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# Baby Food Safety: Baby Food Manufacturing Standards

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**ABSTRACT**

The quality and safety of trendy baby foods should not be compromised, and the nutrient content of the foods offered should be appropriately addressed. Most of these foods undergo thermal processing, which results in the degradation of nutrients and the production of as was be seen later-potential toxic compounds. The present study was intended to identify some Maillard reaction products, including 5-hydroxymethyl furfural (HMF), as well as total Maillard Reaction Products (MRPs) in a variety of baby food samples. In total, 45 samples of milk powder, freeze-dried meat products, powdery cereals, homogenized products in jars, and other types were studied. The results established that all assays had HMF and that none were above the 20 mg/kg limit suggested by EFJA. The highest HMF formation was observed in lyophilized meat–based foods, especially in turkey and veal products. Together, total MRPs prevailed from them, and a maximum quantity of total MRPs were found in Lyophilized meat-based foods. For the 12-month and older group of the population, the daily HMF consumption from the tested food was found to be up to 3.6mg. Infectious homogenized jarred foods, particularly those derived from proteins and veggies, contributed highly to HMF intake. These arise when bioactive proteins in food undergo the Maillard reaction with other food components to form toxic compounds. These substances deserve further study in regard to their impact on the health of infants and children because products with these compounds are clearly present in baby foods that children more frequently consume.

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## Introduction

Over and over again, there have been some changes in the preparation and consumption of foods, especially for families with kids, which have greatly changed in the last couple of decades. While at one time, people were able to take time to set the table and start cooking from a raw hard and spend over an hour preparing homemade food, this practice is no longer the case with ready-to-eat and convenience foods [1]. These are foods that are usually pre-cooked and packaged with the intention of being easily prepared. Indeed, preparing meals that would have once taken more than an hour to prepare can now take just 5 to 30 minutes and, therefore, are perfect for families that are too busy [2]. This change is profound, especially for foods for infants and toddlers, another sector of the food business that has also adapted to the needs of today's society.

Most of the documented recipes can be bought in the stores by applying pre-cooked baby foods, for instance, Formulas, Cereals, and jarred meals, which can easily be administered to working parents or caregivers when they are busy preparing fresh foods for their children [3,4]. These foods are developed for the nutrition of babies and toddlers and contain proteins, amino acids, vitamins, minerals, and fats. These are given in proportions that benefit the little ones. The convenience of these products cannot be overemphasized since they can be used as a way of feeding children aged between 4 months and 3 years. Also, these foods are formulated to cater to the growing abilities of children, particularly the young ones, so as to make sure that they get the nutrients that they humans require at this young age [5]. Nonetheless, due to the urge for convenience foods in the market, the safety and quality of these food products have raised a lot of controversies [6]. Although these foods are whole foods containing nutritious ingredients, what researchers get after processing—fat and proteins, in most instances, undergo thermal treatments such as homogenization and pasteurization, lose nutritional values, and can create potentially toxic byproducts [7]. Among the most critical problems with the safety of baby foods is the formation of Maillard reaction products (MRPs), which are chemicals formed by the reaction between proteins and sugars with heat [8]. Of these, furan and 5-hydroxymethyl furfural (HMF) have been considered as possibly unsafe for human consumption in large portions [9,10].

Maillard reaction is a chemical process that takes place, and foods are subjected to heat by either cooking or processing [11]. This conversion results in the formation of different byproducts, and one of them is HMF, which is generally employed as an index of MRPs. Many reports have been published on HMF because of its toxicity, its ability to induce genotoxic and hepatotoxins, and because it is listed as a carcinogen and neurotoxin [12]. Thus, analyzing the effect of HMF on the human organism, the regulatory bodies of the world have established the maximum and minimum levels of HMF permitted in foods, especially those being used for infants and children individuals. In Europe, the European Fruit Juice Association (2019) has made the limit of HMF to be 20mg per kg in baby foods since it is safe for babies [13]. This regulation is more stringent compared to the 40 mg/kg allowed for honey, as shown in the regulation on the control of HMF in baby food products [14-16].

Even with such regulations in place, the public and consumers are unaware of the amounts of Maillard reaction products in baby foods [17]. These byproducts are strictly dangerous because they are generated at the high thermal processes of the food, and many of the foods being fed to infants are subjected to high thermal processes, mainly cereals, meat-based, and milk powders. Depending on the type of food, temperature, and time it takes to heat it, these byproducts are formed to varying degrees. Some research has proved that products such as lyophilized meat-based products, which are often subjected to high temperatures in order to preserve them, contain relatively high amounts of MRPs. This is rather worrying because such foods are rich in compounds that may be toxic when consumed in large amounts, and infants consume them in large amounts. Furthermore, although the nutritional qualities of the baby foods are specially designed to serve the nutritional needs of the baby, the appearance of the Maillard reaction products and other toxicants add to the compelling inquiries as to the overall effects of these products on the health of the consumer [18]. The infant may suffer more of an impact due to these compounds because their system is not very developed, and the sizes of their bodies are comparatively smaller than that of grownups. Nevertheless, studies are being conducted to determine the long-term implications of putting these derivatives into the human system.

The quality assessment of baby foods in relation to their nutrient composition and Maillard reaction product safety should be considered [19]. The current study seeks to minimize these worries by assessing the concentrations of HMF and other MRPs in a selection of baby foods typically on display in stores. In fact, through these levels, the study aims to reveal the degree of the impact of these byproducts on baby food products and, in this way, evaluate the effectiveness of existing regulations for presenting baby health and safety [20]. The results of this research will be useful for further debates on the topic of food safety as well as for the regulation of potentially hazardous components in baby foods, which would allow children only to be offered healthy and tasty meals. In conclusion, because parents and guardians are carrying their babies to other grocery stores to buy convenient ready-to-eat baby foods, it's important to examine these foods with zeal for their nutritional value for babies and safety aspects as well. To this end, there is still a need to comprehend how MRPs contribute to the production of baby foods and their possible effects on nutritional health.

## Material and Methods

### Sampling Collection

Forty Five baby food samples were taken from different supermarkets around the region. The samples were split into the following baby food types: Two growing-up milk powders for children aged 1 to 3 years; two meat-based lyophilized preparations; Five cereal-based porridges; Three cheese based homogenized jarred preparations; Five fish based homogenized jarred foods; Four vegetable-based-homogenized-jarred-foods-; and finally, twenty-four meat based homogenized jarred preparations. Such samples were selected to cover all the potential. They frequently observed products on the market in order to obtain a broad perspective on Maillard reaction byproducts, HMF, and total MRPs in various types of baby foods.

### Sampling Preparation

#### Protein-based Homogenized Jarred Baby Food Samples

0.5 g of the product was diluted in 10 ml of acidified distilled water (1%) and extracted for 10 minutes. The solution was centrifuged (ALC 4218 centrifuge) at 3000 rpm for 10 minutes. The solid fraction, separated from the supernatant, was then subjected to a new extraction step. The liquid phases were collected and brought to a final volume of 10 ml.

#### Vegetable-based Homogenized Jarred Baby Food Samples

0.5g of the product was dissolved in 10 ml of acidified distilled water (1%) and extracted for 10 minutes. The solution was centrifuged (ALC 4218 centrifuge) at 3000 rpm for 10 minutes. The solid fraction, separated from the supernatant, was then collected and brought to a final volume of 10 ml.

#### Meat-based Freeze-dried Preparations
#### Cereal-based Powder Creams, and Milk Powder Samples

125 ml of water were added to two aliquots of 5 g of freeze-dried meat, two aliquots of 5 g of cereal powder and two aliquots of 30 g of milk powder and each aliquot was brought to 50°C and 100°C respectively. From each solution was taken 20 g, diluted with 100 ml of water and extracted for 30 min. The solution was then filtered (Whatman Schleicher & Schüll filter paper Grade 589/1, 125 mm, Merck, Darmstadt, Germany).

### Sample Analysis for the Determination of HMF and Total MRPs

#### Sample Analysis for HMF Determination

The sample extracts previously prepared were analyzed at room temperature at two wavelengths: 266 nm and 284 nm.

#### Sample ANALYSIS for Total Maillard Reaction Products Determination

The Maillard's reaction can be ideally divided into three steps: a first phase involving the formation of colorless compounds that do not absorb in the spectrum of the visible and that can be analyzed at 280 nm; a second, more advanced, step that can be monitored at 360 nm and finally a third step which leads to the formation of colored high molecular weight compounds, the melanoidin, which absorb at 420 nm [21,22]. The extracts of the previously prepared samples were therefore analyzed at room temperature at the three different wavelengths to highlight the three reaction steps [23].

### Equipment

All analyses were performed using a Cary 60 UV-Vis Spectrophotometer (Agilent, CA, United States).

## Results and Discussion

### HMF Evaluation

Assessment of 5-hydroxymethylfurfural (HMF) in the tested baby foods is essential to evaluate the impact of Maillard reaction products (MRPs) in the course of food processing. HMF stands for Hydroxymethylfurfural and is a substance that is produced as a result of the Maillard reaction, which takes place between reducing sugars and amino acids when exposed to heat [24]. Although HMF is known to be a product of the Maillard reaction, it was cited as being a toxic compound, which some existing studies have linked with carcinogenicity as well as neurotoxicity, especially for immature infants with underdeveloped metabolizing systems [25]. HMF concentrations reported from this study are shown in table form in Table 1 and Table 2 below—data on HMF concentrations in various categories of baby foods. The foods of focus in this analysis consist of cereal-based porridges, growing-up milk, lyophilized meats, and homogenized jarred foods wedged into categories using main cooking ingredients or raw materials such as meats, vegetables, and protein sources. The HMF concentrations were analyzed at 266nm and 284nm, both being standard wavelengths used in spectrophotometer reads to identify the concentration levels of HMF.

Table 1 provides information on the HMF content of cereal-based porridges and growing-up milk. For instance, the scan of 4 cereal samples at 50°C had an HMF level of 2.95 mg/kg and 266 nm, while the same sample at 100°C was 8.62 mg/kg. Likewise, with Whole Cereals, sample HMF rose from 1.23 mg/kg at 50 °C to 2.73 at 100°C. These findings are in concordance with observations in most studies where the formation of HMF increases with the temperature dependence of the Maillard reaction. In the current study, most of the samples of growing-up milk were fairly low. GU1 was 4.15 mg/kg, while GU 2 was 4.77 mg/kg at 266 nm. Thus, at 284 nm, the values were slightly lower but still very similar, which proves that, even though milk powder is heat treated at very high temperatures, its HMF content is not as high as in more carbohydrate-containing products such as cereals.

**Table 1: HMF Values at 266 nm and 284 nm Expressed in mg/Kg for the Cereal-based Porridges and Growing up Milk**

| | HMF Content (mg/Kg) | |
|---|---|---|
| | 266 nm | 284 nm |
| 4 Cereals (50°C) | 2.95 ± 0.61 | 2.08 ± 0.10 |
| 4 Cereals (100°C) | 8.62 ± 0.72 | 5.90 ± 0.22 |
| Whole Cereals (50°C) | 1.23 ± 0.17 | 1.08 ± 0.13 |
| Whole Cereals (100°C) | 2.73 ± 0.04 | 1.34 ± 0.04 |
| Maize and Tapioca (50°C) | 3.28 ± 0.35 | 2.30 ± 0.09 |
| Maize and Tapioca (100°C) | 3.92 ± 0.44 | 2.92 ±0.05 |
| Creamy Rice (50°C) | 2.44 ± 0.16 | 1.65 ± 0.08 |
| Creamy Rice (100°C) | 3.84 ± 0.25 | 2.53 ± 0.02 |
| Wheat Semolina (50°C) | 1.68 ± 0.11 | 1.04 ± 0.15 |
| Wheat Semolina (100°C) | 3.31 ± 0.34 | 2.19 ± 0.13 |
| Growing up Milk 1 | 4.15 ± 0.01 | 2.79 ± 0.01 |
| Growing up Milk 2 | 4.77 ± 0.05 | 2.96 ± 0.01 |

Values are means ± s.d. of three separate determinations.

The HMF values of the lyophilized meat-based food and other protein and vegetable-homogenized jarred meals are presented in Table 2. For example, Lyophilized Turkey had a higher concentration of HMF content with 266 nm = 18.19 mg/kg and 284 nm = 9.02 mg/kg for 50°C prepared. Having drug concentration values of 11.19 mg/kg at 266 nm when heated at 100°C, it appears that although the Maillard reaction is dependent on temperature, the decline in HMF concentration at these higher temperatures with this specific sample may be due to the breaking down of HMF. Other meat-based samples, including Chicken and Veal, also contained high amounts of HMF; Chicken at 50°C had HMF at 266 nm 14.74mg/kg, and at 284nm was 8.71mg/kg. Thus, comparing these findings to the literature, the number of works that described increased HMF formation in high-protein foods, especially when cooked at high temperatures, cannot be counted on the fingers. For instance, Calabretti et al, named GMOs in connection with the HMF formation in infant formulas and determined that although the HMF concentrations in cereal-based products were also high, meats, especially lyophilized meats, contained significantly higher amounts of HMF [26]. In agreement with these observations, the present investigation also reveals that meats and meat products, especially those prepared through the lyophilization process, are more susceptible to the generation of higher levels of HMF than cereals or dairy products [27]. In addition, Zhang and Wang study on the level of HMF in baby foods showed that HMF level rises when foods of meat origin, for example, are dried or cooked at high temperatures [28]. Their conclusion is virtually similar to those derived from this paper: lyophilized meat products contain elevated levels of HMF; however, when compared with other food types, such as vegetables or cereals, they rank lower. This observation agrees with previous conclusions that suggested the need to keep HMF levels low in baby foods and more so in products that contain meats [29].

**Table 2: HMF Values at 266 nm and 284 nm Expressed in mg/Kg for the Meat-based Lyophilized and Various Protein- and Vegetable- based Homogenized Jarred Meals**

| | HMF Content (mg/Kg) | |
|---|---|---|
| | 266 nm | 284 nm |
| Chicken (50°C) | 14.74 ± 0.99 | 8.71 ± 0.62 |
| Chicken (100°C) | 18.07 ± 0.39 | 10.14 ± 0.97 |
| Turkey (50°C) | 18.19 ± 1.9 | 9.02 ± 0.99 |
| Turkey (100°C) | 11.19 ± 0.11 | 6.13 ± 0.73 |
| Lamb | 4.61 ± 0.32 | 3.03 ± 0.13 |
| Horse | 8.71 ± 0.01 | 4.04 ± 0.76 |
| Rabbit | 8.95 ± 0.12 | 4.64 ± 0.08 |
| Cheese | 7.25 ± 0.10 | 5.60 ± 0.72 |
| Beef 1 | 7.99 ± 0.46 | 7.19 ± 0.68 |
| Beef 4 | 7.23 ± 0.87 | 4.04 ± 0.53 |
| Peas and zucchini | 5.86 ± 0.62 | 3.17 ± 0.02 |
| Plaice | 4.83 ± 0.11 | 2.56 ± 0.27 |
| Chicken 1 | 15.70 ± 1.97 | 7.63 ± 0.07 |
| Chicken 2 | 12.46 ± 0.19 | 5.89 ± 0.46 |
| Turkey 1 | 8.61 ± 0.06 | 3.92 ± 0.09 |
| Turkey 4 | 6.61 ± 0.66 | 3.14 ± 0.69 |
| Vegetables 1 | 6.32 ± 0.09 | 3.67 ± 0.14 |
| Vegetables 2 | 11.59 ± 0.37 | 5.91 ± 0.72 |
| Veal 1 | 17.76 ± 0.25 | 9.35 ± 0.01 |
| Veal 3 | 9.65 ± 0.31 | 4.73 ± 0.39 |

Values are means ± s.d. of three separate determinations

In terms of averages across food categories, the study found the following HMF concentrations: cereal-based porridges at 3.4ppm, meat lyophilized products at 15.55ppm, protein-based homogenized jars at 9.25ppm, vegetable-based homogenized jars at 7.92ppm, and milk powders at 4.46ppm. These values follow the trend of previous works, like the work done by Swiech, who observed that cereal-containing products generally have low HMF content, while products containing high protein, especially those processed by heat, and have higher HMF content [30]. One of the most conspicuous revelations in this research is a relatively high level of HMF in protein-based homogenized baby food. HMF was detected in all the identified products, particularly in the products containing meat and fish, where the levels were considerably higher. This reveals that heating and homogenization could also increase the formation of this compound. These results are particularly pertinent because protein-based jarred foods are widely employed as an easily prepared and adequately nutritious meal for babies. These foods have HMF levels beyond safe levels, hence raising concern about the health effects of HMF on infants with probable neurotoxic and carcinogenic features. Regarding the realm of legislating norms, it is important to mention that HMF contents in the analyzed baby foods were below the upper European limit, which is 20 mg/kg, as established by the European Fruit Juice Association for foods for babies. Although none of the samples in this study attained this value, total HMF and other MRP intake by infants should not be overlooked. The HMF level in most of the baby foods detected in this study exceeds the background level. The daily intake of HMF from the analyzed baby products, especially from homogenized meat and vegetable-based products can be regarded as a substantial part of the allowed daily intake, especially in the case when infants consume them regularly as part of their diet.

For cereal and meat lyophilized porridges analyzed, were made from the same powder base added with distilled water at two temperatures: 50°C and 100°C. The samples obtained with water at a higher temperature showed HMF levels higher than those obtained with water at a medium temperature in accordance with the temperature dependence of the Maillard reaction. At 266 nm the percentage increase showed to vary from 19.48% of Maize and Tapioca sample to 192.2% of 4 Cereals sample with a mean value of 67.36%. Only the lyophilized Turkey sample showed a decrease in values (-38.48%). At 284 nm the increase in HMF values between preparations at 50°C and those at 100°C was between 25.22% of Maize and Tapioca porridge and 183.65% of 4 Cereals porridge with a mean increase of 52.4%. In the same way, the values decreased by 32.0% for the lyophilized Turkey sample.

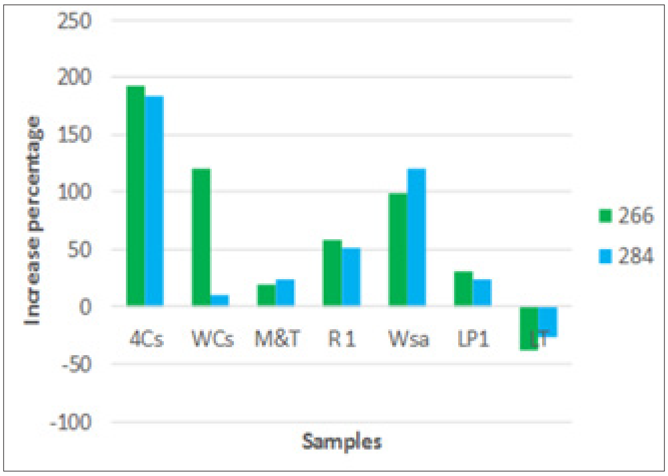


**Figure 1:** Shows the Percentage Increase in the Two Different Cooking Temperatures

Figure 1 Comparison between the HMF value increases for the samples prepared at 50°C and 100° at 266 nm and 284 nm, expressed as percentages. Legend: 4Cs = 4 Cereal cream; WCs = Whole Cereal cream; M&T = Maize and Tapioca cream; R1 = creamy Rice porridge; Wsa = Wheat semolina; LP1 = Lyophilized chicken; LT = Lyophilized Turkey

More studies are required involving the chronic toxicity of HMF to evaluate the hazards of the consumption of Maillard reaction byproducts when taken on a long-term basis, especially among infants and young kids. Reineccius (2014) in his prior study, pointed out that while the HMF may have an additive effect when combined with other dietary ingredients, long-term consumption may elicit adverse health consequences. In view of this information, it is important to survey and control the levels of such biomolecules in baby foods. The findings from this study, therefore, call for an evaluation of HMF in baby foods, but especially in foods that are processed at high temperatures, such as lyophilized meats and homogenized proteinaceous foods. HMF concentrations examined in the analyzed products did not exceed EU safety standards; however, the total daily intake of HMF may be harmful from a long-term point of view, especially regarding baby foods, which are consumed daily. More studies should be conducted in the future to examine the chronic effects of HMF and other MRPs on infants and their neural and cancer development.

**Total MRPs Evaluation**

In order to determine the degree of the Maillard reaction up to which the foods have been thermally treated, the total amount of MRPs in baby foods was analyzed. MRPs are the compounds that are produced when reducing sugars and amino acids combine under heat. The Maillard reaction is identified as one of the basic steps in food processing, which contributes to the color, aroma, and taste of the cooked products. However, the formation of MRPs, especially in foods for infancy, is a major concern due to the potentially toxic nature of some of these compounds. In this study, the MRP analysis was done employing spectrophotometric methods, where the samples were scanned at three specific wavelengths: 280 nm, 360 nm, and 420 nm, pertaining to the three different stages of the Maillard reaction. Phase I at 280 nm corresponds to the formation of colorless intermediates, phase II at 360 nm to the formation of brown-colored products, and the final phase at 420 nm to the formation of highly condensed compounds, including melanoidins. These stages are important in establishing the level of past Maillard reaction the tested baby foods have undergone. As demonstrated in Table 3 and Table 4 below, the figures in the total MRP evaluation point to high MRP densities in numerous subcategories of baby food. For example, the comparison made between cereal-based porridges and milk powders and the MRPs obtained for homogenized meat and protein products lowers those obtained. High MRPs are found in lyophilized meats, and it is interesting to note that many baby foods, especially those that are meat-based, are thermally processed, which leads to the Maillard reaction.

**Table 3: Total MPRs Values at 280 nm, 360 nm and 480 nm Expressed in mg/100g for the Cereal-based Porridges and Growing up Milk**

| | Total MPRs Content (mg/100g) | | |
|---|---|---|---|
| | **280 nm** | **360 nm** | **480 nm** |
| 4 Cereals (50°C) | 341 ± 10.99 | 1929 ± 114.56 | 2126 ± 49.45 |
| 4 Cereals (100°C) | 2582 ±19.78 | 4521 ± 61.81 | 3983 ± 35.87 |
| Whole Cereals (50°C) | 302 ± 16.48 | 1175 ± 66.33 | 1294 ± 46.07 |
| Whole Cereals (100°C) | 1117 ± 10.16 | 1287 ± 10.82 | 1326 ± 48.08 |
| Maize and Tapioca (50°C) | 775 ± 1.92 | 1476 ± 13.08 | 1485 ± 35.75 |
| Maize and Tapioca (100°C) | 1092 ± 7,69 | 1835 ± 41.73 | 1914 ± 20.19 |
| Creamy Rice (50°C) | 133 ± 1.56 | 1368 ± 93.68 | 1477 ± 36.86 |
| Creamy Rice (100°C) | 677 ± 3.57 | 2026 ± 95.60 | 1977 ± 18.52 |

| | | | |
|---|---|---|---|
| Wheat Semolina (50°C) | 882 ± 84.58 | 1118 ± 28.75 | 1318 ± 23.54 |
| Wheat Semolina (100°C) | 700 ± 33.75 | 2106 ± 43.75 | 2104 ± 31.72 |
| Growing up Milk 1 | 2077 ± 12.36 | 2407 ± 16.33 | 2785 ± 19.14 |
| Growing up Milk 2 | 2334 ± 15.84 | 3215 ± 28.12 | 3840 ±23.76 |

Values are means ± s.d. of three separate determinations.

In the first phase of the Maillard reaction at 280 nm, total MRPs were observed to be highest with lyophilized meat samples, with a standard of 3256 mg/100g chicken and 4267 mg/100g veal. These results are in concordance with Richter, who identified that foodstuffs with a high proportion of meat, including meat-based products, recorded significantly high MRPs attributed to extreme heat as well as protracted heating time during processing [31]. The high thermal stress common with meat due to its amino acids and protein content promotes the formation of MRPs. This trend was observed in different samples of meat, confirming once again that Maillard reaction in protein-containing foods is largely influenced by temperature. At 360 nm, the second phase of the Maillard reaction, significantly higher MRPs were noted in cheese-based homogenized jar and vegetable samples. In the cheese sample, the MRPs touched 5104 mg/100g, which was the second highest after the formation of the reference standards for s Pratt 3, vegetable 2 that reached 5075 mg/100g of the total figure of MRPs indicating that as the Maillard reaction proceeded the generation of the MRPs enhanced. These levels of MRPs in vegetable-based foods may look strange since vegetables themselves contain a lesser amount of protein than that found in meats. However, as noted by Limsuwanmanee, the Maillard reaction may also take place in non-protein foods where glucose or fructose is implicated and undergoes thermal breakdown [32].

Record levels of MRPs at 420 nm: the end product of the Maillard reaction was observed in lyophilized meat samples as well as cheese and veal samples, having 5971 mg/100g and 6921 mg/100g, respectively. This last step is the production of melanoidins, which are high molecular-weight brown pigments. These compounds are used reaction in processed food and primarily contribute to the browning reaction and the development of the sensory properties related to tastes and smells; however, it is a known fact that some compounds, such as melanoidin, show the potential to give rise to potentially toxic compounds such as acrylamides and heterocyclic amines. The same was pointed out by Shrama et al, who also concluded that excessive heating of meat and cheese products might lead to high MRPs, most of which have related health hazards [33]. The findings in this study support and also expand on prior research conducted on MRPs in baby foods and other processed foods. For instance, Offiah et al, found that MRPs in meat-based products were higher than in dairy or cereal products, as was noticeable in the present investigation [34]. The high amounts of MRPs established in the lyophilized meats, particularly in turkey, chicken, and veal, are support, who also observed that meats that undergo heat processes such as roasting or lyophilization have higher amounts of MRPs. An interesting area identified in this study is the analysis of the MRPs of vegetable-based homogenized foods, an aspect that has received relatively limited research attention in the past. The results presented here are consistent with the current studies by calabretti et al, where MRPs for vegetable-based foods were reported to be higher, with vegetables 1 and 2 at 5075 mg/100g and 5971 mg/100g at 360 nm, 420 nm respectively, similar to the result found by the current study [26]. According to their study, they concluded that vegetable-based foods subjected to thermal treatments, especially those containing higher levels of sugars, could attain high levels of Maillard reactions and form MRPs similar to animal-based foods. Observations of high MRPs in the samples under test indicate that the thermal processing method used in baby foods is unsafe. Despite playing a vital role in enhancing attractive product qualities like color, aroma, and flavor, the presence of MRPs, especially in high concentrations, is associated with some adverse health consequences. For instance, compounds such as acrylamide, which are formed in the Maillard reaction, have been rated as possible human carcinogenic by the IARC. Furthermore, the existence of melanoidins, despite the fact that not all of them cause hazardous effects, might cause oxidative stress and inflammation in bodies experiencing challenges within the detoxifying body, including infants whose ability to handle such by-products of AGEs is not quite developed. As seen from the study, manufacturers need to pay close attention to other thermal processing parameters in order to reduce the formation of toxic MRPs, mainly in baby foods that are targeted at consumers with sensitive stomachs.

**Table 4: Total MPRs Values at 280 nm, 360 nm and 480 nm Expressed in mg/100g for the Meat-based Lyophilized and Various Protein- and Vegetable-based Homogenized Jarred Meals**

| | Total MPRs Content (mg/100g) | | |
|---|---|---|---|
| | **280 nm** | **360 nm** | **480 nm** |
| Chicken (50°C) | 3888 ± 12.5 | 7119 ± 32.48 | 7481 ± 31.65 |
| Chicken (100°C) | 4683 ± 39.67 | 8381 ± 25.19 | 9075 ± 35.86 |
| Turkey (50°C) | 5185 ± 54.13 | 7994 ±27.55 | 9843 ± 33.67 |
| Turkey (100°C) | 2150 ± 33.18 | 5084 ± 18.45 | 2521 ± 19.41 |
| Lamb | 1671 ± 19.57 | 3570 ±11.53 | 4240 ± 28.26 |
| Horse | 2239 ± 26.31 | 4800 ± 27.19 | 5570 ± 25.73 |
| Rabbit | 827 ± 13.07 | 4363 ± 26.33 | 5243 ± 18.56 |
| Cheese | 2324 ± 21.54 | 5104 ± 19.0 | 5971 ± 16.45 |
| Beef 1 | 2522 ± 16,77 | 4015 ± 20.76 | 4967 ± 18.37 |
| Beef 4 | 1798.5 ± 24.65 | 3952 ± 17.83 | 4510 ± 19.19 |
| Peas and zucchini | 1365 ± 14.11 | 3520 ± 18.32 | 3759 ± 20.71 |
| Plaice | 812 ± 23.05 | 3470 ± 24.93 | 4057 ± 16.86 |
| Chicken 1 | 2103 ± 19.66 | 2950 ± 13.72 | 3596 ± 16.49 |
| Chicken 2 | 3256 ± 14.17 | 4665 ± 10.64 | 3357 ± 21.28 |
| Turkey 1 | 1561 ± 11,96 | 3757 ± 21,45 | 4498 ± 24.75 |
| Turkey 4 | 878 ± 9.45 | 3462 ± 15.35 | 3960 ± 18.66 |
| Vegetables 1 | 1764 ± 14.62 | 3810 ± 14.66 | 4530 ± 16.49 |
| Vegetables 2 | 2705 ± 20.18 | 5075 ± 23,19 | 5714 ± 24.54 |
| Veal 1 | 4267 ± 24.22 | 6080 ± 26.30 | 6921 ± 26.11 |
| Veal 3 | 2136 ± 15.70 | 4253 ± 19.44 | 4654 ± 23.32 |

Values are means ± s.d. of three separate determinations.

The assessment of overall total MRPs in diverse baby food products proves that heat treatment, especially in meat and protein-containing foods, generates high amounts of Maillard reaction products. The findings of the present work are consistent with the literature and raise the issue of the need to regulate cooking temperatures and times in order to reduce the formation of detrimental MRPs in hypoallergenic infant diets. The outcomes of this research suggest the need for the development of more effective techniques to minimize the impact of thermal treatments on MRPs solely on the nutritional and sensory properties of the observed baby foods. Such measures are very important, especially given that infants, which are a sensitive group, are at high risk of suffering from the effects of food contaminants.

**HMF Daily Intake Assumptions by an Infant or a Baby in Early Childhood**

**Sample Meal Plans According to the Child's Age**

In developing an adequate diet for infants and children, it is important to take into account the nutrients required for each growth and developmental period. The dietary needs of the child begin to change immediately after birth, one day, week, month, and up to 24 months as the Child grows, develops, and starts taking solid foods.

**Menu for Babies at Six Months**

An infant of 6 months is fed breast milk or infant formula but may additionally be given semisolid foods. This is so because, as explained earlier, their digestive system has yet to develop, and they cannot properly chew foods. Breast milk or formula is necessary for the growth of fat, protein, carbohydrates, vitamins, and minerals during this stage.

The sample meal plan for a 6-month-old would include the following:

**Morning:** Formula feeding: In today's meal, your baby needs 200—230 ml of milk (written feed or breast milk).

**Breakfast:** 170-200 ml of milk and 5 ml of iron-enriched cereals (bouten puree or mixed with breast milk/formula).

**Lunch:** 170-200 ml of milk, 5 ml of soft food vegetable (carrot and pea), 15 ml of soft food meat (chicken or beef).

**Dinner:** 170-200 ml of milk; 5 ml vegetable jar food, 5 ml fruit jar food – apple and pear puree

**After Dinner:** 170-200 ml of milk

At this age, it is said that fortified cereals are required based on the fact that the infant has a higher requirement of iron for their own growing-up needs. Citing the AAP, the introduction of solid foods should take place at 6 months, and iron-fortified cereals are often introduced first as they are a rich source of iron that the infant stores start to be depleted at around 6 months of age. However, some works, for instance, Dewey pointed out that there is a new trend of breastfeeding for as long as possible to ensure their babies are well fed on all nutrients [35].

**Sample Meal Plan for 7-9 months baby**

At 7 to 9 months, most infants should be ready to try out many foods in their mouths, aside from the usual thin, pureed foods. They can gradually start on textured foods when their teeth are budding, and they are also gaining oral-digital coordination for chewing [36]. It is at this stage that the introduction of a wider variety of solids is critical as the child gains the physical developmental skills of sitting up and feeding himself or herself [37].

The sample meal plan for a 7-9-month-old would include:

**Morning:** 200-230 ml of milk

**Breakfast:** 170-200 ml of milk, 15-45 ml of iron-enriched cereals, and 15 ml of fruit jar food.

**Lunch:** 140-170 ml of milk, 45 ml of iron-fortified cereals, and 15 ml of vegetable jar food, such as mashed sweet green peas.

**Dinner:** 170 ml milk, 45 ml rice or other cereal, 30 ml meat jar food, 15 ml fruit jar food

**After Dinner**: 140-170 ml of milk

Solid products during this stage are important, and therefore, more complex foods like fruits, vegetables, and meats should be introduced. The WHO recommends the following regarding complementary foods: they should be introduced incrementally by 6 months and continuing breast/formula feeds WHO. It is an important time for the child's feeding development, and foods that require some chewing elements should be introduced, but these have to be soft and mashed.

The study by Bothwell et al, shows that it is appropriate to introduce foods containing iron at this phase as the infant loses the iron reserves they were born with [38]. This is necessary to require the inclusion of foods high in iron, including meat, legumes, and iron-fortified cereal. Other previous researchers also hold the same view that offering fruits and vegetables ensures that the child gets vital vitamins besides nurturing a healthy dietary pattern.

**MLP of the Infant at the Age of 9-12 Months**

In 9 to 12 months, the nutrients a baby needs are not the same as those required in the previous months. At this age, infants are growing into more accomplishments in feeding and can take small amounts of foods familiar to the family, which may be minced, chopped, or softened. Breast milk or formula remains significant the whole day, while solid foods replace a part of the regular breast milk or formula as the baby now takes larger portions of it.

The sample meal plan for a 9-12-month-old would include:

**Morning:** 140-170 ml of milk

**Breakfast:** A glass of 140ml of milk, a bowl of iron-full cereal 125ml, or a glass of fruit jar food 45ml.

**Lunch:** 140-170 ml of milk, 30 ml of rice or other cereals, 30 ML of meat jar food, and 45 ml of vegetable jar food, such as mashed carrots or broccoli.

**Dinner:** One should take 140 ml of milk as their portion size, 30 ml of pasta or other cereals, 30 ml of meat jar food, 45 ml of vegetable jar food, and 30 ml of fruit jar food.

**After Dinner:** 140 ml of milk

At this stage, the child is taking solids three times a day, and snacks and self-feeding are preferred. Giving small pieces of bread and fruits/r xmlDoc: Giving small pieces of bread and fruits/r cooked vegetables helps in the mastering of small movements such as Chewing. According to the AAP, providing a range of textures should help advance the baby's oral motor skills. Satter also associate the introduction with the expansion of a variety of food options to help with the fine motor development of the baby when eating [39].

Concerning food consumption patterns, the emergence of food rich in proteins like meat, fish, and eggs is essential to cater to the increasing demand for muscles and tissues. In addition, the consumption of vegetables containing fibre, vitamins, and minerals should remain the main food for the baby. One can get his or her vitamins, particularly Vitamin C, from fruits; these vitamins aid in the absorption of iron.

**Table 5: An Example of Meal Plans for Different Baby Age Groups: 6 Months, 7-9 Months and 9-12 Months**

| Timing | 6 Months | 7-9 Months | 9-12 Months |
|---|---|---|---|
| Awakening | Milk 200-230 ml | Milk 200-230 ml | Milk 140-170 ml |
| Breakfast | Milk 170-200 ml Iron enriched Cereals 5 ml | Milk 170-200 ml<br>Iron enriched Cereals 45 ml Fruit jar 15 ml | Milk 140 ml<br>Iron enriched Cereals 125 ml Fruit jar 45 ml |
| Lunch | Milk 170-200 ml Vegetable jar 5 ml Meat jar 15 ml | Milk 140-170 ml<br>Iron enriched Cereals 45 ml<br>Vegetable jar 15 ml | Milk 140 ml<br>Rice or other cereal 30 ml Meat jar 15 ml<br>Vegetable jar 45 ml |
| Dinner | Milk 170-200 ml<br>Iron enriched Cereals 5 ml Vegetable jar 5 ml<br>Fruit jar 5 ml | Milk 170 ml<br>Iron enriched Cereals 45 ml Meat jar 15 ml<br>Fruit jar 15 ml | Milk 140 ml<br>Pasta or other cereal 30 ml Meat jar 15 ml<br>Vegetable jar 45 ml<br>Fruit jar 30 ml |
| After dinner | Milk 170-200 ml | Milk 140-170 ml | Milk 140 ml |

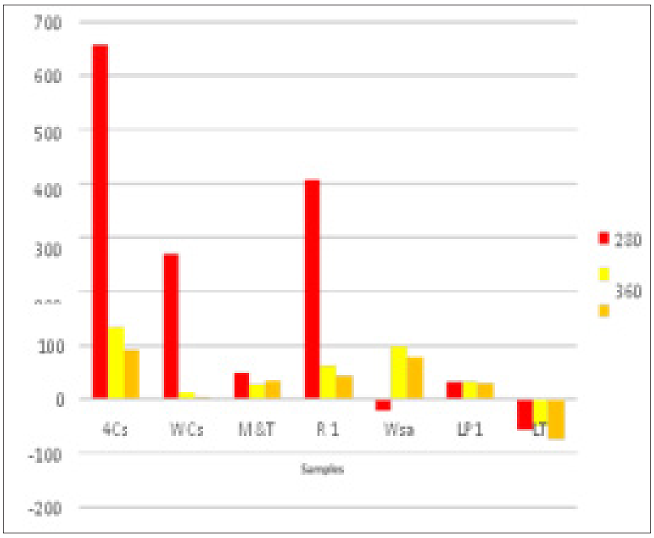


**Figure 2:** Comparison among the MPRs value increases for the samples prepared at 50°C and 100° at 280 nm, 360 nm, and 420 nm, expressed as percentage .Legend: 4Cs = 4 Cereal cream; WCs = Whole Cereal cream; M&T = Maize and Tapioca cream; R1 = creamy Rice porridge; Wsa = Wheat semolina; LP1 = Lyophilized chicken; LT = Lyophilized Turkey

These sample meal plans conform to general guidelines but are also more liberal as the child grows; the variety of foods and textures is more diverse. Authors like Bothwell et al, have pointed out that by 9-12 months, providing different types of solid foods like proteins, fruits, vegetables, and cereals is not only for achieving nutrient needs but also for guiding infants' food choices [38]. Therefore, as the infant moves from milk to the new table foods to eat, the complication of planning a meal that will fully satisfy all the nutritional requirements of the infant arises. Here, the AAP, WHO, and other researchers' guidelines for sample meal plans make a distinction that guarantees infants are supplied with an adequate quantity of nutrients such as iron, vitamins, and protein.

**The Determined Content of HMF**

The level of HMF in the baby food samples ranged from one category to another, and its level varied significantly. The levels of HMF were quantified at two wavelengths: 266 nm and 284 nm. Altogether, the study included different types of baby foods, namely, cereal-based porridges, lyophilized meat preparations, milk powders, and homogenized jar foods. The results show that HMF is found in all considered samples regardless of its concentration. Total concentrations were below 20 mg/kg, which is the limit EFSJ set for foods for children below 10 years of age. With regards to cereal-based products, HMF varied with a minimum range of 1.23 mg/kg of the whole cereal sample being cooked at 50°C up to a maximum of 8.62 mg/kg of the same sample being cooked at 100°C, as detected at 266 nm.

**Table 6: HMF Content for Different Baby Food Products. Data are Expressed as Mean Values (in mg/kg)**

| Baby Food Category | HMF |
|---|---|
| Creamy cereals porridge | 3.4 |
| Meat lyophilized | 15.55 |
| Meat jars | 9.25 |
| Vegetable jars | 7.92 |
| Milk powder | 4.46 |

A similar trend was observed with the results obtained at 284 nm; the highest values were obtained in the 4-cereal porridge at 100°C with a value of 5.90 mg/kg. These results are consistent with earlier studies concerning the impact of temperature on the formation of HMF during the Maillard reactions. In agreement with the temperature dependence of HMF formation, the same authors reported that increasing cooking temperature up to 95°C in the cereal model resulted in a higher concentration of HMF. For example, lyophilized meat-based foods had some of the highest levels of HMF recorded. For example, at 50, in a lyophilized turkey sample, HMF was found to be 18.19 mg/kg at 266 nm and 9.02 mg/kg at 284 nm. The content was slightly lower when the sample was heated to 100°C, giving HMF values of 11.19 mg/kg and 6.13 mg/kg at the same wavelengths, correspondingly. Such an observation tallies with the data obtained in other studies as identified in works which include those by Nunes et al, where processed meats are said to be prone to the reaction since they contain amino acids and reducing sugars, which elevate the HMF levels in the meat.

**Table 7: Daily HMF Intake Level from a Hypothetical Diet Based Only on Commercial Baby Foods Expressed in mg/kg and as Percentage from Each Food Category on the Daily Total Amount**

| Age | Daily amount of HMF (mg/kg) | Daily Percentage HMF Intake |
|---|---|---|
| 6 Months | 0.99 | 77.57% from milk powder |
| | | 8.02% from vegetable jars |
| | | 0.34% from creamy cereals porridge |
| | | 14.06% from meat jar |
| 7-9 Months | 0.93 | 75.11% from milk powder |
| | | 12.77% from vegetable jars |
| | | 4.93% from creamy cereals porridge |
| | | 7.19% from meat jar |
| 9-12 Months | 1.6 | 34% from milk powder |
| | | 44.66% from vegetable jars |
| | | 3.94% from creamy cereals porridge |
| | | 17.39% from meat jar |
| > 12 Months | 3.62 | 14.76% from milk powder |
| | | 49.15% from vegetable jars |
| | | 1.64% from creamy cereals porridge |
| | | 34.44% from meat jar |

Poultry and related jarred homogenized foods such as chicken and veal had higher HMF levels in this category as well. For instance, from the HMF calibration curve, it was found that Chicken at 50°C contained 14.74 mg/kg of HMF, and at 100°C contained 18.07 mg/kg of HMF for 266 nm. Comparably, detected values of veal-based foods were relatively high, with a maximum of 17.76 mg/kg at 266 nm. These findings are in accord with other studies that have pointed out that meat has a high HMF generation potential because of the high protein and sugar content, which enhances the Maillard reaction when cooked. Among all the types of milk products examined in this study, the manufacturers of milk powders had a relatively low level of HMF. For instance, HMF values of growing-up milk samples varied from 4.15 mg/k of milk at 266 nm to 4.77 mg/kg of milk at 266 nm. These values are consistent with the data obtained from the study of FAT, which has values more similar to those obtained from dairy products: while experiencing a certain level of the Maillard reaction, dairy products, as a rule, give less HMF than protein and meat-containing food in their composition.

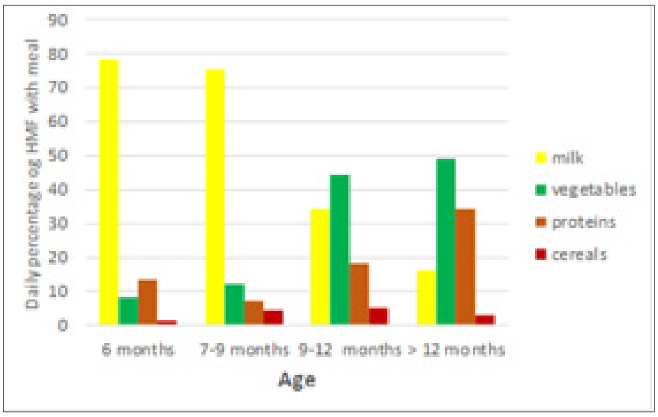


**Figure 3:** Percentage of HMF Intake on the Daily Total Amount of A Hypothetical Diet Based on Only Commercial Products for Each Category of Food

HMF was identified in all the baby food groups analyzed, and the mildest concentrations were obtained with lyophilized meat and meat-based homogenized food products. Fluorescence analysis of HMF levels in the baby food samples indicated that most foods contained HMF concentrations in the range of 10 pg/g. At the same time, the pure maize starch had no detectable HMF concentration. At temperatures used in processing most baby foods, the level of HMF produced is still below the regulatory limit of 20mg/kg. According to the level of the observed HMF, the results correspond with the stated research findings on the effect of temperature conditions on the formation of HMF byproducts

## Conclusions

The present analysis revealed the presence of 5-hydroxymethylfurfural (HMF) and Maillard Reaction Products (MRPs) in the selected baby food even though all the samples contained HMF below 20 mg/kg set by the European Fruit Juice Association [13]. Aim 3 of this study revealed that among all the food types tested, the lyophilized meat-based foods had the highest levels of HMF and MRPs, with a measurable level of MRPs at all three reaction stages of 280 nm, 360 nm, and 420 nm [40]. The result also pointed out that food with carbohydrate content, especially cereal-based porridges, contains lower HMF levels and that the temperature during cooking affects their formation considerably. Although the HMF concentrations identified in the study did not exceed the regulatory limit, the continual consumption of commercial baby foods containing these byproducts is a cause of concern owing to the immature detoxifying systems in infants and young children. It thus calls for an increased understanding of the conceivable hazards of MRPs in baby foods to fashion appropriate safety measures among food producers and policymakers in case the presence of MRPs in the foods is inevitable for nutritional benefits among babies. Consequently, subsequent studies are needed to evaluate the chronic health effects of HMF and MRPs in terms of infant diets, as well as to create better techniques to reduce the formation of these compounds through processing techniques. Some of the general guidelines to the makers of baby foods are as follows: one should aim at minimizing MRPs during production and processing in order to prevent the formation of hazardous byproducts, and one should ensure they use raw materials that don't have a high tendency of forming MRPs. Finally, it is necessary to understand how the Maillard reaction influences some aspects of infant food safety to increase the total quality of commercial baby foods [41-44].

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