

# How to estimate the Phe content of a food from its protein content

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Phenylalanine (Phe) is an amino acid that is present in all proteins we consume. Generally speaking, the more protein a food contains, the more Phe it contains. But exactly how much Phe does one gram of protein contain? Actually, it depends on the food. For example, if you look up coconut milk in the USDA National Nutrient Database [2], you will see that one gram of coconut milk contains 0.02g of protein and 1mg of Phe. This gives a Phe to protein ratio equal to  $1/0.02 = 50$ mg Phe per gram of protein. On the other hand, an apple contains 0.0026g protein and 0.06mg Phe per gram of apple. This gives a Phe to protein ratio equal to  $0.06/0.0026$ , which is approximately 23 mg Phe per gram of protein. As you can see, the protein in an apple contain much less Phe than the protein in coconut milk.

Therefore, it is impossible to know exactly how much Phe a food contains solely from its protein content. However, it is possible to find an estimate for the Phe content. More specifically, it is possible to find a range of Phe values that contains the true Phe value.

## 1 Method details

The idea is to multiply the protein content of the food by the maximum possible Phe per protein ratio, and by the minimum possible Phe per protein ratio, to obtain the maximum and the minimum possible Phe values, respectively. We suggest to use 20mg Phe per gram of protein as the minimum multiplier and 64.5mg Phe per gram of protein as the maximum multiplier. Explanation for the choices of multipliers will be discussed in Section 3.

Here is an example. Suppose that some food contains 0.5g of protein. First make sure that the food does not contain any aspartame. For instance, many diet soft drinks, candies and gums that are indicated as sugar-free contain aspartame. The artificial sweetener extremely increases the amount of Phe content in a food because 1g protein in aspartame includes 546.54mg Phe. Therefore, patients with PKU need to pay attention not to consume products made with aspartame. In this document, we assume that the food does not contain any aspartame.

**Step 1** Multiply the protein content in grams by 64.5. Here we have  $0.5 \times 64.5 = 32.25$ . The result, 32.25 in this case, is the maximum Phe content of the food. In other words, the Phe content of the food cannot be higher than 32.25mg.

**Step 2** Multiply the protein content in grams by 20. Here we have  $0.5 \times 20 = 10$ . The result, 10 in this case, is the minimum Phe content of the food. In other word, the Phe content of the food cannot be lower than 10mg.

### Quick Facts

<i>Protein content (rounded to the nearest gram)</i>		<i>Phe Estimation (Foods only made of Fruits)</i>	
0 gram	⇒	<i>min Phe</i> 0 mg      (0 mg)	<i>max Phe</i> 32 mg      (19.5 mg)
1 gram	⇒	<i>min Phe</i> 10 mg      (10 mg)	<i>max Phe</i> 96.75 mg      (58.5 mg)
2 gram	⇒	<i>min Phe</i> 30 mg      (30 mg)	<i>max Phe</i> 161.25 mg      (97.5 mg)
3 gram	⇒	<i>min Phe</i> 50 mg      (50 mg)	<i>max Phe</i> 225.75 mg      (136.5 mg)

## 2 Taking rounding errors into account

In Section 1, we assumed that the protein content was known exactly. Unfortunately, on the Nutrition Facts Label, the protein content is rounded up to the nearest gram. This means that, if the protein content listed is 1g, then the true protein content can be anywhere between 0.5g and 1.5g. In that case, one can find out a lower bound on the Phe content by multiplying the minimum possible protein content, namely 0.5g in our example, by the multiplier 20. So we have  $0.5\text{g} \times 20 = 10$ , and thus the Phe content cannot be less than 10mg. Now to find an upper bound on the Phe content, you have to multiply the maximum possible protein content, namely 1.5g in our example, by the multiplier 64.5. So we have  $1.5 \times 64.5 = 96.75\text{mg}$  and thus the Phe content cannot be more than 96.75mg.

Now imagine that the protein content listed in the nutrition fact label is 0g. Because the number is rounded up to the nearest gram, then the true protein content can be anywhere between 0g and 0.5g. In that case, we find the minimum Phe by multiplying zero by 20, which gives zero, and thus it is possible that the food contains zero Phe. To find the maximum Phe, we multiply 0.5 by 64.5, which gives 32.25, and thus the maximum Phe content is 32.25mg.

However, the protein content is not always rounded up to the nearest gram. Sometimes, in particular on the label of some food produced in Asia, the protein content is rounded to the nearest 0.1g. For example, a package of ramen noodles might state that it contains 1.4g of protein per serving. In that case, you can multiply 1.35 by 20 to find the minimum Phe, and multiply 1.45 by 64.5 to find the maximum Phe, taking into account the higher precision of the protein content. As you might have learned in high school chemistry, the last digit of a rounded up number indicates the precision of the measurement. So while a rounded up protein content of 1g would indicate true protein content between 0.5 and 1.5, a rounded up protein content of 1.0 would indicate a true protein content between 0.95 and 1.05.

## 3 Justification for 20-64.5 multipliers

Where do the multipliers 64.5 and 20 come from? We studied the USDA National Nutrient Database [2] and found out that the vast majority of foods without aspartame (more than 97%) have a Phe:protein ratio above 20 and below 64.5. Some patients may have been told by their dietician to use the multipliers 30 and 50 instead of 20 and 64.5. Indeed, the traditional multipliers, which have been used for decades by dieticians, are 30 – 50. However, we found that these traditional multipliers are only accurate for about 67% of all foods and ingredients without aspartame. Thus, we prefer the more accurate 20 – 64.5 multipliers.

## 4 Obtaining more accurate estimation

As you may have noticed, the upper bound (the maximum) can sometimes be quite far from the lower bound (the minimum), and so it may be hard to guess what the true Phe content of the food really is from this estimate.

But there are many ways to obtain a more accurate estimate. The first thing one can do is check which of the ingredients contains Phe. If the protein content is listed as 0g (meaning that the true protein content is between 0g and 0.5g), then it is possible that no ingredient contains any Phe. If that is the case, then you are lucky because you will know for sure that the food is free of Phe. For quick reference, we put a list of Phe-free foods and ingredients at the end of this document.

Another interesting case is when the only ingredients containing Phe are fruits. An example of this would be fruit juice, or roll up fruit snacks without gelatin. One remarkable thing about fruits is that their Phe:protein ratio tends to be lower than for other foods. In our study, we found that the vast majority of fruits have between 20mg Phe per gram protein, and 39mg Phe per gram protein. Therefore, for a fruit-based food, the multiplier 64.5 can be replaced by 39. Hence, the maximum Phe content is obtained by multiplying the maximum protein content by 39 (instead of 64.5). This gives a smaller range of possible Phe, and thus a more accurate estimate. Besides discerning properties of ingredients, we also have developed an advanced method providing narrower bounds of Phe content for foods based on the Nutrition Facts Label and the ingredients list. We will post the related application on our webpage as soon as it is completed.

Here is a list of foods and ingredients that contain no protein and no phenylalanine. The data was extracted from two sources : the USDA National Nutrient Database [2] (US) and the Danish Food Composition Databank [1] (D). Please direct all comments to mboutin@purdue.edu.

Src	Desc	mg Phe	g prot
US	Alcoholic beverage, creme de menthe, 72 proof	0	0
US	Alcoholic beverage, distilled, all (gin, rum, vodka, whiskey) 100 proof	0	0
US	Alcoholic beverage, distilled, all (gin, rum, vodka, whiskey) 80 proof	0	0
US	Alcoholic beverage, distilled, all (gin, rum, vodka, whiskey) 86 proof	0	0
US	Alcoholic beverage, distilled, all (gin, rum, vodka, whiskey) 90 proof	0	0
US	Alcoholic beverage, distilled, all (gin, rum, vodka, whiskey) 94 proof	0	0
US	Alcoholic beverage, distilled, gin, 90 proof	0	0
US	Alcoholic beverage, distilled, rum, 80 proof	0	0
US	Alcoholic beverage, distilled, vodka, 80 proof	0	0
US	Babyfood, juice treats, fruit medley, toddler	0	0
US	Carbonated beverage, club soda	0	0
US	Carbonated beverage, cream soda	0	0
US	Carbonated beverage, grape soda	0	0
US	Carbonated beverage, orange	0	0
US	Carbonated beverage, pepper-type, contains caffeine	0	0
US	Carbonated beverage, tonic water	0	0
D	Coconut oil, refined, Palmin	0	0
D	Corn oil	0	0
US	Fat, beef tallow	0	0
US	Fat, chicken	0	0
US	Fat, duck	0	0
US	Fat, goose	0	0
US	Fat, mutton tallow	0	0
US	Fat, turkey	0	0
D	Gin	0	0
D	Goose fat	0	0
US	Lard	0	0
D	Lard, pork	0	0
D	Linseed oil	0	0
D	Liqueur, Creme de Menthe	0	0
D	Non-alcoholic beverage (light), concentrated (1+10), sugar not added	0	0
D	Non-alcoholic beverage, concentrated (1+5), sugar added	0	0
US	Oil, almond	0	0
US	Oil, apricot kernel	0	0
US	Oil, babassu	0	0
US	Oil, cocoa butter	0	0
US	Oil, coconut	0	0
US	Oil, corn, industrial and retail, all purpose salad or cooking	0	0
D	Oil, cotton seed	0	0
US	Oil, cottonseed, salad or cooking	0	0
US	Oil, cupu assu	0	0
US	Oil, grapeseed	0	0
US	Oil, hazelnut	0	0
US	Oil, industrial, coconut (hydrogenated), used for whipped toppings and coffee whiteners	0	0
US	Oil, industrial, coconut, confection fat, typical basis for ice cream coatings	0	0
US	Oil, industrial, coconut, principal uses candy coatings, oil sprays, roasting nuts	0	0
US	Oil, industrial, palm and palm kernel, filling fat (non-hydrogenated)	0	0
US	Oil, industrial, palm kernel (hydrogenated) , used for whipped toppings, non-dairy	0	0
US	Oil, industrial, palm kernel (hydrogenated), confection fat, intermediate grade product	0	0
US	Oil, industrial, palm kernel (hydrogenated), confection fat, uses similar to 95 degree hard butter	0	0
US	Oil, industrial, palm kernel (hydrogenated), filling fat	0	0
US	Oil, industrial, palm kernel, confection fat, uses similar to high quality cocoa butter	0	0
US	Oil, industrial, soy ( partially hydrogenated), all purpose	0	0
US	Oil, industrial, soy (partially hydrogenated ) and soy (winterized), pourable clear fry	0	0
US	Oil, industrial, soy (partially hydrogenated ), palm, principal uses icings and fillings	0	0
US	Oil, industrial, soy (partially hydrogenated) and cottonseed, principal use as a tortilla shortening	0	0
US	Oil, industrial, soy (partially hydrogenated), multiuse for non-dairy butter flavor	0	0
US	Oil, industrial, soy (partially hydrogenated), principal uses popcorn and flavoring vegetables	0	0
US	Oil, industrial, soy, refined, for woks and light frying	0	0
US	Oil, nutmeg butter	0	0
US	Oil, olive, salad or cooking	0	0
US	Oil, palm	0	0
US	Oil, peanut, salad or cooking	0	0
US	Oil, poppyseed	0	0
D	Oil, rape seed (low eruca acid content)	0	0
D	Oil, rape seed (no eruca acid)	0	0
US	Oil, rice bran	0	0
D	Oil, safflower (high linoleic acid content)	0	0
D	Oil, safflower (high oleic acid content)	0	0
US	Oil, safflower, salad or cooking, high oleic (primary safflower oil of commerce)	0	0

US	Oil, safflower, salad or cooking, linoleic, (over 70%)	0	0
D	Oil, sesame	0	0
US	Oil, sesame, salad or cooking	0	0
US	Oil, sheanut	0	0
US	Oil, soybean, salad or cooking	0	0
US	Oil, soybean, salad or cooking, (partially hydrogenated)	0	0
US	Oil, soybean, salad or cooking, (partially hydrogenated) and cottonseed	0	0
US	Oil, sunflower, linoleic (less than 60%)	0	0
US	Oil, sunflower, linoleic, (approx. 65%)	0	0
US	Oil, sunflower, linoleic, (partially hydrogenated)	0	0
US	Oil, teaseed	0	0
US	Oil, tomatoseed	0	0
US	Oil, ucuhuba butter	0	0
US	Oil, walnut	0	0
US	Oil, wheat germ	0	0
D	Olive oil	0	0
US	Puddings, lemon, dry mix, instant	0	0
D	Rum	0	0
US	Salad dressing, home recipe, vinegar and oil	0	0
D	Salt, block	0	0
D	Salt, sea salt (no iodine fortification)	0	0
US	Salt, table	0	0
US	Shortening bread, soybean (hydrogenated) and cottonseed	0	0
US	Shortening cake mix, soybean (hydrogenated) and cottonseed (hydrogenated)	0	0
US	Shortening confectionery, coconut (hydrogenated) and or palm kernel (hydrogenated)	0	0
US	Shortening frying (heavy duty), beef tallow and cottonseed	0	0
US	Shortening frying (heavy duty), palm (hydrogenated)	0	0
US	Shortening frying (heavy duty), soybean (hydrogenated), linoleic (less than 1%)	0	0
US	Shortening household soybean (hydrogenated) and palm	0	0
US	Shortening industrial, lard and vegetable oil	0	0
US	Shortening industrial, soybean (hydrogenated) and cottonseed	0	0
US	Shortening, confectionery, fractionated palm	0	0
US	Shortening, household, lard and vegetable oil	0	0
US	Shortening, household, soybean (partially hydrogenated)-cottonseed (partially hydrogenated)	0	0
US	Shortening, industrial, soy (partially hydrogenated ) for baking and confections	0	0
US	Shortening, industrial, soy (partially hydrogenated), pourable liquid fry shortening	0	0
D	Soft drink, sugar added	0	0
D	Soft drink, unsweetened, average values	0	0
D	Soyabean oil, refined	0	0
D	Spirits, 70 % proof	0	0
D	Sugar, brown	0	0
D	Sunflower oil	0	0
D	Sweets, boiled	0	0
US	Tea, black, brewed, prepared with distilled water	0	0
US	Tea, black, brewed, prepared with tap water	0	0
US	Tea, black, brewed, prepared with tap water, decaffeinated	0	0
US	USDA Commodity Food, oil, vegetable, low saturated fat	0	0
US	USDA Commodity Food, oil, vegetable, soybean, refined	0	0
US	Vegetable oil, palm kernel	0	0
US	Vinegar, cider	0	0
D	Vodka	0	0
D	Walnut oil	0	0
US	Water, bottled, PERRIER	0	0
US	Water, bottled, POLAND SPRING	0	0
D	Water, carbonated	0	0
D	Water, tap, drinking, average values	0	0
D	Wheat germ oil	0	0
D	Whisky	0	0

## References

- [1] Christensen A.T. Mller A. Hartkopp H.B. Hess Ygil K. Hels O.H. Saxholt, E. Danish food composition databank, revision 7. Department of Nutrition, National Food Institute, Technical University of Denmark. Website: <http://www.foodcomp.dk/>, 2008.
- [2] Agricultural Research Service U.S. Department of Agriculture. USDA national nutrient database for standard reference, release 25. Nutrient Data Laboratory Home Page, <http://www.ars.usda.gov/ba/bhnrc/nd1>, 2012.