which uses sound waves to generate potential differences in the suspension macroscopic[18].

The aim of this work was to study the feasibility of application and for a process for the treatment of electrocoagulation removal of the organic load, coloring and acid whey turbidity in a batch type electrochemical reactor.

## EXPERIMENTAL

Whey was obtained from dairy production plant of the Institute of Agricultural Sciences of the Autonomous University of the State of Hidalgo, in Tulancingo, Hidalgo, Mexico. It was transported and stored under refrigeration in glass containers previously sterilized to prevent degradation. Whey was analyzed initially in content and pH, zeta potential (ζ), isoelectric point (pI) and chemical oxygen demand (COD). The purified samples were also analyzed liquid during and after the conclusion electrocoagulation these processes. CD is carried out under conditions optimized in previous studies, a 2-L reactor (Fig. 1) aluminum anode, cathode, graphite applied voltage of 4.67 Volts, the fluid dynamic conditions of 39.6 whey L min$^{-1}$, electrode spacing of 1 cm and a time of 8 h[9].

The COD was determined by the method according to the open reflux[19-21]. The pH determination was performed with a potentiometer Conductronic (model PH10) and zeta potential (ζ) Zeta-sizer team signature Malvern, model 3000 Hsa[22] ζ measurements were performed with variations in pH between 1.0-10.0 to evaluate the point Pi initial acid whey. Turbidity measurements were performed using HACH 2100 AN turbidimeter and colorimeter color HACH DR 2800 wavelength of 475 nm[23-24]. In the case of color determination applied the methodology proposed by some authors[9,25,26].

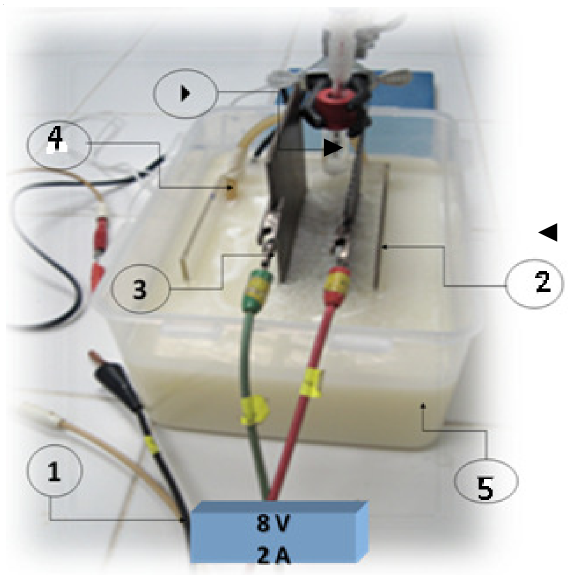


Fig. 1. Electrochemical cell with recirculation of the solution of whey. 1. Potentiostat / galvanostat 2. Anode: aluminum 3. Cathode: graphite 4. Recirculation pump 5. Effluent (whey) from cheese making

The tests were conducted over a period of ten months between September 2011 and July 2012, were conducted with different samples of acid whey is systematically brought to the laboratory as indicated, comprising initial turbidity values ranging between 2.31 NTU and 211 NTU and with a color ranging equally apparent in absorbance units at 475 nm, between 0074 and 0241, with samples taken at different times covering morning and evening. The initial ζ showed variations between -4.9 mV and -13.6 mV, being within the range suggested that particles generated are usually present in such aqueous residue -1 mV to -40 mV[27].

## RESULTS AND DISCUSSION

Fig. 2 shows values of ζ whey samples obtained after the electrocoagulation and their association with the minimum values of parameters and color turbidity of the refined liquid, ie separate parts after each experiment resulting flocculated (30 total of three per month).

We observed an average value of ζ found to -4.03 and 3.06 mV for turbidity NTU (dotted lines). Performing a statistical inference on mean ζ desired optimum with a significance level of 5 %, this value should be optimal ζ is 0 mV (p = 0.7638) as proposed in work reported[28] with a confidence interval of 95 %. For the average found confidence interval ranged from -3.64 mV to -4.22 mV. This indicates that as the value of ζ purified whey by electrocoagulation under the conditions already studied, approaches 0 mV, it would be finding the optimum pH value (point isoelétrico) for total precipitation of casein in milk in the preparation of cheese and as reported[9], is 4.67. During the study period and sampling (10 months) of whey, the average pH value was found 4.82 ± 0.16 (confidence interval 4.66-4.98). This shows that during the manufacturing process of cheese making, to despite a strict quality control is not achieved the complete elimination of casein in milk.

Similarly, Fig. 3 shows the values of ζ whey samples after CD and its association with the minimum color values purified

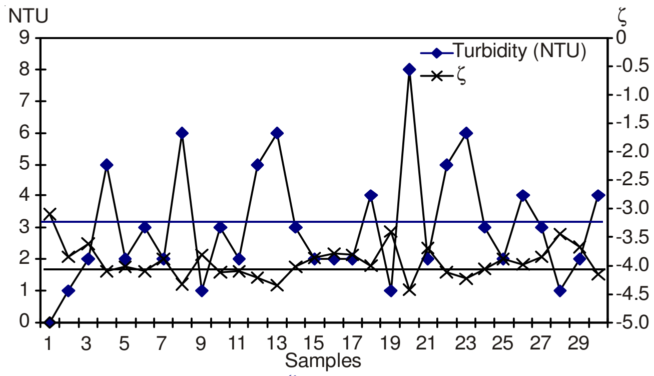

Fig. 2. Values of zeta potential (ζ) in the acid whey purified by EC, resulting turbidity associated with each experiment

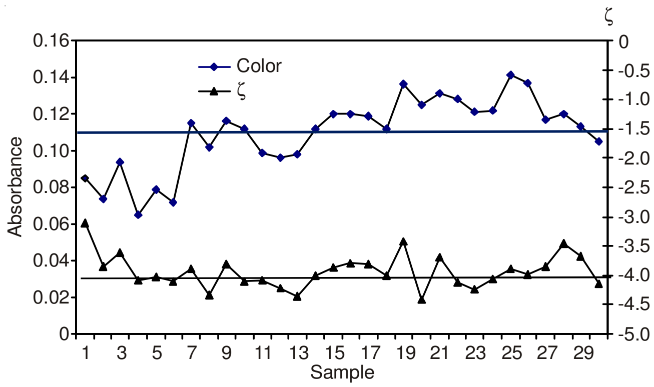

Fig. 3. Zeta potential values (ζ) in acid whey purified by EC, associated with the absorbance of the resulting

liquid (reported as absorbance at 475 nm). Notably significantly, the initial color of the whey samples was yellowish white turbidity was always present and marked, then the process of CD greenish yellow coloration but with minimal turbidity. This figure shows a direct correspondence between absorbance values and ζ, it is noted that ups and downs occur proportionally. It may be noted that on average was obtained for ζ of -4.03 mV ± 0.29 mV and 0.02 ± 0.110 absorbance.

Previous studies[29] state that depends ζ particles and the type of ions that make up the electrolyte solution in which are suspended colloids. In the case of whey will have negative charges of the colloidal particles of organic matter. Because of this, it is expected that a higher concentration of negative ions in the electrolytic solution, ζ values of suspended colloids tend to be more negative. To the extent that the process is performed electrocoagulation reactions occur:

**Cathode:** $3/2O_{2(g)} + 3H_2O_{(l)} + 6e^-$
$\Longrightarrow 6OH^-_{(ac)}$ E° = 0,40V

**Anode:** $2\,Al^0_{(s)} \Longrightarrow 2\,Al^{3+}_{(ac)} + 6e^-$ E° = 1,66 V

**Global equation:** $3/2O_{2(g)} + 3H_2O_{(l)} + 2\,Al^0_{(s)}$
$\Longrightarrow 2Al^{3+}_{(ac)} + 6OH^-_{(ac)}$
$\Longrightarrow Al(OH)_{3(s)}$

During the formation of $Al(OH)_3$ is produced by coprecipitation occlusion, solubilized organic species or in colloidal form which corroborates the disruption of emulsion stability and the process of flocculation and/or sedimentation[9].

When zeta potential values away from zero and have values lower than -4.0 mV, then values are above 3 turbidity in NTU and purified whey is directly related to absorbance values greater than 0.110.

## Conclusion

It is possible to achieve optimum process performance optimized electrocoagulation and under conditions indicated above and at the same time a reduction of the sedimentation and organic load present in the acid whey, carrying out measurements in the liquid phase ζ whey as an indicator electrocoagulated effectiveness of destabilization of the particles. The ζ is positively and effectively with the initial pH, direct correlation with the color (measured as absorbance of purified liquid) and turbidity.

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