Use of Atwater Factors in USDA's Nutrient Databank

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Introduction

Most food energy values are based on theoretical calculations, rather than on direct energy measurement as just discussed by Dr. Moe. For nutrition labeling, the U.S. Food and Drug Administration (FDA) allows calorie content to be calculated by either the Atwater method (figure 1) or a procedure using 4, 9, and 4 calories per gram of protein, fat, and carbohydrate (CHO), respectively. The total dietary fiber content is subtracted from the total carbohydrate content before calories are calculated (figure 2).

FDA-APPROVED METHODS
FOR DERIVING FOOD ENERGY VALUES

* Food/ingredient-specific calorie factors
* Based on metabolizable energy (ME)
* Dietary fiber (if present) included in total CHO content
* CHO determined by difference (total CHO)
* Used to determine food energy values in Agriculture Handbook No. 8

Figure 1 - Atwater System

* 4 calories per gram of protein

* 9 calories per gram of fat

* 4 calories per gram of carbohydrate

* Dietary fiber subtracted from total CHO (available CHO) before calorie calculation

* Used widely by food companies for nutrition labeling

Figure 2 - General Factors (4,9,4)

Food energy values in Agriculture Handbook No. 8 (AH-8) are based on the Atwater system for determining energy values. Atwater factors, developed nearly a century ago, are limited. The factors are for basic food products or food groupings. Atwater factors do not exist for multi-ingredient foods unless they are calculated.

Multi-Ingredient Calorie Factors

Composite protein, fat, and carbohydrate calorie factors must be calculated using values per 100 grams for protein, fat, and carbohydrate for each ingredient; the percentage of each ingredient; and ingredient-specific Atwater factors (figure 3).

Before 1988, calorie factors for multi-ingredient foods in AH-8 were calculated by hand. Examples include AH-8-6, Soups, Sauces, and Gravies; and AH-8-8, Breakfast Cereals.

Food	Factors				
	Protein calories /g	Fat calories /g	Carbo-hydrate calories /g	Nitrogen to protein conversion	
				Nitrogen	Alternate nitrogen
Milk/Milk Products	4.27	8.79	3.87	6.38	6.38
Vegetable fats/ oils (other than margarine)	0.0	8.84	0.0	6.25	6.25
Sugar (sucrose)	0.0	0.0	3.87	6.25	6.25
Chocolate/Cocoa	1.83	8.37	1.33	5.63	4.74

Figure 3 - Ingredient-Specific Atwater Factors

Composite calorie factors for each commercially prepared multi-ingredient food are listed in separate appendixes for applicable AH-8 revised sections (figure 4). Composite nitrogen-to-protein factors are printed next to "protein" on data pages.

Multi-Ingredient Food	Factors			
	Nitrogen to protein conversion	Protein calories /g	Fat calories /g	Carbo-hydrate calories /g
Milk chocolate	5.9	3.7	8.7	3.7
White bread	5.7	3.9	8.7	4.1
Reduced-calorie white bread	5.9	4.0	8.7	3.4

Figure 4 - Composite Factors for Multi-Ingredient Foods

Conversion Factor Calculation Program (CALFAC)

In 1988, a computer program (CALFAC) was developed by the Nutrient Data Research Branch of USDA's Human Nutrition Information Service (HNIS) to calculate factors needed by the Nutrient Data Bank System for multi-ingredient commercial food products, such as calorie factors, nitrogen-to-protein conversion factors, and alternate nitrogen-to-protein factors (when ingredients containing nonprotein nitrogen are used). The flow chart in figure 5 depicts the information needed by the CALFAC program to calculate factors. Figure 6 shows a CALFAC input record for determining composite factors for milk chocolate, requiring codes and percentages for four ingredients

Milk chocolate
FOOD DESCRIPTION

	PDS ID #	Ingredients	%	CALFAC ID #
1	*19335*	*Sugar*	*47*	*601*
2	*01090*	*Whole milk, dried*	*21*	*105*
3	*04551*	*Cocoa butter*	*17*	*204*
4	*19078*	*Baking chocolate, unsweetened*	*15*	*802*

Figure 6 - CALFAC Entry Format

The data source accessed is the Primary Nutrient Data Set (PDS). Therefore, the PDS identification numbers of the ingredients must be entered; the ingredient descriptions are printed out automatically. Next, the proportions of the ingredients, expressed as percentages of the total, are entered. Last, the appropriate calorie and nitrogen factor identification numbers are entered. The calorie and nitrogen factors are in a separate computer file and are utilized during the CALFAC session.

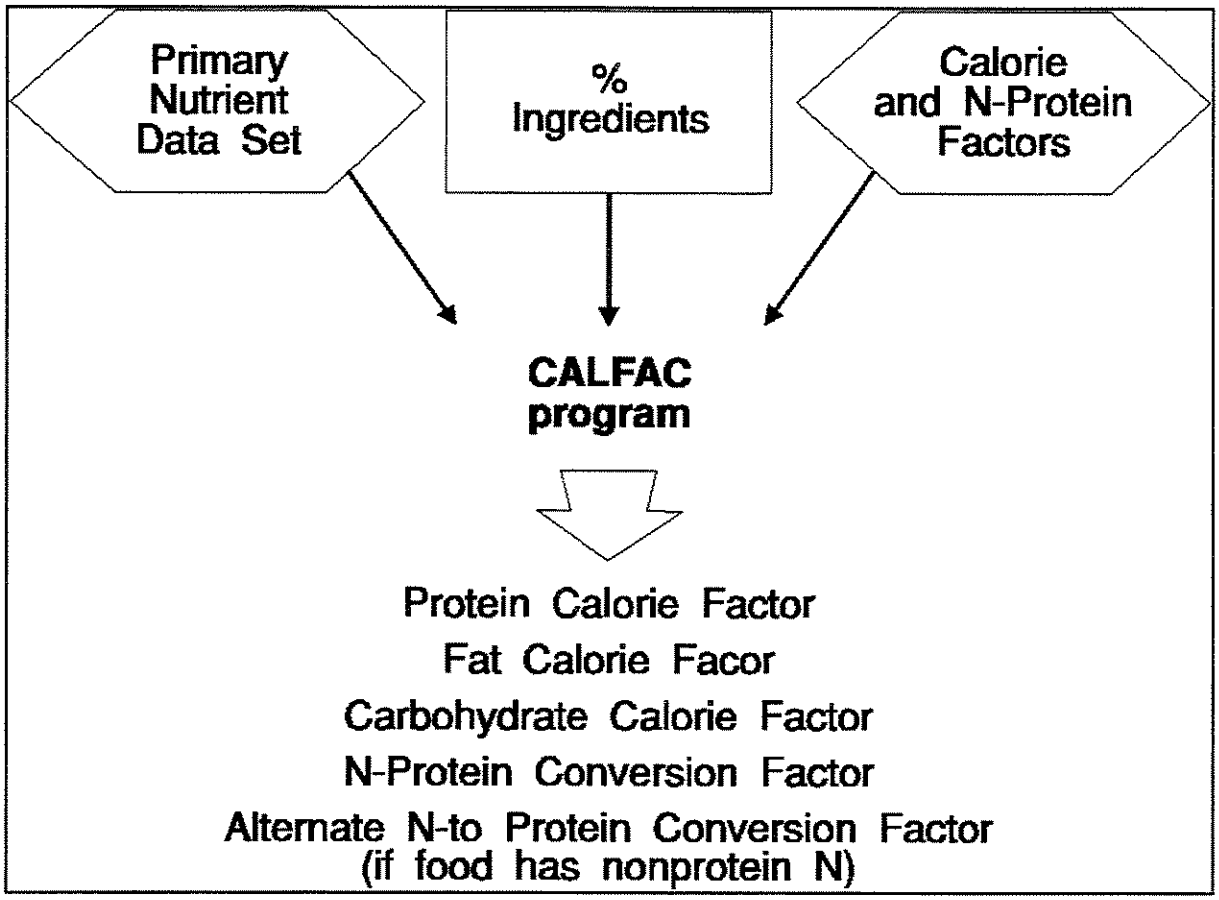

Figure 3 - Calfac Flow Chart

Figure 7 depicts the calculations done by the CALFAC program to generate the composite calorie factors for milk chocolate.

Protein Calorie Factor

Ingredients	% ingred	g protein in 100 g ingred.		g protein in recipe		protein calorie factor		protein calories
Sugar	47	X	0	=	0	X	-	= -
Dry whole milk	21	X	26.32	=	5.527	X	4.27	= 23.600
Cocoa butter	17	X	0	=	0	X	-	= -
Bitter chocolate	15	X	10.7	=	1.605	X	1.83	= 2.937
					7.132			26.537

26.537 / 7.132 = 3.721

Fat Calorie Factor

Ingredients	% ingred	g fat in 100 g ingred.	g fat in recipe	fat calorie factor	calories

Figure 7 - Calorie Factor Calculations

Figure 8 illustrates the calculations that generate nitrogen-to-protein conversion factors.

Ingredients	%ingred.	g protein per 100 g ingred.	g protein per 100 g recipe	N Factor	g N per 100 g recipe	% of N ingred.
Sugar	47	X 0	= 0	-	= -	-
Dry whole milk	21	X 26.32	= 5.527	/ 6.38	= .866	71.9
Cocoa butter	17	X 0	= 0	-	= -	-
Bitter chocolate	15	X 10.70	= 1.605	/ 5.63 (4.74)	= .285 (.339)	28.1
			7.132		1.151 (1.205)	
		7.132 / 1.151 = 6.196 [1]		7.132 / 1.205 = 5.919 [2]		

The steps used to calculate the nitrogen conversion factor(s) are–

1. % of each ingredient times the grams of protein in 100 g of the ingredient = grams of protein in 100 g of the recipe
2. g of protein in the recipe divided by the nitrogen conversion factor (for ingredients containing nonprotein nitrogen there are 2 different factors) = g of nitrogen in 100 g of recipe
3. the total g of protein in recipe divided by the total grams of nitrogen in the recipe = protein conversion factor(s)

Percent of nitrogen-containing ingredients (used to calculate amino acids) is determined by dividing the g of nitrogen contributed by each ingredient by the total nitrogen in 100 g of the recipe (use the alternate nitrogen conversion factor, which takes into account the nonprotein nitrogen, for those products with 2 conversion factors).

[1] This factor is used to get the protein for calculating carbohydrate by difference and calories.

[2] This factor is used to get the protein shown in the stub and calculating amino acids.

Figure 8 - Nitrogen (N) Conversion Factor Calculations for Milk Chocolate

The factors generated from the CALFAC program are based on estimated percentages of ingredients, since exact formulations have not been available from food companies. Ingredient percentages for generic products may be obtained from food product formularies or from trade associations. Ingredient proportions may also be estimated from product ingredient and nutrition label information. HNIS has a computer program that produces ingredient percentages and nutrient profiles from label information. Kristin Marcoe presented a paper on this program procedure during one of the concurrent sessions at this conference.

The CALFAC program has evolved to generate percentages of nitrogen-containing ingredients--used to calculate amino acid values--and to generate percentages of fat-containing ingredients--used to calculate fatty acid values. The CALFAC program also produces factors for converting Vitamin A (IU) to Vitamin A (RE) and Vitamin A (IU) to carotene (figure 9).

Protein Calorie Factor	3.721	[1] 3.7
Fat Calorie Factor	8.709	[1] 8.7
Carbohydrate Calorie Factor	3.684	[1] 3.7
Nitrogen to Protein Factor	6.196	[2] 6.2
Alternate Nitrogen to Protein Factor $Protein_2$ Factor #2	5.919	[3] 5.9
Sum of Vit. A (IU)	196.620	
Sum of Vit. A (RE)	59.100	
IU to RE Factor	3.327	
IU to Carotene Factor Facto	65.509	

[1] Factors included with food code
[2] Use for carbohydrate by difference and calorie calculations
[3] Use for amino acid calculations and nitrogen-to-protein conversion factor reported on Handbook page.

Figure 9 - CALFAC Output with Composite Factors for Milk Chocolate

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Summary

The CALFAC program works reasonably well--

* if proximate nutrient values (water, protein, fat, carbohydrate, and ash) exist in the Primary Nutrient Data Set
* if it is possible to estimate the percentages of ingredients
* if ingredient-specific Atwater calorie and nitrogen factors are in the CALFAC computer file

Commercial foods with multiple ingredients for which nutrient data and Atwater calorie and nitrogen-to-protein conversion factors are missing are not good "candidates" for determining composite factors within the CALFAC program. Problems arise if any input information is lacking (Figure 10).

- Ingredient percentages are estimated rather than specific
- Information gaps exist for many commercial ingredients and basic food products:
  - Nutrient composition - must have proximates
  - N to protein conversion factors
  - Amount of nonprotein N in some foods
  - Calorie factors (degree of digestibility)

Figure 10 - Points to Consider when Calculating Factors