# Use of Heme Iron Concentrate in the Fortification of Weaning Foods

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The purpose of this study was to evaluate the technological feasibility of fortifying homogenized weaning food with a porcine heme concentrate. The stability of iron and the organoleptic qualities of two infant weaning foods (a commercial homogenized nonfortified weaning food, NFWF, and the same food fortified with 0.5% of porcine heme concentrate, FWF) were tested throughout 8 months of storage at room temperature and at 37 °C. Heme iron decreased with storage time; however, the proportion of this highly available iron was considerably higher in FWF than in NFWF. The addition of heme iron changed significantly the color of the weaning food measured instrumentally, although high temperatures and length of storage time, did not modify *L*a*b**, chroma, and hue angle values in both samples. Organoleptic attributes presented a marked stability even in NFWF stored at room temperature and 37 °C.

**Keywords:** *Heme iron; infant weaning foods; iron fortification*

## INTRODUCTION

Iron deficiency is particularly prevalent in infants and is a major nutritional problem in the world today. Food fortification is generally considered to be the best long-term strategy to combat iron deficiency (International Nutritional Anemia Consultative Group, 1977; Cook and Reusser, 1983; Hurrel et al., 1994); however, there are technical problems in the choice of the iron compound to be used as a fortificant. Compounds of high relative bioavailability, such as iron sulfate, often provoke unacceptable organoleptic changes, whereas the compounds that are acceptable are often poorly absorbed (Hurrell, 1992). The food vehicle and iron compound have to be matched in order to optimize iron bioavailability and to avoid catalytic actions of iron causing rancidity in food, thereby spoiling its taste and odor (Schumann et al., 1998). For this reason, alternative forms of iron have been selected for use in fortification trials such as sodium ethylenediaminotetracetate (Viteri et al., 1995), iron glycine (Fox et al., 1998), and hemoglobin concentrates (Walter et al., 1993; Martínez et al., 1998).

The availability of heme iron is superior to nonheme iron (Morries, 1983; Zhang and Ma, 1989), and animal blood is a good source of heme iron for use as a food fortificant (Hertrampf et al., 1990). Bovine heme concentrates have been used to fortify infant foods such as cereals (Calvo et al., 1989), milk (Hertrampf et al., 1978), or biscuits (Asenjo et al., 1985), but there is no published information on its utilization in homogenized weaning foods (ready to eat "wet" infant foods). This type of baby foods constitutes the main diet of babies aged from 6 to 12 months and young children from 1 to 3 years old. The majority of these contain meat, since it is a food source of protein and minerals; however, most of them are fortified with inorganic salts of iron in order to increase the iron intake in infants. In a recent study, porcine heme iron concentrate has been shown to be as well absorbed as ferrous sulfate when added to an homogenized weaning food at the time of consumption (Martínez et al., 1998). It has been shown that the heme iron content of food is influenced by processing and storage (Gomez-Basauri and Regenstein, 1992). In addition, some authors have reported serious problems of rancidity after storing milk powder fortified with a bovine heme iron concentrate (Morales and Topp, 1978).

The purpose of this study was to evaluate the technological feasibility of fortifying homogenized weaning foods with the porcine heme concentrate and to test the stability of iron and the organoleptic qualities of a heme iron fortified weaning food under different storage conditions.

## MATERIAL AND METHODS

**Materials.** A commercial homogenized nonfortified weaning food ("chicken and lamb with vegetables", HERO S. A., Alcantarilla, Spain) was used for the experiment. Addition of 0.5% of porcine heme concentrate to the commercial weaning food was produced for the test food, the level of fortified iron being adopted after trials at the pilot plant in which different percentages of heme iron were added to the commercial recipe to obtain a product with a pleasant red color and with the appropriate iron content which would allow the product to be labeled as "iron fortified" (DOCE, 1996). Five hundred samples of both weaning foods were obtained as 250 g jars, with a final iron content 0.71 mg/100 g for the nonfortified weaning food (NFWF) and 1.46 mg/100 g for the heme iron fortified weaning food (FWF). The heme concentrate source consisted on a dry powder prepared from hemolyzed erythrocytes obtained from pork, supplied by APROCAT S.A., Granollers, Spain. This heme concentrate contains the entire molecule of hemoglobin, not just the heme group. FWF was carried out in a pilot plant

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following the standard recipe for the commercial weaning food except for the iron fortificant. Final products of both weaning foods were autoclaved under the same conditions.

**Experimental Design.** Two hundred fifty subsamples of NFWF and FWF were stored at room temperature for 8 months or at 37 °C for the same period. Both weaning foods were analyzed prior to the storage term for proximate analysis, mineral composition, nonheme and heme iron content, amino acid composition, and sensory evaluation. The influence of storage conditions (time and temperature) on heme iron content and color were evaluated monthly. Sensory analysis was repeated at months 4 and 8.

**Methods. Proximate Analysis.** Moisture content and ether extract were determined by methods 964.22 and 920.39C, respectively, described by AOAC (1990). Crude protein content was calculated by converting the nitrogen content determined by Kjeldahl digestion (method 955.04, AOAC, 1990) and multiplying the determination by 6.25. Fe, Zn, Ca, Mg, and Cu contents were determined by dry ashing sub-samples in a furnace oven for 12 h with a final temperature of 525 °C. The ash was dissolved in 2 mL of concentrated $HNO_3$ on a hot plate and the volume made up to 50 mL with distilled deionized water. The dissolved mineral ash was measured by flame atomic absorption spectrophotometry (Perkin-Elmer model 3100, Norwalk, CT). Ca concentrations were determined in the presence of 10 g of La/l (as $La_2O_3$). A CRM-189 wholemeal flour (Community Bureau of Reference, Brussels) was used as reference material. The criteria of the American Chemical Society (ACS 1980) were followed to determine detection limits.

**Amino Acid Composition.** The amino acid composition of freeze-dried samples was determined with an amino acid analyzer LKB Alpha Plus (Pharmacia LKB Biochram Ltd., Cambridge, UK). Hydrolysis of protein was carried out at 110 °C with 6 mol/L HCl for 14 h in brown sealed tubes under vacuum. After hydrolysis, samples were filtered through 0.22 $\mu$m Millipore filters, diluted to 2 mL, and adjusted to pH 2.2 with 0.2 M lithium citrate loading buffer (pH 2.2) (Pharmacia Biotech, Biochrom, Ltd, Cambridge, U.K.) prior to loading on the ion exchange column. Amino acid standard solution was used as reference to calibrate the amino acid analyzer (Pharmacia LKB Biochrom Ltd, Cambridge, UK, part. no. 40 00 9037).

Amino acid scores were calculated using the following equation:

$$\text{amino acid score} = \frac{\text{mg of amino acid per g of protein in the weaning food}}{\text{mg of amino acid per g of protein in the reference pattern}} \times 100$$

The essential amino acid in each weaning food present in the lowest concentration relative to the recommended reference pattern was designated as the limiting amino acid. The reference pattern used in scoring is based on the essential amino acid requirements of infants from 2 to 5 years of age (FAO, WHO, UNU, 1985).

**Nonheme and Heme Iron Determination.** Nonheme iron was determined by the method of Schricker et al. (1982). Samples (6 g) of FWF were incubated in the presence of 15 mL of an acid mixture (1:1) of 6 N HCl and 40% trichloracetic acid at 65 °C for 20 h. After the mixture was cooled to room temperature, 1 mL of the solution above the residue was transferred to a test tube. A 5 mL portion of color reagent was added, and after 10 min, the absorbance was read at 540 nm (Hitachi Model U-2000 Spectrophotometer, Hitachi, Ltd., Tokyo, Japan). Heme iron was calculated as the difference between total iron and nonheme iron.

**Color.** Objective measurements of color were obtained with a Chroma Meter CM-508i (Minolta Camera, Osaka, Japan). $L^*$ (brightness), $a^*$ (red-green axis), and $b^*$ (yellow-blue axis) values (Comission Internationale de l'Eclairage, 1976) were obtained using duplicate readings. These values where used to calculate chroma ($C^*$) and hue angle by the following equations: hue angle = arctangent $(b^*/a^*)[360°/(2 \times 3.14)]$. Chroma = $(a^{*2} + b^{*2})^{0.5}$.

**Table 1. Proximate Composition and Mineral Content of the NFWF, FWF, and Heme Iron Concentrate**

| | NFWF[c] | FWF | heme iron concentrate |
|---|---|---|---|
| moisture (%) | 82.62[a] | 83.32[b] | 10 |
| total protein (%) | 4.93[a] | 5.0[a] | 60 |
| carbohydrates (%) | 8.37[a] | 8.25[b] | 25 |
| fat (%) | 3.35[a] | 2.71[b] | <1 |
| ash (%) | 0.73[a] | 0.72[a] | 5 |
| Fe (mg/100 g) | 0.72[a] | 1.46[b] | 189.75 |

[a] Means of triplicate analyses. [b] Means within the same row with different superscript letters were significant at $p < 0.05$ for NFWF and FWF. [c] Abbreviations: NFWF, nonfortified weaning food; FWF, fortified weaning food.

**Sensory Evaluation.** Appearance, color, flavor, taste, texture, and overall acceptance were performed by a panel of 12 people recruited form the faculty staff of the Department who have experience in sensory analysis. A 9-point rating scale was used (9 = excellent, 1 = very poor) to evaluate the weaning foods. NFWF and FWF were served warm (approximate 40 °C) and presented to the panel in coded white cups. Four samples were presented at random in each session. Spring water was provided for rinsing between samples.

**Statistical Analysis.** All determinations were carried out at least three times, and the results were statistically analyzed by multifactorial analysis of variance (ANOVA) to study the variation of the data referring to time, temperature, and type of weaning food. In addition, the effect of time and temperature on the variables were performed separately for each type of weaning food. Correlation analysis was conducted for sensory parameters of FWF and NFWF. Multidimensional scaling was applied to describe the dissimilarities between sensory variables (acceptance and color) and objective measurement of red color ($a^*$) for the FWF. All the statistical analyses were performed using the SPSS (8.0 for Windows) software.

## RESULTS AND DISCUSSION

Chemical composition and mineral content of the porcine heme concentrate, FWF, and NFWF are shown in Table 1. Heme concentrate is an excellent source of iron and protein; however, the fortification level used for iron fortification of FWF was not significant to enrich the protein content above that of NFWF. On the other hand, NFWF had lower fat, carbohydrate, Ca, and Mg concentrations but was higher in moisture content than FWF. The most striking result was that addition of only 0.5% of the heme concentrate to the weaning food significantly increased the iron content 2-fold in FWF compared with NFWF. According to NRC (1989), recommended dietary allowances (RDA) for iron are 10 mg for infants aged between 6 months and three years. Following these recommendations, a 250 g jar of FWF will cover an average of 36% of the RDA. At this period of life the infant will have other sources of iron (infant formulas and cereals); however, FWF would provide a highly bioavailable source of iron.

Protein quality, also known as the nutritional or nutritive value of a food, depends on its indispensable amino acid content and on the physiological utilization of specific amino acids after digestion and absorption (Friedman, 1996). The procedure that was adopted by a recent FAO/WHO Expert Consultative Committee (1991) on protein quality evaluation is based on the concept of an amino acid score defined as the concentration of the limiting amino acid in the food protein and is expressed as a proportion or percentage of the concentration of the same essential amino acid in a

**Table 2. Essential Amino Acid Content and Amino Acid Scores of NFWF, FWF, and Heme Iron Concentrate**

| | NFWF[c] | | FWF | | heme iron concentrate | | FAO/WHO/UNO |
|---|---|---|---|---|---|---|---|
| amino acid | mg/g protein | amino acid score | mg/g protein | amino acid score | mg/g protein | amino acid score | reference pattern (1985) 2−5 years |
| His | 12.1[a] | 0.64 | 13.2[b] | 0.69 | 35.3 | 1.86 | 19 |
| Ile | 35.2[a] | 1.26 | 36.3[b] | 1.29 | 6.5 | 0.23 | 28 |
| Leu | 54.7[a] | 0.83 | 60.1[b] | 0.91 | 78.3 | 1.18 | 66 |
| Lys | 20.4[a] | 0.35 | 27.3[b] | 0.47 | 36.8 | 0.63 | 58 |
| Met+Cys | 32.5[a] | 1.3 | 24.4[b] | 0.98 | 19 | 0.76 | 25 |
| Phe+Tyr | 53.5[a] | 0.85 | 48.5[b] | 0.77 | 60.3 | 0.96 | 63 |
| Thr | 30.6[a] | 0.9 | 23.4[b] | 0.69 | 28.4 | 0.83 | 34 |
| Val | 33.6[a] | 0.96 | 37.6[b] | 1.07 | 62.2 | 1.78 | 35 |

[a] Means of triplicate analyses. [b] Means of amino acid content within the same row with different superscript letters were significant at $p < 0.05$ for NFWF and FWF. [c] Abbreviations: NFWF, nonfortified weaning food; fortified weaning food.

reference amino acid pattern. This expert committee proposed that the 1985 FAO/WHO/UNU amino acid requirement for the group aged 2−5 years be used to assess the protein quality of foods in reference to young children, older children, and also adults. Table 2 shows the amino acid analysis of the porcine heme iron concentrate compared with a reference essential amino acid pattern for infants from 2 to 5 years of age (FAO/WHO, 1991). Although it was deficient in some amino acids, it was an excellent source of histidine, leucine, and valine. Heme concentrate was added in a concentration insufficient to improve protein content with respect to NFWF; however, essential amino acid composition of FWF and NFWF was analyzed and values compared between weaning foods and with the FAO/WHO pattern (Table 2). Among essential amino acids FWF exhibited significantly higher content ($p < 0.05$) of histidine, isoleucine, leucine, lysine and valine; although it was still deficient in lysine, methionine + cystine and tyrosine + threonine. Lysine was the first limitant amino acid for both weaning foods.

The main purpose of this study was to obtain an infant food that would provide iron in a stable, highly bioavailable form. Initially, the average total iron content in FWF was $1.46 \pm 0.02$ mg/100 g (mean ± SE), of which heme iron was $0.69 \pm 0.05$ and nonheme iron was $0.77 \pm 0.03$ mg/100 g. On the other hand, total iron content in NFWF was $0.72 \pm 0.02$ mg/100 g, with only $0.09 \pm 0.01$ mg/100 g being heme iron and $0.63 \pm 0.02$ mg/100 g nonheme iron. It is probable that a great proportion of heme iron from the heme concentrate and meat in FWF or from meat in NFWF was converted to nonheme iron during autoclaving. However, it is important to emphasize that the increase of heme iron content in FWF with respect to NFWF was due to the addition of the heme concentrate and which would improve the iron absorbed from the homogenized weaning food. It has been stated that the amount of heme iron absorbed is a linear function of the concentration of heme iron in the meal, as this type of iron is absorbed into the mucosal cell, still contained within the porphyrin ring, thus bypassing controlling mechanisms for iron absorption at the mucosal border (Bezwoda et al., 1983). At the same time, heme iron has an indirect influence on the enhancement of nonheme iron absorption, which is important for individuals with low iron stores (Carpenter et al., 1992).

It has been established that food processing, storage, chemical treatment, and cooking methods alter the heme and nonheme content of food (Lee and Clydesdale, 1980; Chen et al., 1984; Gomez-Basaurin and Regenstein, 1992). The effect of time and storage temperature on heme and nonheme iron content in FWF and NFWF was therefore analyzed (Figure 1). A marked change was found for nonheme iron content, which increased significantly with the time of storage in both samples stored at both temperatures. Heme iron decreased with the storage in both samples stored at both temperatures. Heme iron decreased with the storage time, resulting in a total conversion of heme iron to nonheme iron in NFWF at the end of 3 months. This trend was also observed in FWF; however, at the end of the study, there was still 17% and 21% of heme iron present for samples stored at room temperature and 37 °C, respectively, exhibiting a trend toward stabilization. Significant differences between heme iron and nonheme iron contents at both temperatures of storage were not found for FWF and NFWF. Wang and Lin (1994) reported that at a temperature above 65 °C the porphyrin ring of the heme group of a porcine blood curd is destroyed, resulting a linear relationship between heating time and nonheme iron content. The longer the time of hemoglobin exposure under high temperature the more porphyrin was destroyed and the more denatured hemoprotein complexes formed (Hayakawa et al., 1983). However, Wang and Lin did not find significant changes in nonheme iron of the same sample when temperatures did not exceed 55 °C. Probably the 37 °C chosen in our experiment to simulate extreme storage temperatures conditions did not have an influence on heme and nonheme iron content of samples as much as time of storage. The increase of nonheme iron content of FWF and NFWF during storage time, may be due to a progressive release of iron from the porphyrin ring destroyed during the autoclaving process. Although heme iron content was relatively low in FWF after 8 months of storage, it has been stated that iron bioavailability is consistently improved by heat treatment on meat and meat/hemoglobin mixtures (Jansuittivechakul et al., 1986). Any residual heme iron in the weaning food after autoclaving will contribute significantly to infants nutriture.

Color is one of the major attributes that affects the perception of quality by the consumer. If color is unacceptable, the consumer may not judge the flavor and texture at all (Francis, 1995). The subjectivity of visual color specification has led to the development of instrumental measurements of color based on the principle that a color can be mathematically described as a combination of the three primary color intensities (Clydesdale, 1978). When food products are stored, specially at extreme temperatures, an obvious sign of deterioration is often a change in color, which can be quantified instrumentally (Solomon et al., 1995; Wang et al., 1995). This fact was considered an important point in the investigation of our samples, mainly on

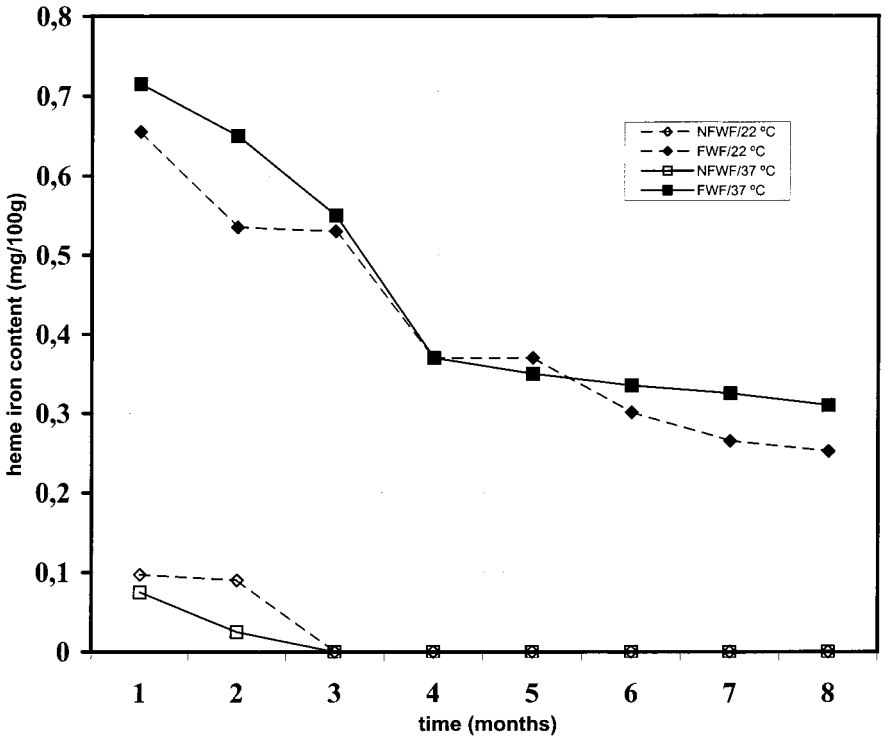


**Figure 1.** Heme iron content of NFWF (nonfortified weaning food) and FWF (fortified weaning food) at 22 and 37 °C during 8 months of storage.

**Table 3. NFWF and FWF Lab* Values Measured at 22 and 37 °C during 8 Months of Storage**

| time (months) | $L^*$[a] | $a^*$ | $b^*$ | $C$ | $L^*$ | $a^*$ | $b^*$ | $C$ |
|---|---|---|---|---|---|---|---|---|
| | NFWF[b]/22 °C | | | | NFWF/37 °C | | | |
| 1 | 54.85 ± 0.05 | 9.45 ± 0.02 | 32.00 ± 0.12 | 33.37 | – | – | – | – |
| 2 | 54.45 ± 0.18 | 9.82 ± 0.06 | 30.64 ± 0.19 | 32.18 | 54.90 ± 0.23 | 10.09 ± 0.33 | 30.78 ± 0.34 | 32.39 |
| 3 | 55.40 ± 0.15 | 9.50 ± 0.16 | 32.05 ± 0.41 | 33.43 | 53.92 ± 0.26 | 10.00 ± 0.30 | 31.40 ± 0.43 | 32.95 |
| 4 | 55.68 ± 0.01 | 10.08 ± 0.02 | 31.32 ± 0.67 | 32.90 | 54.14 ± 0.19 | 10.59 ± 0.06 | 30.77 ± 0.26 | 32.54 |
| 5 | 56.26 ± 0.15 | 9.44 ± 0.17 | 32.36 ± 0.38 | 33.71 | 53.43 ± 0.08 | 9.77 ± 0.02 | 30.54 ± 0.43 | 32.06 |
| 6 | 54.99 ± 0.15 | 10.17 ± 0.07 | 29.66 ± 0.35 | 31.36 | 53.11 ± 0.08 | 11.00 ± 0.06 | 30.04 ± 0.04 | 31.99 |
| 7 | 55.72 ± 0.12 | 10.13 ± 0.11 | 30.10 ± 0.32 | 31.76 | 53.43 ± 0.08 | 10.45 ± 0.02 | 30.52 ± 0.17 | 32.26 |
| 8 | 55.55 ± 0.01 | 9.21 ± 0.15 | 29.72 ± 0.18 | 31.11 | 53.27 ± 0.08 | 10.13 ± 0.01 | 29.68 ± 0.12 | 31.36 |
| | FWF/22 °C | | | | FWF/37 °C | | | |
| 1 | 44.83 ± 0.24 | 9.91 ± 0.02 | 18.73 ± 0.11 | 21.19 | – | – | – | – |
| 2 | 45.31 ± 0.03 | 10.15 ± 0.18 | 18.55 ± 0.05 | 21.15 | 44.85 ± 0.13 | 10.67 ± 0.01 | 18.68 ± 0.19 | 21.51 |
| 3 | 45.38 ± 0.07 | 10.28 ± 0.13 | 18.74 ± 0.06 | 21.37 | 44.82 ± 0.09 | 10.61 ± 0.04 | 18.69 ± 0.12 | 21.49 |
| 4 | 45.27 ± 0.16 | 11.04 ± 0.21 | 18.84 ± 0.08 | 21.84 | 45.03 ± 0.09 | 10.92 ± 0.11 | 18.52 ± 0.09 | 21.50 |
| 5 | 45.56 ± 0.13 | 10.09 ± 0.07 | 18.87 ± 0.28 | 21.40 | 44.67 ± 0.11 | 10.31 ± 0.10 | 18.52 ± 0.09 | 21.20 |
| 6 | 45.46 ± 0.14 | 9.90 ± 0.16 | 18.79 ± 0.22 | 21.24 | 44.97 ± 0.02 | 10.19 ± 0.12 | 18.06 ± 0.16 | 20.74 |
| 7 | 45.74 ± 0.23 | 10.10 ± 0.07 | 19.10 ± 0.11 | 21.61 | 44.61 ± 0.06 | 10.38 ± 0.04 | 18.52 ± 0.14 | 21.23 |
| 8 | 46.17 ± 0.12 | 10.58 ± 0.30 | 18.80 ± 0.27 | 21.57 | 44.88 ± 0.37 | 11.21 ± 0.67 | 18.60 ± 0.59 | 21.72 |

[a] Color index: $L^*$, brightness; $a^*$, red-green axis; $b^*$, yellow-blue axis; $C$, chroma. [b] Abbreviations: NFWF, nonfortified weaning food; FWF, fortified weaning food.

FWF, as the addition of the red concentrate to the weaning food could provide an unstable color compound throughout the storage period and provoke a rejection of the product by the consumer. Instrumental color measurements of FWF and NFWF are shown in Table 3. Although many studies report and evaluate $L^*a^*b^*$ readings, conversion of such to chroma (Table 3) and hue angle (Figure 2) provide functions more closely associated with human perception. Hue is the characteristic associated with the conventional perceived color name. An angle of 90° represents a yellow hue. Objects with higher hue angles are more green while lower angles are more orange-red (Gnanasekharan et al., 1992). FWF resulted darker ($p < 0.001$) than NFWF as mean $L^*$ values (lightness) were 45.27 and 54.71, respectively. The addition of the heme concentrate also significantly reduced ($p < 0.001$) the contribution of yellowness ($b^*$), chroma, and hue angle from 30.75, 32.32, and 72.2°, respectively, in NFWF to 18.75, 21.64, and 60.1° in FWF. Obviously, redness ($a^*$) was significantly higher ($p < 0.001$) in FWF (10.8) with respect to NFWF (9.91). As is appreciated in Figure 2, NFWF can be described as a yellow product while FWF resulted in an orange-brown coloration. The effect of time and temperature on objective color measurement was studied separately for each type of weaning food. ANOVA results indicated no influence of these two factors on $L^*a^*b^*$, chroma, and hue angle values in both samples. According to these data we can deduce that the addition of the heme concentrate changes significantly the color of the weaning food; however, high temperatures and length of storage time did not modify such variables. This results in color stability have an obvious advantage in the food industry.

The mean sensory rating for NFWF and FWF at 22 and 37 °C were evaluated at the first month of the

**Table 4. Mean Score Ratios of Sensory Attributes of NFWF and FWF over Time (Months)**

| | storage temperature | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 22 °C | | | | | | 37 °C | | | |
| | 0 | | 4 | | 8 | | 4 | | 8 | |
| sensory attributes[a] | NFWF[b] | FWF | NFWF | FWF | NFWF | FWF | NFWF | FWF | NFWF | FWF |
| appearance | 6.2 | 5.1 | 6.4 | 6.4 | 6.3 | 6.1 | 6.1 | 6.6 | 6.4 | 6.1 |
| color | 6.3 | 4.7 | 6.5 | 6.1 | 6.1 | 5.8 | 6.2 | 6.1 | 6.5 | 5.8 |
| flavor | 5.7 | 6.5 | 5.7 | 6.8 | 6.4 | 7.0 | 6.0 | 6.8 | 6.5 | 7.0 |
| taste | 6.7 | 6.7 | 6.7 | 7.2 | 6.4 | 6.2 | 6.2 | 7.2 | 6.1 | 7.2 |
| texture | 6.7 | 7.1 | 6.3 | 7.2 | 5.7 | 6.7 | 5.8 | 7.2 | 5.9 | 6.9 |
| acceptance | 6.7 | 6.8 | 6.5 | 7.1 | 6.1 | 6.5 | 6.5 | 7.8 | 6.1 | 6.9 |

[a] Sensory attributes for NFWF and FWF at 22 and 37 °C evaluated at the first month of the experiment and repeated at 4 and 8 months. [b] Abbrevitations: NFWF, nonfortified weaning food; FWF, fortified weaning food.

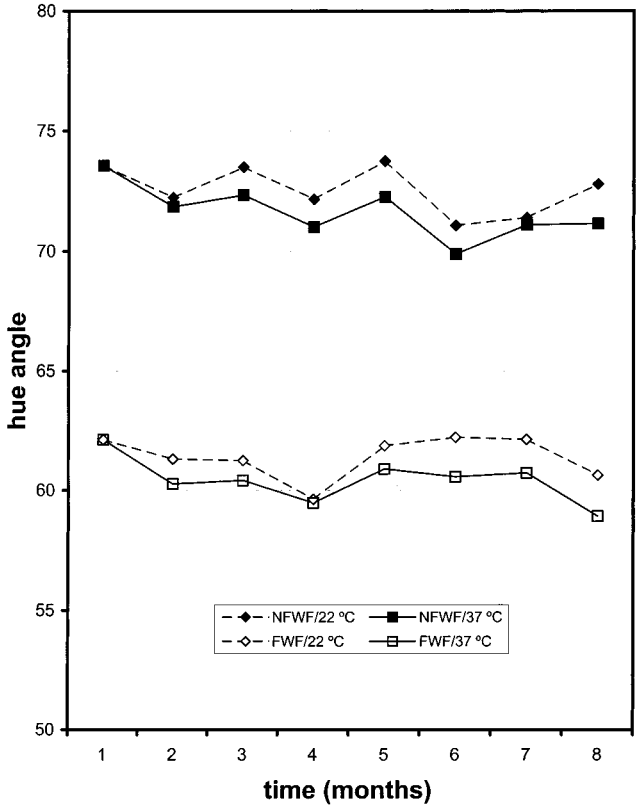


**Figure 2.** Hue angle of NFWF (nonfortified weaning food) and FWF (fortified weaning food) at 22 and 37 °C during 8 months of storage.

experiment and repeated at 4 and 8 months (Table 4). Only color scored significantly higher ($p < 0.01$) in NFWF than in FWF having average values of 6.3 and 5.7, respectively, calculated from color sensory ratings showed at Table 4. On the other hand, there were no significant differences in appearance, taste, odor, texture, and acceptance. Despite that, flavor, taste, and texture scored better in FWF while visual attributes (appearance and color) were preferred in NFWF. Time and temperature did not influence sensory scores, and samples stored for 8 months maintained the same sensory quality with average scores of around 6 or higher, even those samples stored at 37 °C. Rancidity of lipids did not appear, despite some authors postulating that heme concentrates would catalyze lipid autooxidation (Asenjo et al., 1985). Higher concentrations of heme iron may develop this effect.

Correlation between all the sensory attributes (Table 5) indicated that all these variables were significantly associated ($p < 0.01$) in both types of weaning foods. Acceptability indicated a higher correlation with taste

**Table 5. Correlation of Sensory Scores of NFWF and FWF**

| | appearance | color | flavor | taste | texture |
|---|---|---|---|---|---|
| | | NFWF[a] | | | |
| color | 0.787*[b] | | | | |
| flavor | 0.527* | 0.628* | | | |
| taste | 0.602* | 0.510* | 0.532* | | |
| texture | 0.655* | 0.540* | 0.574* | 0.769* | |
| acceptance | 0.675* | 0.586* | 0.609* | 0.898* | 0.849* |
| | | FWF | | | |
| color | 0.895* | | | | |
| flavor | 0.542* | 0.634* | | | |
| taste | 0.369* | 0.424* | 0.564* | | |
| texture | 0.429* | 0.502* | 0.447* | 0.438* | |
| acceptance | 0.459* | 0.575* | 0.635* | 0.851* | 0.547* |

[a] Abbreviations: NFWF, nonfortified weaning food; FWF, fortified weaning food. [b] Correlation index were significant at $p < 0.001$.

($r = 0.90$) and texture (0.85) in NFWF and with taste (0.85) in FWF. Obviously appearance and color were highly correlated since both are visual attributes. To understand the contribution of the different sensory attributes to the general acceptance of weaning foods, a stepwise linear regression analysis was conducted in NFWF and FWF and a regression equation were developed:

$$\text{acceptance NFWF} = 0.871 + 0.556(\text{taste}) + 0.319(\text{texture}) \text{ with } r^2 = 0.87$$

$$\text{acceptance FWF} = 1.378 + 0.626(\text{taste}) + 0.202(\text{color}) \text{ with } r^2 = 0.78$$

Both equations show high coefficients of determination ($r^2$) taste being the primary factor, since it had greater contribution to the equation than any other variable. Color was also an important factor in FWF; as pointed out earlier, it was the only sensory attribute influenced by storage time. A multidimensional scaling analysis of acceptance and color was performed at time 0, 4, and 8 months to determine variations in the distances (dissimilarities) between these two variables (Figure 3). Instrumental measurement of red color ($a^*$ value) was included as a reference since FWF's color was described as brown-orange and it did not change during the storage period. The position of the variables in two dimensions may help us to understand the associations between these parameters. A reduction of the distances between color and acceptance through storage time (Figure 3: 0 month = A; 4 month = B; 8 month = C) could be understood as a decreased in the dissimilarities. This fact could be explained as the panel grew accustomed to the brown-orange color of the FWF,

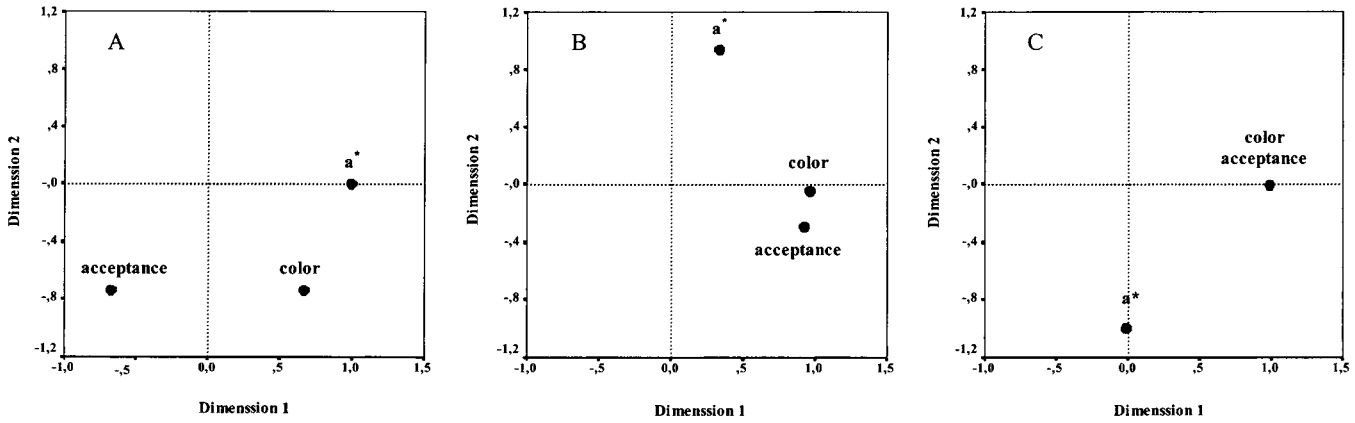


**Figure 3.** Multidimensional scaling of acceptance, color, and *a** value of FWF (fortified weaning food) at the beginning storage period (A), 4th month (B), and 8th month (C) of storage. Multidimensional scaling relates a group of measurements of the distances between cases or objects.

which was scored lower at month 0 than at month 4 or 8 (Table 4).

## CONCLUSION

The present study has shown that the addition of heme iron concentrate at a level of 0.5% to weaning foods may be used as an alternative in the fortification of this type of infant foods in order to prevent iron deficiency. Heme iron decreased with storage time; however, the proportion of this highly available iron is considerably higher in FWF than in NFWF. The sensory scores of the experimental weaning food, even in those stored at high temperatures (37 °C) and after 8 months, confirm the stability of sensory characteristics.

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