Ability of some food preservation processes to modify the overall nutritional value of food
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ABSTRACT
The impact of food transformations on final nutritional quality of food products is a major question that has been studied only partially. This paper propose an assessment of different preservation processes with the light of two overall nutritional scores, positive (SAIN) and negative (LIM), developed in 2008, in response to a European regulation made to improve nutritional information on processed food. With the example of two different products, apple and pork meat, the objective is to monitor the nutritional scores as a function of the preservation operation chosen, isolated or combined, traditional or innovative. The results show that nutritional scores are very different as a function of the mass transfers involved during the preservation operation. The results give insights in the ability of a technological choice to modify the nutritional quality of a food item and potentially orientate a food label. This work also shows the limitations of using global nutritional scores as a tool to evaluate a food process.

Keywords: food processing; air drying; osmotic treatment; nutritional scores; apple

INTRODUCTION
The aim of this paper is to evaluate the sensitivity of a nutrient profile model to estimate the nutritional impact of some food preservation processes. The SAIN-LIM profile model proposed by Darmon and Darmon (2008) is selected. This work is done by analysis the nutritional trajectory of different products: apple, French fries and pork belly during a single or a combined isothermal preservation process in the two-dimension plan made by the SAIN, LIM coordinates. The model responses are calculated and discussed for different process itineraries and choices, i.e. operating conditions, succession of food transformations, traditional or innovative technologies. These results propose a way to describe the nutritional evolution of food during processing. The method is explained on the apple process description and discussion is extended to pork belly and frying operation.

MATERIALS & METHODS
The scores SAIN and LIM were previously developed by Darmon and Darmon (2008) and in Damon et al. (2009). They evaluate respectively the capacity of a food product to cover the nutritional needs and not to exceed the recommended intake in disqualifying nutrients. A sweet fruit product, apple, and salted products, French fries and pork belly, are used to assess the preservation processes. Air drying and osmotic treatment have the same objective to stabilize food products by a decrease of the water activity by lowering water content and/or by adding salts or sugars. These unit operations can be combined. The choice of these operations is motivated by the involvement of mass transfers that can modify the energy density and micro-nutrient contents of the product.

The SAIN score is a nutrient density calculated by the unweighted arithmetic mean of the percentage adequacy for the food positive nutrients. The selection of the number of nutrient, from 5 to 23, is a trade-off between the need to have a complete model including nutrients of importance to public health and the need for a manageable number of nutrients (Darmon et al. 2009). Because apple, French fries, and pork meat are very different in terms of composition, the definition of the SAIN score includes 23 positive nutrients (equ 1). The second score LIM calculates the mean content in disqualifying nutrients in 100 g of foods. The chosen disqualifying nutrients are sodium, saturated fatty acids and added sugars. Where $\text{Nut}_j$, is the quantity (g, mg or $\mu$g) of disqualifying nutrient $j$ in 100g of food and $\text{MRV}_j$, the daily maximal recommended value for nutrient $j$ (equ 2).
\[
\text{SAIN} = \frac{\sum_{i=1}^{23} \frac{\text{Nut}_i}{\text{RV}_i} \times 100}{E} \times 100 \quad (1) \text{ and } \text{LIM} = \frac{\sum_{j=1}^{3} \frac{\text{Nut}_j}{\text{MRV}_j} \times 100}{3} \times 100 \quad (2)
\]

Where \(\text{Nut}_i\), is the quantity (g, mg or µg) of the positive nutrient \(i\) in 100 g of food, \(\text{RV}_i\), is the daily recommended value for nutrient \(i\) and \(E\) is the energy (in kcal) in 100 g of food.

Taking into account an optimum value of 100% in 2000 kcal of food (reference daily energy intake) a SAIN value superior to 5 indicates a good nutrient density. This optimum was therefore equivalent to 5% for 100 kcal of food. Unlike the SAIN score, the LIM score is calculated for 100 g of food and the maximal recommended values are based on food intake rather than energy intake. A limit value for the LIM score of 100% in 1330 g (mean daily food intake of the French population) is also defined. This threshold corresponds to 7.5% for 100 g of food. A LIM value inferior to 7.5 indicated a low content of disqualifying nutrient.

These two limits enabled the representation of the SAIN, LIM coordinates of a food item into 4 nutrient profile classes: recommended, neutral, to limit and to avoid. The space that is built by this way in the two dimensions SAIN LIM permit to describe a space where the trajectory of the process is easy to represent.

The experimental results used for Apple processing are presented in Vega-Galvez et al. (2008) and Thémelin et al. (1994). The apple composition is obtained from Favier et al. 2006; USDA 2009. Experimental mass transfer data were chosen in previous works to reach an apple final water activity which range between 0.64 and 0.65 (i.e. stable products at ambient temperature). In the first technological choice (a), apple cubes were dried in a conventional air dryer at 60°C during 524 min. In the second case (b), apple cubes underwent a previous osmotic treatment at 59°C during 284 min (i.e. immersion in a concentrated sugar solution) followed by air drying in a conventional dryer at 69°C during 300 min.

During air-drying and osmotic treatment, concentration of initial positive nutrients \(i\) \(\text{Nut}_i^{(0)}\) in apple is multiplied by a factor \(\frac{M^{(0)}}{M^{(t)}}\), where \(M^{(0)}\) and \(M^{(t)}\) are the food weight at \(t=0\) and time \(t\):

\[
\text{Nut}_i^{(0)} = \frac{M^{(0)}}{M^{(t)}} \times \text{Nut}_i^{(0)}
\]

Because of water loss, which is the main mass transfer, \(\text{Nut}_i^{(0)}\) is assumed to increase as a function of the process time \(t\). The equation (1) was modified to take into account the composition modifications during air-drying and osmotic treatment and generate a value of \(\text{SAIN}^{(t)}\) at each time \(t\) of the process according to the experimental mass transfer data:

\[
\text{SAIN}^{(t)} = \frac{\sum_{i=1}^{23} \frac{M^{(0)} \times \text{Nut}_i^{(0)}}{\text{RV}_i^{(t)}} \times 100}{E^{(t)}}
\]

The energy in 100 g of apple, noted \(E^{(0)}\), is dependent on the only water loss during drying. In the case of osmotic treatment, \(E^{(t)}\) is dependant on water loss but also on sugar gain. This situation, where no nutrient loss occurs, can be considered as the most optimistic scenario. Indeed, during processing, undesired loss of nutrients can happen because of reactions and transport phenomena. We also consider a pessimistic scenario considering that the chemical reactions affecting the nutritional quality of food are mainly caused or enhanced by temperature, oxygen and light. They affect vitamins, and especially vitamins A, and C which are considered the most sensitive. Transport phenomena of nutrients can occur when the product is soaked in water and affect mainly hydrosoluble nutrient such as minerals or hydrosoluble vitamins. As a consequence, vitamin losses are frequently reported during air-drying loss because of oxygen and temperature (Marfil et al. 2008; Timoumia et al. 2007). On the opposite, because of oxygen limitation, osmotic dehydration was proven to preserve micronutrient of fresh products (Dermesonlouogloua et al. 2007; Rastogi et al. 2005) but, because of the immersion of food product in an aqueous solution, this operation can induce a loss of water-soluble vitamins and minerals from the product to the concentrated solution (Peiro et al. 2006; Osorio et al. 2007). Therefore, in the most pessimistic case, we will consider the total destruction of vitamin A and C during drying and the total loss of minerals and hydrosoluble vitamins in the case of osmotic treatment.
As well as positive nutrients, disqualifying nutrients Nut\(^{(0)}\) concentrates by a factor (M\(^{(0)}\)/M\(^{(0)}\)) during both processes. However, the nutrient “added sugar” is particular because by definition absent at t=0. Therefore, in this case, the concentration was assessed at each time of the process thanks to the data of sugar gain of Thémelin et al. (1994). Equation (2) was modified in order to have a value LIM\(^{(0)}\) at each time t of the process:

\[
\text{LIM}^{(0)} = \frac{\text{Nut}_{1}^{(0)}}{\text{MRV}_{1}} + \sum_{j=2}^{3} \frac{M_{j}^{(0)}}{M_{j}^{(0)}} \times \frac{\text{Nut}_{j}^{(0)}}{\text{MRV}_{j}} \times 100.
\]

Where index 1 stands for added sugar while 2 and 3 stand for saturated fatty acids and sodium respectively.

RESULTS & DISCUSSION

The values of the 23 positive and negative nutrients of apple lead to an initial SAIN score of 3.6 and a LIM score of 0.13. The experimental mass transfers during the two technological routes (hot air drying, osmotic dehydration, than drying) were used to calculate the SAIN and LIM scores during processing. In the case of a single air drying, a water loss of 83 g for 100 g of initial apple occurred and finally, 17.0 kg of end products were obtained after processing 100 kg of raw apples. For the combined process, water loss occurred in both osmotic treatment and air drying, but this loss was partly compensated by a sugar gain during the first osmotic dehydration step. Therefore, for the same final water activity, 30.4 kg of end product were obtained in this case. Figure 1 presents the dynamic evolutions of SAIN and LIM scores as a function of processing time for the two technological routes.

During air drying (figure 1a), the SAIN score remained equal to 3.6. This stability was due to the proportionality of nutrient and energy concentrations as a function of dehydration and the fact that the two values are on the numerator and the denominator of the SAIN score. The LIM score slightly increased from 0.13 to 0.78 (figure 1). This increase is due to the concentration of the initial saturated fatty acids in apple.
cubes because of dehydration and the fact that the energy density is not taken into account in the case of the LIM score. As a consequence, the air drying operation has a low impact on the SAIN, LIM scores of apple cubes and the end products also belonged to the neutral nutrient profile class. However, the SAIN score might be over evaluated. The important contact time (nearly 550 min) between the air oxygen and the product at a temperature of 60°C is assumed to degrade thermo-sensitive molecules (i.e. vitamin A and C). Therefore, supposing that the two vitamins were totally destroyed, the final SAIN was calculated and was found to drop from 3.6 to 2. This scenario was foreseen in figure 2.

Regarding figure 1b, the consequences of mass transfers during osmotic treatment had a marked impact on the SAIN but also on the LIM score. Indeed, during this treatment, the SAIN score decreased from 3.6 to 2. This decrease was due to the increase of sugar content of the apple increasing its caloric-density. Therefore, the nutrient concentration because of water loss did not compensate in an equal manner the increase of caloric-density. The sugar impregnation during osmotic treatment had a higher consequence on the LIM score. Indeed, the LIM value increased at constant speed as a function of the osmotic process time and rise from an initial value of 0.13 to 15.4 after 284 min. The sugar implementation during this operation had a dramatic impact on the numerator value of the LIM score. During the following air drying, the SAIN score remained stable. Because of the water loss only, the increase of the SAIN denominator due to the sugar concentration was compensated by the positive nutrient concentration (numerator of SAIN). On the opposite, LIM score increased during air drying to reach a final value of 24.2.

In figure 2, nutritional trajectories of the apple cubes are presented in the SAIN, LIM frame during air drying and during the combination of osmotic treatment and air drying. Due to process conditions, they turned into products of which consumption should be limited. In addition, during osmotic treatment, nutrient loss can occur with water leak. This scenario was also foreseen in figure 2. In this case, the SAIN, LIM coordinates would pass out of the frame defined by Darmon and Darmon (2008) that is to say with a SAIN score <1. Thus, while improving the stabilisation, the yield, and the sensory properties of apples, osmotic dehydration has a dramatic negative impact on the SAIN and LIM values.
**DISCUSSION**

A similar approach was done for french fries and pork belly processing by a salting, drying and smoking process (Achir *et al.* 2010). The results of this work show the impacts of mass transfers and reactions involved in different preservation processes on the nutritional quality of product assessed with the SAIN-LIM profile model proposed by Darmon and Darmon (2008). In the case of apple or pork meat, the two scores have proven to be easy to manage and to well discriminate the different operations or processes. The resulting nutritional trajectories in the two-dimension frame allowed a visual and convenient analysis of the marked impact of the process on the nutritional quality of foods. These projection plots is an interesting way to identify the main nutritional critical point of an operation or a process till the domestic use and may help to propose improvements such as a change of operation, process, and device. On a quantitative aspect, the use of SAIN and LIM scores suppose the knowledge of mass transfer but also nutrients evolutions during processing. Regarding the number of couple product/process in food industry, this supposes a tremendous data base. Though, realistic hypothesis can be done as regard to existing literature. Besides, the most common unit operations of food processing are well described and robust models of heat, mass transfers and reactions are available in literature. The results of this paper are based on experimental data of mass transfers during air drying and osmotic treatment and on hypothesis about the reactions or diffusions associated. They showed that providing conditions used are favourable to nutrient retention, dehydration has a poor impact because of the simultaneous concentration of nutrients and energy. However, the concentration of penalising nutrient is taken into account in the LIM score because of the weight base used in its calculation. Therefore, a dehydrated food will be placed less favourably than the initial raw product in the SAIN, LIM system, which seems justified. Therefore, the two calculation bases of SAIN, LIM scores are complementary. Therefore, this work of process analysis with the SAIN, LIM scores also triggers off limitation of the use of a nutrient...
profile model to assess a food process. The limitations are important to consider as outputs of food profile models are a classification of foods which may have consequences on consumer health or on products sells. Firstly, the characterisation of raw product is important and must be reliable as it represents the beginning point of a process. Initial calculation of SAIN and LIM scores showed that for a same product, the food class could change as a function of the number of nutrients considered.

REFERENCES