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TÍTULO PROYECTO : MODELING THE EFFECT OF MICROSTRUCTURE AND PROCESSING IN THE PREDICTION OF MAILLARD'S UNDESIRABLE COMPOUNDS DEVELOPMENT IN STARCH FOOD MATRIXES USING NON-DESTRUCTIVE IMAGING METHODS

DISCIPLINA PRINCIPAL : OTRAS ESPECIALIDADES DE LA INGENIERIA
GRUPO DE ESTUDIO : INGENIERIA 3
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DIRECCIÓN :
COMUNA :
CIUDAD : SANTIAGO
REGIÓN : METROPOLITANA

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**OBJETIVOS**

Cumplimiento de los Objetivos planteados en la etapa final, o pendientes de cumplir. Recuerde que en esta sección debe referirse a objetivos desarrollados, NO listar actividades desarrolladas.

<table>
<thead>
<tr>
<th>Nº</th>
<th>OBJETIVOS</th>
<th>CUMPLIMIENTO</th>
<th>FUNDAMENTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>To know how the formulation affects the microstructure and then the development of Maillard compounds (Acrylamide, furan and HMF) behavior</td>
<td>TOTAL</td>
<td>An objective pattern recognition technique to evaluate the microstructure of variable processing / formulation samples was developed. The Effect of HMF and Furan in matrixes formulated with variable processing / formulation conditions was evaluated. In this means, the effect of gluten, fiber, sucrose glucose content and type of native starch (wheat and potato) was evaluated.</td>
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<tr>
<td>2</td>
<td>To compare the mechanical effect in the dough formation in the development of Maillard compounds as well as in the microstructure</td>
<td>TOTAL</td>
<td>The combination of two levels of mechanical factors involved in dough formation were tested. Rolling out time, kneading time, kneading temperature was tested onto microstructure analysis. Effect of mechanical processing had a slight effect on microstructure. HMF and Acrylamide was determined founding no effect.</td>
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<tr>
<td>3</td>
<td>To compare the effect of starch, fibre, proteins and reducing sugars on the food microstructure, as well, in the non enzymatic browning during processing.</td>
<td>TOTAL</td>
<td>The effect of reducing sugar (comparison of glucose- fructose sugars in formulated samples), type of starch (Potato or wheat), the amount of fibre and the content of gluten on the microstructure and HMF formation was evaluated.</td>
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<td>4</td>
<td>To establish the interactions among food components in the non enzymatic browning and Maillard’s intermediate development.</td>
<td>TOTAL</td>
<td>The non-enzymatic browning effect of 3-level multi-component (dietary fiber, fat and gluten), time and temperature were studied under microstructural perspective. In matrices elaborated with wheat starch, from multiway ANOVA having as independent variable ingredient type, ingredient level and bake time, was found that the type of ingredient had a significant effect on diameter and C. The diameter and circularity values were lower to fat, followed by dietary fiber and was higher to gluten. Regarding the development of browning in the matrices, the brightness value L decreased during baking. The proportion of this decrease was different depending on the formulation, being higher for made with potato starch (lower value of L) matrices. The biggest change in color was observed between 13 and 19 minutes.</td>
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<td>5</td>
<td>To determine de degree of reliability of prediction and classification models in the correlation of sample color and spectral image information during thermal processing with the development of Maillard reaction compounds.</td>
<td>TOTAL</td>
<td>Models to establish de degree of prediction and classification were developed under PLS regression methodology by using computer vision image features. Then, ten strategies were tested in order to select the most relevant image features able to improve the performance of the predictive models to build. These strategies include prediction with grouped chromatic, geometrical and textural features and an intermediate step of feature selection based on interval least square regression (iPLS), interval multiple linear regression (iMLR) and genetic algorithm (GA). Finally, the best predictions with all the extracted features per class were obtained with intensity features. Selecting whole features suggests that textural ones are good enough to predict the furan content by themselves.</td>
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<tr>
<td>6</td>
<td>To determine the effect of thermal processing in matrixes (i.e. vacuum and laser, microwave and radiofrequency baking) in the Maillard intermediate formation.</td>
<td>TOTAL</td>
<td>Effect of thermal processing on the Maillard reaction formation was accomplished by using traditional Baking (oven) and radiation baking. Both treatments were preferred over vacuum, laser and microwave since neo-contaminant compounds formation studies is a recently topic of investigation and its micro - meso and macro structural formation required more deep in this study. Two Maillard intermediate formation were studied: HMF and Furan. Effect of thermal processing was also studied under mass and heat transference modeling wish was not originally considered, however, this side offer a better understanding in deep over an horizontal expansion.</td>
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<td>7</td>
<td>To study the microwave cooking in the development of non enzymatic browning compounds.</td>
<td>TOTAL A boundary study in order to define microwave cooking condition for furan and HMF formation was establish. No detection (LOD~10 um/kg for furan) was observed for a feasible microwave use in dough (20 min x 1000 W). Over this condition, doughs were not in edible condition (texture).</td>
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<td>8</td>
<td>To demonstrate the feasibility of sorting the quality of baked / cooked products based in toxic levels of Maillard undesirable compounds using non-destructive technologies.</td>
<td>TOTAL Starchy doughs were fried at 150, 160, 170, 180, and 190°C for 5, 7, 9, 11, 13, and 30 min; the furan content was measured, and some color images were extracted. To train the classifier, the furan content was quantified by gas chromatography–mass spectrometry (GC–MS). Corresponding images were acquired and processed to extract 2175 chromatic and textural features. Principal component analysis (PCA) was used to reduce the dimensionality to 8–12 principal components. In parallel, sequential forward selection (SFS) coupled with linear discriminant analysis (LDA) was the best strategy to select only 5-7 features, being mean intensity measured in red channel (R) and local binary patterns (LBP) the most important. Remarkable results show that LDA resulting in the best classifier, 91.39-97.60 % of samples above 113 µg/kg. Finally, support vector machine (SVM) recognized 87.71-96.74% of class 3 (114-398 µg/kg) from class 4 (399-646 µg/kg).</td>
<td></td>
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</table>

Otro(s) aspecto(s) que Ud. considere importante(s) en la evaluación del cumplimiento de objetivos planteados en la propuesta original o en las modificaciones autorizadas por los Consejos.

Deseo reconocer el apoyo de Universidad de Santiago de Chile Universidad tecnológica Metropolitana que a través de profesores y directores de departamento ofrecieron apoyo a la realización de la experimentación. También al apoyo de MSc. Germán Mondragón por su apoyo en métodos estadísticos y Dra. Marcela Quilaqueo y de Insense Limitada quienes apoyaron en el análisis de microestructura y de modelación matemática.
RESULTADOS OBTENIDOS:

Para cada uno de los objetivos específicos, describa o resuma los resultados. Relacione las publicaciones y/o manuscritos enviados a publicación con los objetivos específicos. En la sección Anexos incluya información adicional que considere pertinente para efectos de la evaluación. 
La extensión máxima de esta sección es de 5 páginas (letra tamaño 10, Arial o Verdana). 

RESULTADOS OBTENIDOS:

1. To know how the formulation affects the microstructure and then the development of Maillard compounds (Acrylamide, furan and HMF) behavior.
2. To compare the mechanical effect in the dough formation (e.g. rolling out, kneading) in the development of Maillard compounds as well as in the microstructure.
3. To compare the effect of starch, fiber, proteins and reducing sugars on the food microstructure, as well, in the non-enzymatic browning during processing.

First objectives were accomplished using a two-step multivariate analysis
First experimentation Brief procedure This study proposes a methodology to determine the effect of formulation and processing on baked starchy samples microstructure development using selected textural features. Automatic Pattern recognition methodology was evaluated by it capability of sorting scanning electron microscopic (SEM) images of 16 different formulation of baked starchy models. Sixteen groups of 30 replicated samples were designed with a Plackett Burman fractional experimental design (11 factors and central points). Formulation designs factors were amount of: starch, shortening, baking powder, water, gluten, glucose, and sucrose. Processing design factors were kneading time and temperature, oven time and temperature. From formulation, six samples were randomly selected. Selected samples were imaged under three magnification (200X, 1000X and 2000X). Images were divided in six parts achieving 36 sub-images per formulation group. Later, images were processed and textural (176) features were extracted, selected (SFS) in order to implement classification and cross validation methodology.

Good level of performance shows objective differences in microstructure caused by formulation and processing conditions. Best results indicate more information from 1000X images. 

MAGNIFICATION Best selected features PERFORMANCE 2000 X 15 63.11% (51.97, 74.25%) 1000 X 18 86.99% (81.50, 92.48%) 200 X 20 84.79% (78.92, 90.65%) 

Classification with 1000X SEM images presented higher values than images of 200X or 2000X. This methodology (SFS) was able to automatically select best unspecific features, extracting only the relevant information in less than the 10% of the original data. From three magnifications, best features include some Local Binary Patterns, and Haralick features. Fig. 4 show a visual example from 1000X SEM images of two formulations and the behavior of one-selected features for 13 formulations included the two formulations presented.

Best-selected features were: Local Binary Pattern 3 (1 and 35 sampling points and 8 neighbors) and Haralick 7th feature (sum of variance with one pixel of distance). For 1000X images, best-selected features were used to evaluate the effects of formulation and processing. Figure 4 also shows Pareto’s graph for standardized effects when sum of variance is used as response in statistical design. 95% of significance was not reach in this study. However, in the design, only one feature was used to evaluate the effects. Effects of water, starch, shortening content and kneading time had higher statistical significance over texture than time and temperature of backing, gluten and kneading temperature. Despite Plackett Burman design is highly fractionated, is interesting to know de descendent degree of relevance of compositional and formulation aspect in the behavior of microstructure.

Second experimentation Brief procedure First multivariate analysis (detailed above) demonstrate the capability of computer vision algorithms to recognize formulation /processing conditions with computer vision algorithms applied to microstructural SEM images. Second experimentation was conducted to proof on the effect of several formulation conditions under a single baking condition. Formulation condition involves degree of sucrose, shortening, and fiber. Processing consisted on a baked four time kinetic construction. In total 12 formulations were carried to four times of baking to know the effect of thermal treatment. in order to reveal the formulation/processing effect on Maillard reaction and microstructure, Analysis of acrylamide in samples was performed. However all samples results were shown under limit of detection.
Hence, HMF was determined under HPLCDAD being its calibration curve $\text{Area} = 2.9825 \times \text{Concentration} \ [\text{mg/kg}]$.

Principal Findings from twelve kinetic of starchy baked samples, an intermediate processing time (19 min of baking) was elected to study the effect of formulation on HMF development (Fig. 3). Potato starch has an important influence on HMF development in comparison with Wheat starch. This is probably caused for asparagine, an amino acid found in more concentration in potato than wheat who acts as precursor of Maillard reaction. Increment of gluten in formulation has a positive toxicological effect since cause a reduction of HMF content. Interesting, increasing of shortening (fat) content, cause a increment of HMF, but in minor degree. Fiber content also increases the content of HMF. Probably this could be caused for fructosans, a type of fiber who is also known as Maillard precursor.

Formulation has an important role in microstructure formation. Result shows how image analysis could be used as tool to find differences in classification. For instance, in an automatic classification of samples with differences in composition Experiment the performances were:

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Performance (Confidence interval)</th>
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<tbody>
<tr>
<td>Four formulations (4 classes)</td>
<td>Potato flour: 91.20 (85.58-95.83)</td>
</tr>
<tr>
<td>Low Sucrose v/s High Sucrose</td>
<td>97.94 (95.63-100.00)</td>
</tr>
<tr>
<td>Low Shortening v/s High Shortening</td>
<td>87.09 (81.61-92.57)</td>
</tr>
<tr>
<td>Low fiber v/s high fibre</td>
<td>79.67 (73.10-86.24)</td>
</tr>
<tr>
<td>Low gluten v/s high gluten</td>
<td>84.31 (78.37-90.25)</td>
</tr>
</tbody>
</table>

The development of the microstructure was evaluated by analyzing images obtained in a scanning electron microscope (SEM). Samples were also analyzed under an optical microscope and were determined color using a system of computer vision. The aim of this research was to determine the effect of composition (dietary fiber DF, fat F, and gluten G) and baking time, over microstructure of cookies elaborated with wheat and potato starch. The samples were prepared mixing 10 g of DF, 30 g of G, 178 g of starch, 20 g of glucose, 0.2 of sodium chloride and 117 g of distilled water, and were baked at 230°C. Microstructure was studied analyzing images obtained from scanning electron microscope (SEM). The NEB was evaluated by color image analysis. Through analysis of SEM images it was found that at the end of baking, the starch granules keeping their native form, meaning that they were not completely gelatinized, and their size was similar at different baking times. However, samples with different levels of DF and G increased their circularity over baking. NEB was developed during baking and the maximum increase was observed between 13 and 19 min, reflected by decreasing of luminosity (L) value. After that, luminosity did not vary significantly. The ingredients used and their levels can affect L values of samples. Thus, suitably selecting the components and their levels could be obtained different types of microstructures with different level of NEB of biscuits. This characteristics could be focused toward the development of products with better nutritional quality (e.g. low degree of gelatinization that is related with slow digestibility of starch; not excess development of NEB that is related with occurrence of toxic compounds), seeking not diminish the sensory quality.

4. To determine the degree of reliability of prediction and classification models in the correlation of sample color and spectral image information during thermal processing with the development of Maillard reaction compounds.

Brief procedure In order to test algorithms for predicting Maillard reaction compounds, an experiment consisted in correlate furan content and color image features from starchy fried models was performed. The objective of this study was to implement furan predictive models in starchy matrices based on partial least square regression (PLS) by digital processing of color images acquired by a computer vision system. For this mean, fried starchy samples composed of 60 % wheat flour and 40% water were fried at selected different time–temperature conditions: 5
frying times (5, 7, 9, 11 and 13 min) and 5 oil temperatures (150, 160, 170, 180 and 190ºC). Furan content in fried samples was quantified by gas chromatography/mass spectrometry (GC/MS) analysis and simultaneously their corresponding color images were acquired in standard conditions, segmented and, then, processed in order to perform a subsequent extraction of 2914 geometrical, textural and chromatic features. Then, ten strategies were tested in order to select the most relevant image features able to improve the performance of the predictive models to build. These strategies include prediction with grouped chromatic, geometrical and textural features and an intermediate step of feature selection based on interval least square regression (iPLS), interval multiple linear regression (iMLR) and genetic algorithm (GA).

**Principal findings**

Color measurement was very important to build predictive models since this research considers that furan content correlates with other NEBR compounds as well, such as melanoids and acrylamide, which may provide also information for furan estimation in samples. Calibration and prediction results First set of experiments consisted on testing total number of features (i.e. all extracted features 2914, geometric 54, intensity 48 and texture 2811) by classes without an intermediate step of selection. Modeling was performed with all the extracted features (geometric, chromatic, and textural features). Result shows scarcely correlation between features and furan content (Rc = 0.51 ± 0.05 and Rp = 0.38 ± 0.17) with high error or prediction values of 173 ± 32.5 µg/kg and a RPD value under 1.5 (1.01 ± 0.17), model is not successful for classification neither for prediction. Despite PLS algorithm is specially robust for correlated or even collinear information, a possible cause of this discrete result maybe the high amount of features utilized (2914) with redundant information may affect the formation of orthogonal latent variables. When features were grouped into classes to modeling, better prediction results were obtained with features extracted from chromatic features than geometric or textural. Rc values ranged between 0.51 and 0.86, while Rp values were between 0.38 and 0.84, with the RMSEPs of 172.8-94.4 µg/kg (Figure 6a). The RPD values were between 1.01 and 1.86. In this mean, chromatic features shown best predictive model able to sort two classes of furan content (RPD of 1.86, above from 1.5). Chromatic features could represent changes product of MR, specifically for instance melanoids, a group of high molecular weight nitrogen brown colored compounds whose formation have a similar route to furan at high temperature processing (Alves and Perrone, 2015). Strategies to select features to improve prediction in order to improve the capacity of systems to sort or predict a preliminary step of feature selection was implemented by using three algorithms: (i) interval partial least square (iPLS), (ii) interval multiple linear regression (iMLR), (iii) genetic algorithms (GA). The iPLS algorithm was applied separately with all extracted features, geometric, chromatic and textural features (Table 3). Results showed the possibility of not only separation in two classes, but also the prediction using only ten selected textural features. Thus, textural features may offer information regarding the development of NEBR, yielding a different value to samples with intermediate thermal treatments in comparison to samples that are either full of singularities such as bubbles, porous regions, or fissures.

Color image features are able to predict furan concentration in fried starchy model systems. Results indicate that the best prediction of furan contents between geometric, textural and intensity was obtained with intensity features (Rp of 0.92 and RPD of 1.86). After feature selection, prediction results improve significantly: Rp of 0.93 and RPD of 2.66 for the best data set performed with iPLS of textural features and Rp of 0.92 and RPD of 2.55 for iMLR selecting whole features, respectively. These results suggest that textural features in color images of deep fried starchy food models are good enough to predict the furan content. Reduced number of features ensures better feasibility of model implementation in sorting lines increasing the capacity of equipment and reducing the necessity of complex computational implementation of feature extraction. More research is needed to assess furan content in starchy food matrix before an industrial implementation. Factors such as formulation and processing condition and microstructure also should be studied.

5. **To determine the effect of thermal processing in matrixes (i.e. vacuum and laser, microwave and radiofrequency baking) in the Maillard intermediate formation.**

In order to generate samples with a wide range of furan contents to allow better modeling, frying conditions were adjusted combining five temperatures and five different frying times. Accordingly, as a preliminary furan formation behavior study, kinetics of furan formation during frying were achieved (Figure 3). Fried samples at 150 ºC and 160 ºC describe similar slight
increments of furan content as time increases: where maximal furan concentration just reaches around ~ 40 µg/kg at 11 min of frying. Kinetics of furan formation at 150 and 160 ºC are different from those corresponding to 170º C and 180º C. Thus, for those samples processed at higher temperature, the increment of furan content is significantly higher reaching values above 150 µg/kg for 170ºC or even above 350 µg/kg for 180ºC for equal frying times. Interesting, for higher frying times, their furan content reach a plateau and furan tends to reach maximum at intermediate thermal processing and then decay due to finishing of the formation reaction when their precursors disappear.

There is evidence that in processed starchy baked foods, the content of toxic compounds could decrease due to their transformation to non-enzymatic browning compounds and similar tendency could occur for frying, as well. The variability of furan content in samples - measured as the ratio of standard deviation divided by the average content - was 1.03; this elevated value was induced by the experimental design combining the time-temperature factors of the thermal treatments. In this way, disperse values of furan content in samples make possible to extend this kind of analysis for a wide range of other experimental conditions.

6. To determine the effect of thermal processing in matrixes (i.e. vacuum and laser, microwave and radiofrequency baking) in the Maillard intermediate formation.

Effect of thermal processing on the Maillard reaction formation was accomplished using traditional Baking (oven) and radiation baking. Both treatments were preferred over vacuum, laser and microwave since neo-contaminant compounds formation studies is a recently topic of investigation and its micro - meso and macro structural formation required more deep in this study. Two Maillard intermediate formation were studied: HMF and Furan. Effect of thermal processing was also studied under mass and heat transference modeling wish was not originally considered, however, this side offer a better understanding in deep over an horizontal expansion.

7. To demonstrate the feasibility of sorting the quality of baked / cooked products based in toxic levels of Maillard undesirable compounds using non-destructive technologies.

Starch dough circular pieces were immersed in oil and fried at 150, 160, 170, 180, and 190ºC for 5, 7, 9, 11, 13, and 30 min to obtain a wide range (30) of temperature-time combinations; the furan content of these combinations was measured, and some color images were extracted. To train the classifier, the furan content was quantified by gas chromatography–mass spectrometry (GC–MS). Class 1, 2, 3 and 4 were defined with values of 0 – 38 µg/kg; 39 – 113 µg/kg ; 114 – 398 µg/kg and 399 – 646 µg/kg, respectively. Corresponding images (360) were acquired and processed to extract 2175 chromatic and textural features. Principal component analysis (PCA) was used to reduce the dimensionality to 8–12 principal components. In parallel, Sequential forward selection (SFS) coupled with linear discriminant analysis (LDA) was the best strategy to select only 5-7 features. Being Mean intensity measured in Red channel (R) and Local Binary Patterns (LBP) the most important. Remarkable results show that LDA resulting in the best classifier, 91.39 - 97.60 % of samples above 113 µg/kg under 10-fold cross validation and 69.54 - 83.80 % of class 1 from class 2. Finally Support Vector Machine (SVM) recognized 87.71 - 96.74% of class 3 from class 4. This part demonstrates how valuable the use of computer vision may be to detect and eventually discard high amount of furan in fried, starchy matrices after thermal processing.

For baking matrices and evaluation of the variable parameters of these, a system of computer vision, consisting of a glass furnace that allowed monitoring the process, a photographic camera on a tripod to acquire images every 4 seconds was implemented during all the baking, an infrared thermometer and thermocouples to record the temperature change. To assess the impact of temperature and baking time in color formation and HMF in duplicate experiments 180, 200, 230 and 250 ºC for times of 2, 4, 6, 10, 14,18 were performed, 24 and 30 minutes.
Using data obtained surface temperature and baking temperature was possible to develop an equation to predict the temperature in the cracker for any baking time, the model fit for each baking temperature (180, 200, 230 and 250 °C) It validated by cross validation, showing the following $r^2$: 0.908; 0.974; 0.986; 0.948 respectively.

To predict the HMF content of the matrices an exponential model of experimental concentration versus the surface temperature calculated using the temperature model was used, cross-validation model gave $r^2$ values: 0.964; 0.975; 0.953; 0.938 for each baking temperature (180, 200, 230 and 250 °C) respectively.

The color change of samples, correlated with the content of HMF did not return a statistically significant adjustment, but it was possible to set a range in which the HMF content does not exceed the usual limit in food (74.5 ug / kg).
DESTAQUE OTROS LOGROS DEL PROYECTO TALES COMO:
- Estadías de investigación.
- Actividades de difusión y/o extensión en la temática del proyecto.
- Cualquier otro logro no contemplado en los ítem anteriores y que Ud. quiera destacar.

La extensión máxima de esta sección es de 1 página (letra tamaño 10, Arial o Verdana).

1) Este tercer año: Formación de tesista:
Viviana Gajardo, ingeniero civil químico (USACH)
Finalización de tesis con resultados de años anteriores:
-Daniela Rivas, Sara Seguel, ingenieros de industria alimentaria (UTEM)
-Daniela Lagos, ingenieros de industria alimentaria (UTEM)

2) Escritura de Manuscrito: Effect of formulation and baking conditions on structure and Non-Enzymatic Browning development of biscuit model Gabriel A. Leiva-Valenzuela1, Marcela Quilaqueo, Daniela Lagos, Franco Pedreschi

Este manuscrito se suma a los otros presentados, aún se encuentra en estado de preparación se enviará prontamente a su revisión de inglés y se subirá a la revista Food Structure.
INFORME DE EVALUACION DEL (DE LA) INVESTIGADOR(A) PATROCINANTE

A continuación realizo una descripción de las actividades que realizó el Dr. Gabriel Leiva Valenzuela durante el último año de desarrollo de postdoctorado.

Desarrollo y finalización de la investigación llamada: “Modelling the development of backing and drying of starchy models by using of in situ computer vision systems”
(1) se montó un sistema de visión por computador que adquirió imágenes de alta resolución a medida que se realizaba el horneado de sistemas modelos basados en almidón de maíz. (2) se pudo modelar el secado, la evolución de 5-HMF, el cambio en la forma de las galletas en función del tiempo, de la temperatura de horneado y de la variación de color medido por imágenes. Este estudio es el otro paso adelante para montar sistemas de control in situ de horneado y complementa los estudios que realizó Gabriel el año dos. Durante esta etapa, Gabriel guió tesis de Ingeniería civil química Sta. Viviana Gajardo. Fruto de esta investigación nos encontramos escribiendo un manuscrito para su envío a revista ISI. Adicionalmente presentó dos trabajos en la conferencia de CIGR-AgEng 2016 (CIGR International Commission of Agricultural and Biosystems Engineering) llevada a cabo en Aarhus, Dinamarca en junio de 2016, exponiendo el primero de forma oral y el segundo como poster:

a) Development of non-enzymatic browning in starchy matrixes using image acquired during baking
b) Measuring of local surface changes in fried samples by using computer vision

Adicionalmente, Gabriel ha intentado publicar uno de los estudios generados en el primer año de postdoctorado hasta la fecha sin éxito (“Statistical pattern recognition classification with computer vision images for assessing the furan content of fried dough pieces”). Este paper anteriormente ya fue reformulado debido a sus constantes rechazos. La nueva versión de ese manuscrito se presentó en varias revistas encontrándola “out of scope” (no ha sido rechazado por calidad) y actualmente se encuentra en la revista LWT-Food Science an Technology.

Fruto del segundo año de postdoctorado, con Gabriel hemos escrito un manuscrito sobre cambios microestructurales que se producen durante el horneado de galletas con cambios en su formulación (“Effect of formulation and baking conditions on structure and Non-Enzymatic Browning development of biscuit model”). Este es un trabajo promisorio, donde muestra los cambios medidos con SEM, esteriomicroscopio y visión por computador. Este paper se encuentra en su etapa final antes de la revisión del inglés.

Toda la parte experimental del postdoctorado ha sido realizada satisfactoriamente estando conforme con su trabajo. Con respecto a las publicaciones, lamento que hasta la fecha no tengamos una publicación aceptada. Sin embargo, Gabriel ha mantenido el compromiso de publicar al menos tres manuscritos fruto de su postdoctorado como se acordó al inicio del trabajo.

Saludos cordiales,

Firma investigador patricinante

Dr. Franco Pedreschi
Director Departamento Ingeniería Química y Bioprocesos
Pontificia Universidad Católica de Chile

Fecha: 05 / 12 / 2016
N° : 1
Autor (a)(es/as) : Leiva-Valenzuela, GA; Mariotti, MS; Mondragón, G.; Pedreschi, F
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ISSN : 0308-8146
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Vol. : 239
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Autor (a)(es/as) : Leiva-Valenzuela, GA; Mariotti, MS; Mondragón, G; Quiñaqueo, M; Pedreschi, F
Nombre Completo de la Revista : Journal of Food Process Engineering
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Otras Publicaciones / Productos

Sin información ingresada.

Congresos

Nº: 1
Autor (a)(es/as): Leiva-Valenzuela, GA; Mariotti, MS; Pedreschi, F
Título (Idioma original): Prediction of furan content in fried starchy matrix using visible color images
Nombre del Congreso: ICEF12 - 12th International Congress on Engineering and Food
País: CANADA
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FRANCIA
Paris
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Kinetic of furan formation in fried starchy food model systems: influence of oil adsorption and non-enzymatic browning
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Nº : 4
Autor (a)(es/as) : G.A. Leiva-Valenzuela GA., Gajardo V.; Pedreschi, F.
Título (Idioma original) : Development of non enzymatic browning in starchy matrixes using images acquired during baking
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Autor (a)(es/as) : Leiva-Valenzuela, G; Pedreschi, F.
Título (Idioma original) : Measuring surficial changes of fried starchy samples subjected to time – temperature conditions using images
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