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The W/O/W emulsion containing $FeSO_4$ in the different phases alters the hedonic thresholds in milk-based dessert

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ABSTRACT

Food fortification with $FeSO_4$ is an effective practice in preventing iron deficiency anemia. However, the addition of this compound to foods can lead to unpleasant sensory changes. Therefore, the use of carrier vehicles such as the double emulsion, may be an effective alternative to "mask" or minimize sensory perception. The W/O/W emulsion system containing $FeSO_4$ in the internal or external aqueous phase was added to a milk-based dessert in order to evaluate the perception of consumers regarding sensorial changes. For this, the hedonic threshold methodology was applied to determine the minimum concentration of the stimulus at which a significant change in acceptability begins or the point at which it begins to lead to sensorial rejection. The insertion of $FeSO_4$ into the internal aqueous phase of the W/O/W emulsion enhanced the sensory perception of undesirable changes to the dessert, compromising acceptability. However, insertion of the stimulus in the external aqueous phase permitted the addition of a higher $FeSO_4$ concentration, without compromising sensory acceptability and resulting in rejection by the consumers. Therefore, it was concluded that the $FeSO_4$ may be carried in the external aqueous phase of the W/O/W emulsion, minimizing losses to the sensorial quality of the product.

1. Introduction

The iron fortification procedure is an effective practice for the prevention of iron deficiency anemia. However, iron compounds of greatest bioavailability (such as $FeSO_4$) are soluble in water and can therefore react with food components. Most of the time, this reaction causes changes in the sensory characteristics of the product, such as undesirable flavors and changes in coloration, directly affecting acceptability (Hurrell, 2002).

For the addition of these compounds to a food matrix while minimizing sensorial changes of the product, it is recommended to use carrier vehicles in the form of colloidal system, in order to "mask" the undesirable sensorial perceptions to consumers (Fricker et al., 2010). Among the main systems studied, the structure of the double emulsion can be an effective alternative, since substances can be incorporated in the internal, intermediate and/or external phases, acting as vehicles for non-polar and polar compounds. Therefore, the use of double emulsions in the formulation of food products carrying compounds of interest with health claims is an alternative with great potential (Dickinson, 2011; McClements, 2016; Muschiolik & Dickinson, 2017).

One of the main factors related to the application potential of double emulsions is the direct impact of this colloidal system on the sensorial perception by consumers, which could compromise the acceptability or even promote sensorial rejection when incorporated into a food matrix. For the double emulsion system, there are researchers published in literature who affirm that the insertion of a particular compound (stimulus) in the internal aqueous phase tends to enhance sensory perception in relation to taste-related characteristics (Chiu, Hewson, Fisk, & Wolf, 2015; Lad, Hewson, & Wolf, 2012; Oppermann, Piqueras-Fiszman, Graaf, Scholten, & Stieger, 2016; Paula, Oliveira, Teixeira, Soares, & Ramos, 2018); while there are also researchers who believe that the incorporation of compounds into the internal aqueous phase of the double emulsion tends to "mask" the sensory changes resulting from these compounds and which may be undesirable to consumers (Bonnet et al., 2009; Dickinson, 2011; Fang & Bhandari, 2010). Furthermore, scientific literature has not yet elucidated the effect on

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sensory perception when compounds are incorporated only in the external aqueous phase.

However, Prescott, Norris, Kunst, and Kim (2005) affirmed that knowing only the minimal concentration of the stimulus at which individuals perceive the first sensorial changes (threshold of detection) does not necessarily imply that these first alterations will compromise the sensorial acceptance of the product. Thus, it is necessary to investigate the minimum concentration of the stimulus at which a significant alteration in acceptability begins, or the point at which sensorial rejection of the product begins to occur (Lima Filho, Minim, Silva, Della Lucia, & Minim, 2015; 2017).

In this context, the present study sought to evaluate the sensorial acceptability of milk-based desserts fortified with $FeSO_4$ via the different aqueous phases (internal and external) of the W/O/W double emulsion system as the carrier vehicle.

2. Material and methods

The present study was approved by the Human Research Ethics Committee of the Federal University of Viçosa (UFV), Brazil, registered under number 041,414. Evaluations were carried out in the UFV Sensory Analysis Laboratory, in individual booths and under white light.

Sensorial acceptability of milk-based desserts containing the double emulsion (W/O/W) as a $FeSO_4$ carrier, at different locations in the emulsified system, was evaluated by means of the hedonic thresholds methodology, proposed and validated by Lima Filho et al. (2015; 2017). This methodology provides the affective compromised acceptance threshold (CAT) and hedonic rejection threshold (HRT), which represent the intensity of the stimulus in which the sensorial acceptance of the product becomes compromised, and the intensity of the stimulus at which sensorial rejection begins to occur, respectively.

In practice, the $W_i/O/W_e$ emulsions were incorporated in the flan, when the stimulus ($FeSO_4$) is distributed among different locations in the system, being the internal aqueous phase (W_i) and external aqueous phase (W_e).

Additionally, the CAT and HRT values for $FeSO_4$ in strawberry flan were determined, where the stimulus was dissolved in the continuous phase of the simple O/W emulsion and dissolved in water only. This was to verify the effect of the double emulsion system, i.e., water droplets dispersed within oil droplets at the hedonic sensory thresholds.

Four sensorial tests were carried out to determine the $FeSO_4$ thresholds in the milk-based dessert, containing the stimulus in different systems: internal aqueous phase of the $W_i/O/W_e$ emulsion (assay 1), external aqueous phase (assay 2), continuous phase of the simple O/W type emulsion (assay 3) and $FeSO_4$ solution (assay 4).

For each type of system evaluated, determinations of the CAT and HRT were conducted using different consumer teams, made up of 97 people in each team. Thus, it was sought to avoid possible tendency effects by the previous experience of consumers and/or alterations of the results due to sensorial fatigue. The age range between the different teams was practically the same to avoid effects of variation in sensory acceptability as a result of age differences.

The concentrations of $FeSO_4$ present in the milk-based strawberry flan dessert were the same in all assays, in order to allow a direct comparison between the results obtained.

2.1. Materials

Ferrous sulfate ($FeSO_4.7H_2O$) and tween 80 were purchased from Sigma Aldrich (São Paulo, Brazil), along with guar gum and gelatin polymers (pork skin, Type A, Bloom-300). The emulsifier polyglycerol polyricinoleate (PGPR) was donated by Granolab/Granotec. The oil fraction was composed of sunflower oil purchased from a local supermarket (Sinhá, Type 1). Condensed milk (Itambé), cream (17% fat, Itambé), strawberry flavored gelatin (Royal) and strawberry essence (Fine Line) were also purchased at a local supermarket.

2.1.1. Preparation of the emulsions

The $Wi/O/W_e$ double emulsions (assays 1 and 2) used as carriers of $FeSO_4$ were prepared in a two-step procedure. First, a simple W_i/O emulsion (primary emulsion) was prepared and then this emulsion was incorporated as a "dispersed phase" into a second aqueous phase (W_e). The system comprised 15, 30 and 55% (w/w) of the internal aqueous phase, oil phase and external aqueous phase, respectively, totaling 100%.

For preparation of the primary emulsions (W_i/O), an aqueous solution was prepared by dissolving 0, 0.35, 6.32, 12.29, 18.26 or 24.23 mg $FeSO_4$ for each 10 g of double emulsion, 0.75% (w/w) gelatine and 0.05% (w/w) potassium sorbate in filtered water at 90 °C. The gelatin was hydrated for 10 min, followed by magnetic stirring for 30 min.

For the emulsions containing $FeSO_4$ located in the external aqueous fraction (W_e), a specific concentration of lactose was added to the internal aqueous phase in order to balance the osmotic pressure between the internal and external aqueous phases and thus minimize transfer of material between the two phases (Bonnet et al., 2009). Lactose concentrations were 0.046, 0.827, 1.607, 2.388 and 3.169 mmol/L for treatments in increasing order of stimulus concentration, respectively.

The oily fraction (O) was prepared by dissolving 3% (w/w) PGPR in sunflower oil. This system was subjected to magnetic stirring for 30 min at 90 °C (O'regan & Mulvihill, 2010; Paula et al., 2018).

The W_i/O emulsions were prepared from the slow dispersion of 1.5 g of the aqueous solution (W_i) in 3 g of the oily fraction (O) under constant stirring in a high speed homogenizer (T18 Basic Ultra-Turrax-IKA) operating at 20,000 rpm for 4 min. The resulting emulsions were cooled to 4 °C.

To prepare the $Wi/O/W_e$ emulsions, an external aqueous solution (W_e) was prepared by dissolving 0, 0.35, 6.32, 12.29, 18.26 or 24.23 mg of $FeSO_4$ for each 10 g of double emulsion, 3% (w/w) of tween 80, 0.75% (w/w) guar gum and 0.05% (w/w) potassium sorbate. This system was subjected to magnetic stirring for 30 min at 50 °C.

For emulsions containing Fe^{2+} located in the internal aqueous fraction, a specific lactose concentration for each emulsion was added to the external aqueous phase in order to balance the osmotic pressure of the system. The lactose concentrations were 0.153, 3.031, 5.894, 8.757 and 11.620 mmol/L for treatments in increasing order of stimulus concentration, respectively.

The $W_i/O/W_e$ emulsions were prepared from the slow dispersion of 4.5 g of the W_i/O emulsion in 5.5 g of the external aqueous solution (W_e). This system was shaken in a high speed homogenizer, operating at 18,000 rpm for 4 min. The emulsions formed were stored at 4 °C.

Fig. 1 is a schematic representation of preparation steps of the double emulsions.

In preparation of the simple emulsion (O/W) (assay 3), 3 g of oil were slowly dispersed in 7 g of the aqueous phase containing 0.35, 6.32, 12.29, 18.26 or 24.23 mg of $FeSO_4$ for each 10 g of emulsion, 3% (w/w) of tween 80, 0.75% (w/w) of guar gum and 0.05% (w/w) of potassium sorbate. This system was stirred in a high speed homogenizer operating at 18,000 rpm for 4 min. The emulsions formed were stored at 4 °C.

For the different types of emulsified systems (W/O/W and O/W), emulsions were prepared without addition of the stimulus ($FeSO_4$). These systems were later used in the elaboration of strawberry flavored flans, classified as control samples.

2.1.2. Preparation of the flan

Strawberry flavored flans were composed of condensed milk (35%), water (34.5%), cream (17.5%), W/O/W or O/W emulsion (10%), strawberry flavored gelatin and strawberry flavored essence (1%, w/w). For preparation, initially the gelatin was solubilized in boiling water and then added under stirring to the mixture formed of condensed milk