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Research Article
Sensory Evaluation of Nonfat Dry Milk and Skim Milk Powder

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Abstract
Background and Objective: Sensory quality of milk powder is important as it can affect the quality of food products in which the powder is used as an ingredient. The objective of this study was to characterize flavor variability of nonfat dry milk (NFDM) and Skim Milk Powder (SMP) produced in the US. **Materials and Methods:** In this study, samples of low, medium and high heat NFDM/SMP were obtained from four US processors. Attributes looked for were sweet, cooked/heated, animal, cardboard, paint, astringent, acid, bitter, milkfat, buttery, salt, caramelized and metallic. Attribute intensities were scaled using the 0-15 universal intensity scale characterized by the descriptive sensory analysis method. **Results:** Sensory evaluation showed that there were significant differences between NFDM/SMP samples for sensory attributes sweet, cooked/heated, animal, cardboard, paint and astringent. Differences noticed for attributes acid, bitter, milkfat, buttery, salt, caramelized and metallic were not significant. Medium and high heat powders tended to have a cooked flavor note. **Conclusion:** All the evaluated powder samples met the US standard grade requirement for flavor; however, there were significant differences among NFDM/SMP samples in regard to some sensory attributes. It may suggest that differences noted between samples were likely caused by processing conditions.

Key words: NFDM/SMP, sensory evaluation, flavor, milk powder

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Dried dairy ingredients such as nonfat dry milk and skim milk powder are used in a range of food and beverage applications for their nutritional, functional and sensory properties[1]. The flavor of milk powders is the main characteristic that determines acceptance, application and the shelf life of the powder product[1]. The NFDM/SMP and other dried dairy ingredients should have a pleasantly sweet and clean taste to facilitate application in foods[2]. Good quality NFDM/SMP, when reconstituted should have flavor similar to that of fresh skim milk, that is generally flat because of the removal of fat from milk. Otherwise, the flavor should be clean and pleasant and may have a slightly cooked perception[2]. For NFDM/SMP, cooked flavor may be present with different intensities according to heat treatment (low, medium and high heat) of the milk prior to evaporation and spray-drying[2]. Suggested applications of NFDM/SMP are founded on the base of pre-heat treatment[3]. According to US standards the reconstituted NFDM should have a fairly pleasant flavor but may have bitter, oxidized, scorched, storage or utensil flavors to a slight degree and chalky, cooked, feed or flat flavors to a definite degree[4].

The chief flavor defects of SMP are stale/storage, neutralizer and scorched. Flavor defects in NFDM/SMP can result in poor quality end-product. Hence, sensory properties are important for evaluating of NFDM/SMP[5]. It was suggested that the causes of these defects are mostly due to raw milk quality, processing and storage conditions[6-9]. Heat treatment of milk during the production of powder can result in developing of the undesirable cooked flavor in milk powder. On the other hand, the increased heat treatment may improve the oxidative stability of the milk powder. It was suggested that the exposure of milk to heat (pasteurization, evaporation and spry drying) is possibly implicated with the development of off-flavors[7,8].

However commercial NFDM/SMPs conform to mandatory specifications, quality parameters such as composition, sensory and physicochemical properties can vary significantly due to processors[10,11]. The oxidation of lipid in dairy powders is the primarily mechanism responsible for the development of off-flavor. In addition, the distribution of fat may have a significant role in flavor and flavor stability[1]. It was suggested that carbonyl compounds are responsible for storage flavors in several dried or concentrated dairy products[1]. Also, it is well-known that saturated and unsaturated aldehydes have a role in the progress of off-flavors such as tallowy, painty, cardboardy and fishy flavors in oxidized dairy products[11,12]. Negative odor or flavor attributes such as animal, cardboard, paint, astringent, acid, bitter feed, burnt, oxidized, salty and chemical notes in reconstituted milk powder can adversely affect and influence food acceptance and choices[10,11,13]. In addition, off-flavors present in NFDM/SMP and other dried dairy ingredients can cause poor quality end-product[10,14].

Milk powders must display good quality in terms of sensory attributes at the time of purchase[15]. Off-flavors that may build up in milk products as well as the association between different oxidative off flavors and volatile oxidation in products have been described[16,17]. Detection thresholds of off-flavors such as cooked, chalky, feed, flat, burnt, bitter, oxidized, lipolysis, salty, acidic and chemical notes in reconstituted milk powder have been reported[17-19].

Sensory properties are considered important criteria in grading milk powders and other dried dairy ingredients[1]. Also, sensory evaluation of milk powder is important for determining the shelf life of the product[1]. Descriptive sensory analysis method has been used to identify and quantify flavors in several dairy products[2]. In addition, a trained sensory panel could be utilized to recognize the defects most likely caused by extended storage[1]. It is considered a powerful mean for describing and differentiating product flavors as well as product improvement and marketing[14,9].

As flavor is a critical factor in consumer acceptance and application of NFDM/SMP, the objectives of this study were to characterize flavor variability of US NFDM/SMPs. In this study some of the detailed sensory results were reported.

MATERIALS AND METHODS

Milk powder samples: In this study, 23 samples of spray dried NFDM/SMP were collected from US. Samples were 50 pound bags of low, medium and high heat NFDM/SMP that have not been agglomerated or instantized and were approximately 6-9 month old.

Sensory analysis: Samples were reconstituted at 10% solids using deodorized water. Reconstituted products were dispensed into lidded cups with 3-digit codes and stored at 7°C overnight. Samples were tempered to 22°C and served at this temperature with spring water and unsalted crackers for palate cleansing.

Descriptive analysis: A 15-member trained panel scored NFDM/SMP flavor attributes in duplicate in a randomized balanced block design. Attribute intensities were scaled using the 0-15 universal intensity scale characterized by the descriptive sensory analysis method[2]. On the scale 0 indicated nothing, 0.1 threshold and 15 maximum. Any score of 1 or less was considered extremely low. Attributes looked for were; sweet, cooked/heated, animal, cardboard, paint, astringent, acid, bitter, milkfat, buttery, salt, caramelized and metallic.

Sensory data analysis: Analysis of variance (ANOVA) was used to determine significant differences between samples for each attribute using the software Statistical Analysis Systems (SAS) version 9.2 for Windows (SAS Institute Inc., Cary, NC, USA). The probability level of 5% ($\alpha = 0.05$) was used to indicate the significance.

Principal Component Analysis (PCA): The PCA technique estimates the correlation structure of the variables and indicates the relationship between the samples. In addition, PCA was used to group the samples based on some selected variables to determine the importance of each variable. Separation of samples was done by considering each powder sample to be a data vector of some selected variables represented by sensory attributes. The PCA was carried out on selected variables for 23 samples using the software Statistical Analysis Systems (SAS) version 9.2 for Windows (SAS Institute Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

Some flavors are rarely observed in NFDM/SMP while others are more common. For example, medium and high heat powders tended to have a cooked flavor note (Table 1). Heat treatment that milk endures during the production of powder can increase the intensity of the undesirable cooked flavor in milk powder. However, the increased heat treatment can improve the oxidative stability of the milk powder. Milk is pasteurized before evaporation and following heating occurs spry drying. During powder production milk is exposed to heat which possibly implicated with the development of cooked flavor[2,20]. While low heat powders were more often characterized by oxidized or metallic flavors (Table 2), notable flavor attributes detected were sweet, astringent, cardboard (oxidized) and cooked/heated. All the evaluated powder samples met the US standard grade requirement for flavor. Finally, the differences in flavor intensities between samples could be a result of the differences in processing and composition of the products[21].

Preferably, SMP should have flavors similar to fluid skim milk[3]. However, differences in processing and composition can result in some of the differences in flavor types and

Table 1: Flavor scores for significant attributes of NFDM/SMP samples

	Attributes					
	Sweet	Cooked/heated	Animal	Cardboard	Paint	Astringent
P/Product	(Mean±SD)					
Low heat						
P1-NFDM	2.27±1.2	2.46±1.2	0.84±1.3	3.52±2.3	0.74±1.1	2.64±1.7
P1-NFDM	1.93±1.0	2.43±1.1	0.90±1.2	4.59±2.5	1.00±1.1	2.93±1.6
P2-NFDM	2.19±1.2	2.40±1.0	0.91±1.0	3.82±1.6	0.70±1.1	2.73±1.2
P2-NFDM	2.12±1.1	2.60±1.2	0.49±0.7	3.64±1.8	0.47±1.0	2.85±1.3
P2-NFDM	2.27±1.3	2.75±1.1	0.69±0.9	3.13±1.6	0.75±1.2	2.81±1.6
P2-SMP	1.93±1.0	2.67±0.8	0.79±1.3	3.57±1.8	0.84±1.5	2.92±1.3
P3-NFDM	2.26±1.0	2.59±0.9	0.92±1.4	3.75±1.8	1.02±1.5	2.17±1.0
P3-NFDM	2.43±1.4	2.60±1.0	0.62±1.0	3.66±1.8	0.54±1.0	2.18±0.9
P4-NFDM	2.31±1.3	2.84±1.3	0.83±1.0	3.59±2.2	0.76±1.2	2.77±1.5
P4-NFDM	2.14±1.2	2.28±1.1	0.99±1.2	4.34±2.2	0.78±1.4	2.69±1.2
Medium heat						
P1-SMP	2.69±1.3	3.56±1.8	0.60±1.0	2.15±1.6	0.49±0.9	2.76±1.5
P1-SMP	2.30±1.1	3.30±1.7	0.46±0.7	2.11±1.6	0.65±1.0	3.26±1.7
P2-SMP	2.66±1.3	3.26±1.9	0.58±0.7	2.11±1.6	0.38±0.7	2.36±1.4
P2-SMP	2.56±1.4	3.92±2.2	0.36±0.7	2.10±1.6	0.55±0.9	2.70±1.5
P2-NFDM	2.70±1.4	3.32±1.5	0.39±0.7	2.71±1.9	0.66±1.3	2.68±1.5
P2-NFDM	2.30±1.1	3.10±1.6	0.50±0.8	3.02±1.6	0.77±1.3	2.72±1.5
P2-NFDM	2.08±1.3	2.84±2.0	0.57±1.1	2.44±1.7	0.41±1.0	2.64±1.1
High heat						
P1-NFDM	2.39±1.1	3.00±1.7	0.30±0.5	2.55±1.8	0.63±1.1	3.04±1.6
P1-NFDM	2.69±1.4	3.35±1.7	0.53±0.9	1.91±1.4	0.52±1.0	3.21±1.9
P2-NFDM	2.35±1.4	3.46±2.1	0.97±1.7	2.74±1.7	0.79±1.4	3.23±1.7
P2-NFDM	2.05±1.1	3.57±2.2	0.54±0.9	2.93±1.6	0.59±1.3	2.72±1.7
P3-NFDM	2.21±1.3	2.95±1.5	1.08±1.7	3.71±1.9	0.96±1.3	2.66±1.5
P3-NFDM	2.38±1.3	2.42±1.0	0.80±1.1	3.83±2.1	0.93±1.5	2.76±1.4

Intensities were scored on 0-15 universal scale where 0 indicated nothing, 0.1 threshold and 15 maximum. Any score of 1 or less was considered extremely low. P: Processor, P1: Processor 1, P2: Processor 2, P3: Processor 3, P4: Processor 4 intensities[2,22,23]. In this study, attributes without statistical differences ($p<0.05$) between powders included: acid, bitter, milkfat, buttery, salt, caramelized and metallic (Table 3). Flavor scores for the attributes are given in Table 2. Milkfat was the only attribute that probably could be detected by most people with average score of 2.26 (Table 3). Caramel attribute had the next highest average score of 0.98 but it was at a level considered extremely low and not detectable by most people (Table 3). Differences in processing and composition provide some of the different types of flavors. In addition, definite flavors are not present or are more common in NFDM/SMPs[2]. For example, flavors milkfat and fatty flavors were detected in SMP but in low intensity. The NFDM/SMPs when rehydrated contain less than 0.5% fat (w/w) so it was expected that fatty flavors would not be more common in NFDM/SMPs[2].

Significant differences among powders were found for the attributes: sweet, cooked/heated, animal, cardboard, paint and astringent ($p<0.05$) (Table 3). Cardboard attribute had the

Table 2: Flavor scores for non-significant attributes of NFDM/SMP samples

	Attributes						
	Metallic	Salt	Acid	Bitter	Milk-fat	Buttery	Caramelized
P/Product	(Mean±SD)						
Low heat							
P1-NFDM	0.32±0.6	0.81±0.8	0.37±0.5	0.05±0.1	2.29±1.5	0.09±0.2	0.55±0.8
P1-NFDM	0.32±0.6	0.73±0.6	0.42±0.6	0.16±0.4	2.17±1.3	0.00±0.0	0.69±1.0
P2-NFDM	0.73±1.0	0.70±0.7	0.47±0.6	0.10±0.2	2.00±1.3	0.03±0.1	0.87±1.1
P2-NFDM	0.59±0.9	0.81±0.7	0.48±0.6	0.07±0.2	2.21±1.3	0.13±0.2	0.95±1.2
P2-NFDM	0.59±0.9	0.85±0.8	0.52±0.6	0.06±0.2	2.26±1.4	0.09±0.3	1.01±1.2
P2-SMP	0.49±0.8	0.79±0.5	0.40±0.4	0.14±0.3	2.40±1.4	0.19±0.4	0.95±1.1
P3-NFDM	0.57±1.0	0.81±0.6	0.48±0.6	0.05±0.1	1.98±1.4	0.11±0.3	0.84±1.1
P3-NFDM	0.63±1.1	0.61±0.8	0.42±0.5	0.04±0.1	2.08±1.3	0.11±0.3	0.77±1.0
P4-NFDM	0.59±0.9	0.78±0.9	0.52±0.5	0.07±0.2	2.21±1.2	0.00±0.0	0.92±1.1
P4-NFDM	0.57±0.9	0.63±0.5	0.42±0.4	0.04±0.1	2.07±1.3	0.03±0.1	0.92±1.4
Medium heat							
P1-SMP	0.55±1.2	0.74±0.6	0.31±0.4	0.10±0.2	2.65±1.7	0.08±0.1	1.19±1.6
P1-SMP	0.32±0.7	0.67±0.6	0.36±0.5	0.10±0.3	2.51±1.4	0.12±0.2	0.96±1.0
P2-SMP	0.18±0.4	0.77±0.7	0.36±0.5	0.07±0.2	2.27±1.4	0.11±0.2	1.02±1.1
P2-SMP	0.27±0.5	0.89±0.6	0.39±0.5	0.17±0.4	2.02±1.2	0.12±0.3	0.93±1.0
P2-NFDM	0.38±0.7	0.78±0.5	0.55±0.8	0.00±0.0	2.33±1.5	0.17±0.3	1.07±1.1
P2-NFDM	0.34±0.6	0.98±0.7	0.42±0.7	0.05±0.1	2.38±1.5	0.17±0.4	1.20±1.1
P2-NFDM	0.53±1.0	0.55±0.6	0.43±0.6	0.20±0.4	2.40±1.3	0.07±0.2	0.99±1.2
High heat							
P1-NFDM	0.36±0.8	0.64±0.6	0.50±0.8	0.06±0.2	2.50±1.7	0.08±0.2	0.88±1.2
P1-NFDM	0.15±0.4	0.76±0.5	0.78±1.0	0.13±0.2	2.60±1.6	0.23±0.7	1.07±1.3
P2-NFDM	0.48±0.8	0.81±0.7	0.54±0.7	0.08±0.3	2.27±1.5	0.14±0.3	1.14±1.1
P2-NFDM	0.55±0.9	0.59±0.4	0.51±0.5	0.13±0.3	2.04±1.5	0.16±0.3	1.46±1.6
P3-NFDM	0.52±1.0	0.76±0.9	0.42±0.7	0.27±0.7	2.15±1.3	0.15±0.4	1.28±1.4
P3-NFDM	0.51±0.8	0.73±0.7	0.59±0.6	0.18±0.5	2.15±1.4	0.05±0.1	0.94±1.2

Intensities were scored on a 0 to 15 universal scale where 0 indicated nothing, 0.1 threshold and 15 maximum. Any score of 1 or less was considered extremely low. P: Processor, P1: Processor 1, P2: Processor 2, P3: Processor 3, P4: Processor 4

Table 3: Statistical analysis summary of mean flavor attributes of NFDM/SMP samples

Attributes	Low	High	Mean	SS	MS	p-value
Sweet	1.93	2.69	2.31	32.41	1.47	0.0117*
Cooked/Heated	2.28	3.92	2.94	105.97	4.82	<0.0001***
Animal	0.30	1.08	0.68	32.15	1.46	0.0021**
Cardboard	1.91	4.59	3.13	339.11	15.41	<0.0001***
Paint	0.38'	1.02	0.69	23.72	1.08	0.0049**
Astringent	2.17	3.26	2.76	52.11	2.37	0.0003***
Metallic	0.15	0.73	0.46	13.64	0.62	0.0682
Salt	0.55	0.98	0.75	8.90	0.40	0.0869
Acid	0.31	0.78	0.46	5.24	0.24	0.1315
Bitter	0.00	0.27	0.10	2.63	0.12	0.0817
Milkfat	1.98	2.65	2.26	17.29	0.79	0.3723
Buttery	0.00	0.23	0.11	2.20	0.10	0.2573
Caramelized	0.55	1.46	0.98	24.05	1.09	0.0836

*Significant at 5%, **Significant at 1%, ***Significant at 0.1%

highest average score of 3.13 but it was at a level considered low followed by cooked/heated flavor with average score 2.94 (Table 3). It was suggested that carbonyl compounds are responsible for storage flavors in several dairy powders. Also, saturated and unsaturated aldehydes have a role in the progress of off-flavors such as tallowy, painty, cardboardy and fishy flavors in oxidized dairy products[11,24]. However, significant differences were noted among powders for animal and astringent flavors their intensities had average score of 0.68 and 2.76, respectively. Astringent flavor in NFDM/SMPs had average score higher than animal flavor (Table 3). A "Glue-like" flavor was reported in caseins and caseinates and it was suggested that the glue-like flavor was the animal/wet dog flavor as it was also described by mucilage and gelatin flavor[2].

Although, significant differences were noted among powders for the attributes paint and animal the values were at levels such most people could not be able to detect the attribute or any differences between the products. These flavor attributes are not a significant part of the flavor profile of the NFDM/SMP powders. Although, the ADPI[21] reported that the standard shelf-life for SMP is 18 months at 21 °C, it was reported that SMPs of age less than 3 months showed flavors with notes of potato/brothy, animal/wet dog and astringent[2].

Data for the Principal Component Analysis (PCA) are presented in Table 4. The PCA was performed on 4 processors and 13 variables yielded 5 important principal components with eigenvalues greater than 1. The dimensionality of the 13 variables was reduced to 5 uncorrelated components describing approximately 80% of the total variance (Table 4). Based on PCA analysis, the total variables were aggregated to 35.9% of the first principal component PC1 and 13% of the second principal component PC2 (Table 4). The PC1 and PC2 scores explained approximately 49% of the total variance of NFDM/SMPs (Table 4). The PC1 scores explained approximately 36% of the total variance. The NFDM/SMPs were not classified based on processors, as a result, the PC1 scores could be used to explain the property of NFDM/SMPs based on the heat class of the products.

Results of principal component analysis for sensory attributes of reconstituted NFDM/SMP samples are shown in a PCA plot (Fig. 1). The upper and lower circles indicate groupings of powders with shared characteristics. Products were labeled with the initials of heat treatment and the company which produced the product. Powders in the lower circle were characterized by a cardboard (oxidized) note. The powders near the top to the circle had a more metallic note while the powders near the bottom showed an animal (wet dog) or paint-like note. The low heat powders regardless

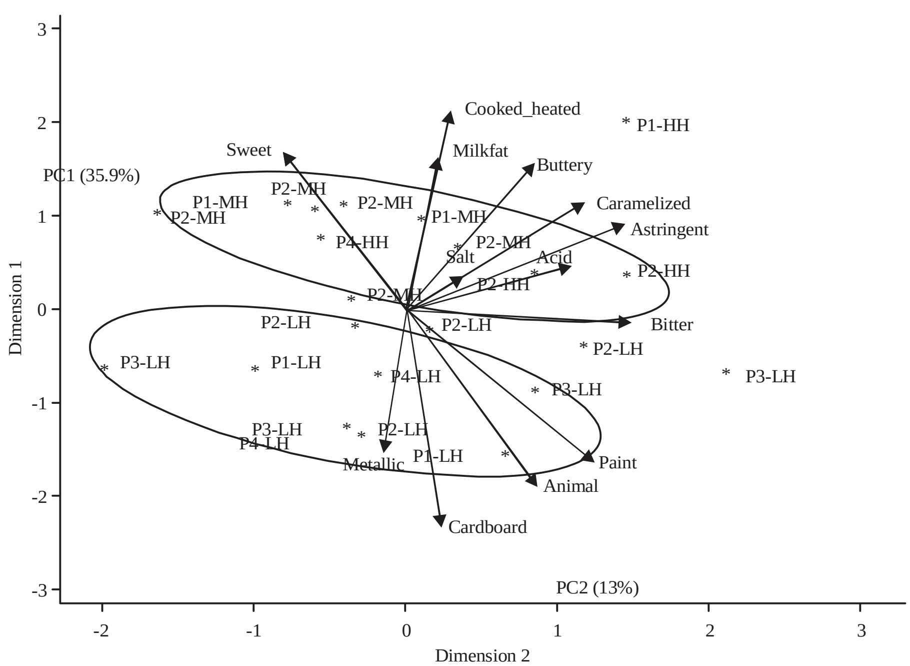

Fig. 1: Principal component analysis biplot for descriptive analysis of NFDM/SMP samples. The low heat powders regardless of manufacturer all fall within the lower circle. Powders in the upper circle were characterized by a cooked flavor. P1: Processor1, P2: Processor2, P3: Processor3, P4: Processor4, LH: Low heat, MH: Medium heat, HH: High heat

Table 4: Results of Principal Component Analysis (PCA) of NFDM/SMP samples

PC	Eigenvalue	Proportion of PC (%)	Cumulative variance (%)
1	4.7	35.9	36.0
2	1.7	13.0	49.0
3	1.5	11.0	60.0
4	1.3	10.0	70.0
5	1.1	8.0	78.0
6	0.7	6.0	84.0
7	0.6	5.0	89.0
8	0.5	4.0	92.0
9	0.3	3.0	95.0
10	0.2	2.0	97.0
11	0.2	2.0	98.0
12	0.1	1.0	99.0
13	0.0	0.3	100.0

of manufacturer all fall within the lower circle. Powders in the upper circle were characterized by a cooked/heated flavor. The powders near the top of the circle had similar sweetness intensity while the powders closer to the bottom of the circle had a more milky note. With the exception of two processor, 3 high heat powders, all of the medium and high heat powders fall within the upper circle.

CONCLUSION

This study indicated significant differences among commercial NFDM/SMP samples in regard to some sensory properties that may be important in application and further processing. All the evaluated powder samples met the US standard grade requirement for flavor. It may suggest that some of the differences observed in this study are expected to be caused by processing conditions.

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