section of consumers and additional evaluations would be needed to provide information about the product's reception in commercial markets. The overall acceptability of the product and its nutritional profile illustrate its merit and suggest that further testing and modification could result in the replacement of the present nutritionally inadequate "snack foods" with more balanced and worthwhile products.

Amino Acid Composition of *Kluyveromyces fragilis* Grown on Cottage Cheese Whey

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Introduction

In previous work from this laboratory it was shown that the yeast *Kluyveromyces fragilis* could be grown on cottage cheese whey, changing the whey sugar (lactose) into a material which was primarily protein. After fermentation the solids could be removed by filtration. The liquid (93% of the original whey volume) had 82% of its chemical oxygen demand (COD) removed after 10-11 hours of fermentation and more than 90% of the COD removed after 24 hours of fermentation. COD is a measure of solid materials which are objectionable in city sewege facilities and streams. Thus fermentation reduced the undesirable solids in the liquid portion of the whey to an acceptable level for disposal.

Handling the remaining seven % solids was the next step. This solid material, or yeast paste, after drying contains 72% protein, 5% ash (minerals), 5% water, and 18% other materials-primarily long chain carbohydrates and fiber in the cell walls of the yeast. The protein material equaled approximately 9% whey proteins and 91% yeast protein. Since this material could be used either in animal feeds or human foods, its amino acid content was of interest. A fairly complete amino acid analysis of *K. fragilis* was conducted in 1961 by Wasserman. However, that study was done fourteen years ago, and the methods used to produce the OSU yeast were somewhat different than those employed by Wasserman. Many

partial analyses of yeast fermentation materials have appeared since 1961, but none of the materials were produced in the same way as OSU yeast.

Experimental

The protein in the yeast paste was determined by the Kjeldahl procedure and lactose by a reducing technique originally devised by Perry and Doan as noted in a previous publication. Ashes (minerals) were determined by conventional ashing procedures and fats by ether extraction. The remaining material was determined by substraction. Its exact nature is not known; it was believed to be composed primarily of yeast cell wall materials. Amino acid analyses were conducted using the equipment and method described by Spackman, et. al. and that described by Moore and Stein.

The analyses are shown in Table 1, and were originally reported as millimoles of amino acid per 100 grams of sample (column 1). This had to be converted into grams per 100 grams of sample and then to grams per 100 grams of protein (or g/16 g Nitrogen) in order to compare the results to those in the literature (columns 4-8). It will be noted that the analysis of the OSU product does not vary significantly from the literature values obtained by Wasserman (column 3 vs. column 4). The variations in amino acid contents can probably be accounted for by the different techniques used in growing the yeast and differences in the per cent of whey to yeast in the two samples.

If one is interested in the composition of the *K. fragilis* itself, this can be obtained by subtracting the proportional amount (9%) of the amino acids in whey proteins (column 6) from those of the *K. fragilis* product in column 3. The whey protein composition in column 6 also represents the percentage of amino acids one would find in the protein of dried whey. The amino acids marked with the superscript "e" are essential for human nutrition.

When comparing the essential amino acids found in casein (milk protein - the usual standard of comparison) to the essential amino acids of yeast proteins, one finds that yeast proteins compare quite favorably to casein. As a further comparison, the essential amino acids of yeast correspond more closely to those of casein than do those in soybean protein which is the protein often used to substitute for meat or milk proteins in human foods (column 7). If the yeast were to be used for animal feed, the amount of lysine and the sulfur amino acids (methionine and cysteine) would be of particular interest. It is noted that yeast protein contains as much or more of all these amino acids than does soybean oil meal or fish meal.

Table 1. Amino Acid Composition of *K. fragilis* Grown in Cottage Cheese Whey Compared to Composition of Certain Other Protein Sources

Column	1	2	3	4	5	6	7	8
	K. fragilis[1]				Other Protein Sources			
	OSU			Literature[2]				
Amino Acid	mmoles/ 100 g protein	g/100 g sample	g/16 g N	g/16 g N	Casein[3] g/16 g N	Whey Proteins[3] g/16 g N	Soybean Oil Meal[4] g/16 g N	Fish Meal[4] g/16 g N
Valine[5]	38.4	4.5	6.2	7.8	7.0	7.3	5.2	6.5
Leucine[5]	64.1	8.4	11.7	9.6	12.1	15.9	7.4	9.0
Isoleucine[5]	31.2	4.3	6.0	6.0	6.5	5.3	5.0	7.4
Phenylalanine[5]	17.8	2.9	4.1	5.4	5.2	5.5	5.2	4.9
Methionine[5]	10.2	1.5	2.1	1.2	3.5	3.1	1.4	3.2
Cystine[5]	22.8	2.8	3.8	—	0.4	3.2	1.6	1.7
Lysine[5]	47.6	7.0	9.7	10.5	6.9	8.8	6.2	9.5
Threonine[5]	32.6	3.9	5.4	6.5	3.9	5.5	3.9	5.2
Tryptophan[5]	—	—	(1.5)[6]	(1.5)[6]	1.8	2.2	1.3	1.1
Alanine	43.7	3.9	5.4	8.2	5.6	0.6	—	—
Proline	29.8	3.4	4.7	4.3	8.2	—	—	—
Glycine	24.5	1.8	2.6	4.6	0.5	—	—	—
Serine	36.0	3.8	5.3	7.0	6.7	4.9	—	—
Tyrosine	16.4	3.0	4.1	3.4	6.4	5.0	3.9	2.9
Aspartic Acid	58.9	7.8	10.8	11.2	6.3	—	—	—
Glutamic Acid	79.0	11.5	16.0	13.3	22.8	3.4	—	—
Arginine	13.6	2.4	3.3	7.1	4.1	3.4	7.3	7.2
Histidine	9.2	1.4	2.0	2.0	2.5	1.9	2.3	2.9
Non-Protein N	93.6	1.6	2.2	9.6	—	—	—	—

[1]The OSU *K. fragilis* sample contained 72% protein of which 91% was from the yeast and 9% from whey protein.
[2]Wasserman (7)
[3]Block and Bolling (1)
[4]49% Soybean Oil Meal, 55.6% Protein on dry matter basis; Fish Meal, 51.5% protein on a dry matter basis (2).
[5]Essential for humans.
[6]Rose and Harrison (5)