17

THE HEAT OF COMBUSTION OF VEGETABLE PROTEINS.

By FRANCIS G. BENEDICT and THOMAS B. OSBORNE.

(*From the Chemical Laboratory of Wesleyan University and the Laboratory of the Connecticut Agricultural Experiment Station.*)

(Received for publication, March 16, 1907.)

Very few determinations of the heat of combustion of vegetable proteins are to be found in the literature. The earliest appear to be those made by Danilewsky,[1] who found for "Pflanzen-fibrin" 6231, for legumin 5573 and gluten 6141 calories per gram.

As these determinations were made according to Stohmann's method at a time when this method was not perfected and as numerous precautions, which later were found to be important, were not considered, Stohmann[2] made new determinations of the heat of combustion of several proteins, among which were the crystallized globulin of the squash seed, prepared by Grübler, for which he found 5598 calories, and conglutin, which gave 5362 calories per gram.

Berthelot and Andre,[3] using the Berthelot bomb found for "Vegetable fibrin" 5837, for crude gluten 5995 calories per gram.

Stohmann and Langbein,[4] next determined the heat of combustion of various carefully prepared proteins using the calorimetric bomb of Berthelot. Most of the preparations were made by Grübler and before combustion were protractedly extracted with ether. The substances were burned in the air dry state and the results calculated to a water and ash-free basis. They found for "Pflanzen-fibrin" (glutenin of wheat) 5942, for legumin from white beans (phaseolin) 5793, for the crystallized globulin of squash seed 5672, and for conglutin from lupines 5479 calories per gram. No other determinations of the heat of combustion of vegetable proteins are known to us.

[1] Danilewski: *Centralbl. f. d. med. Wissensch.*, xix, pp. 465 and 486, 1881.
[2] Stohmann: *Journ. f. prakt. Chem.*, xxxi, p. 273, 1885.
[3] Berthelot and André: *Ann. de chim. et de phys.*, xxii, p. 25, 1891.
[4] Stohmann and Langbein: *Journ. f. prakt. Chem.*, xliv, p. 336, 1891.

In view of the very small number of vegetable proteins of which the heat of combustion has been determined and of their importance in so much of the food consumed both by men and animals, it seemed important to determine this factor for a large number of these substances derived from many of the different kinds of seeds in general use as food.

These proteins were all prepared with special reference not only to their separation from all non-protein bodies but also from other associated proteins. In other words, the preparations represent as nearly as possible definite chemical individuals. That they are in fact definite chemical individuals we are unable to assert for no method is yet available whereby this fact can be established. These preparations, however, represent substances that we have been unable to separate by fractionation into different parts, the composition or properties of which would indicate a mixture. They must for the present be accepted as representing the most definite protein products that can be prepared from the seeds that yielded them. These substances were burned in the Berthelot-Atwater calorimetric bomb.

The calorimeter room was kept at the most constant temperature possible and all the minor precautions, suggested by experience with over 10,000 of these combustions, were employed.

The bomb used in these determinations was so adjusted, as regards its hydrothermal equivalent, as to give the heat of combustion of pure, anhydrous cane sugar as 3959 calories per gram and of pure, fused benzoic acid as 6322 calories per gram.

From 0.5 to 0.8 gram of substance was used for each combustion which was weighed after the thoroughly dried material had assumed constant weight by prolonged exposure to the air.

As it is of the utmost importance that a definite state of desiccation should be established to which the heat of combustion should be referred a series of preliminary experiments were tried with the globulin edestin. The preparation of edestin, made according to the method described by Osborne,[1] was neutral to phenolphthalein and had been recrystallized several times.

Of this preparation 16 samples of the air dry material, each weighing 2 gms. were dried in a high vacuum for 9 days, 17 days, 24 days and 46

[1] Osborne: *Journ. of the Amer. Chem. Soc.*, xxiv, p. 39, 1902; also *Zeitschr. f. physiol. Chem.*, xxxiii, p. 240, 1901.

days and weighed at the end of each period. The average percentage of water, as determined by the total loss of weight at the end of each period, was 5.64, 5.76, 5.95, and 5.99, respectively, the agreement between the several samples being remarkably close. The average weight of material in each dish was therefore 1.8802 gram. After the desiccated edestin had been exposed to the air of the room the average weight in each dish was 1.9915 gram, the protein having regained very nearly all the moisture lost in the desiccator.

The heat of combustion of this material was determined with the following results:

	5184 calories per gram.
	5202 " "
	5185 " "
	5199 " "
	5196 " "
	5193 " "
	5194 " "
Average,	5193 " "

Calculating this result to an ash- and water-free basis, as determined by the above desiccation, we have 5507 calories per gram of edestin.

Of the same edestin 6 samples of 2 gms. each were weighed in shallow aluminum dishes, provided with a tight fitting cover,[1] and dried at 110° for successive periods of 5, 3½ and 4 hours, weighed after cooling in a desiccator, and then placed in the high vacuum for 5 weeks. At the end of this time the loss of weight was 8.37 per cent. After standing for some time in the room, exposed to the air, 4 samples were burned with results shown below:

Dry Weight.	Weight after Standing.	Heat of Combustion, Calories per Gram.	Heat of Combustion Calculated to an Ash- and Water-free Basis.
1.8353 gm.	1.9685 gm.	5228	5614
1.8353 "	1.9700 "	5247	5639
1.8326 "	1.9726 "	5226	5632
1.8322 "	1.9741 "	5222	5633
		Average,	5629

A comparison of these moisture determinations shows that while the highest per cent of moisture found by desiccation at the room temperature in a very high vacuum was 5.99 that found by heating at 110° C. and subsequently drying in the vacuum desiccator for a long time was 8.37 per cent or 2.38 per cent more.

While this large difference in the apparent water content was found in this sample of edestin, in three other samples of edestin the difference was found to be but 0.08, 0.42, and 0.39 per cent,

[1] Cf. Benedict and Manning: *Amer. Journ. of Physiol.*, xiii, p. 309, 1905; xviii, p. 309, 1907.

respectively. We are at present unable to explain the marked difference in behavior of these samples of edestin. In a large number of other vegetable proteins the difference was found to be not far from 0.25 per cent.

It has previously been shown by one of us[1] that protein preparations which have been dried by very long desiccation in a high vacuum over sulphuric acid show a gain in weight when subsequently dried at 110° C. in air. This gain in weight is more than lost if the protein after drying at 110° is again dried for a sufficient time *in vacuo* over sulphuric acid.

The fact that heating at 110° C. and subsequently drying in a vacuum results in a slightly larger loss of weight indicates a slight loss of water of constitution from the protein, which water, owing to the very high hygroscopic power of the dry protein, is retained as moisture, even at 110°, and is subsequently lost in the vacuum desiccator. That this explanation is correct is, however, rendered doubtful by the results obtained in drying the preparations for the determinations of the heats of combustion that are later described in this paper. A certain number of these preparations had, before using them for these experiments, been dried at 110°, the others dried only over sulphuric acid at the room temperature. The results, however, in most cases showed practically the same differences in moisture as determined by the two methods of drying just described. It would seem probable that if this difference was due to water of constitution lost at 110° these samples which had previously been dried at 110° would show no difference in the result of drying by the two methods, for it has been our experience that the protein preparations assume constant weight after drying for a few hours at 110°.

This excess of moisture, found after drying at 110° and then *in vacuò*, over that found by drying *in vacuo* alone, is shown by the following table:

Preparation Previously Dried over Sulphuric Acid.		Preparation Previously Dried at 110° C.	
Conglutin	0.18 per cent.	Amandin	0.28 per cent
Edestin No. 1	0.08 "	Excelsin	0.29 "
" No. 2	0.42 "	Vignin	0.76 "
" No. 3	0.39 "	Glycinin I	0.29 "
Cotton-seed globulin	0.28 "	Legumin, lentil	0.06 "

[1] Cf. Benedict and Manning: *Amer. Journ. of Physiol.*, xviii, p. 213, 1907.

Preparation Previously Dried over Sulphuric Acid.		Preparation Previously Dried at 110° C.	
Phaseolin, adzuki bean	0.21 per cent.	Legumin, horse bean	0.08 per cent.
Hordein	0.20 "	Legumin, Vetch	0.20 "
Edestin 40	2.38 "	Phaseolin, adzuki bean	0.13 "
Conglutin β	1.26 "	Phaseolin, kidney bean	0.20 "
		Conglutin α	0.07 "
		Glutenin	0.09 "
		Glycinin II	0.25 "
		Edestin No. 4	0.68 "

With the exception of Edestin No. 40 and Conglutin β the preparations that had previously *not* been heated show about the same differences as those that had already once been dried at 110° and it would therefore appear that this difference is, in most cases, due to some undetected condition of manipulation. No explanation of the large difference shown by Edestin No. 40 is apparent. This might be attributed to water of crystallization were it not for the fact that the other samples of edestin were likewise crystalline.

In order to detect any possible effect of heating during the drying a large number of determinations of the heat of combustion were made on material that had been dried *only* at room temperature *in vacuo* and the heat of combustion calculated to an ash- and moisture-free basis, the moisture being determined solely *in vacuo* and for comparison with these the heat of combustion was also determined in duplicate samples that had been dried at 110° and then for a long time *in vacuo*, as just stated. In a few samples the moisture was determined simply by long drying in the vacuum and the results in these cases are probably stated a small fraction of 1 per cent too low.

Returning now to the sample, Edestin No. 40, it is to be noted that the heat of combustion of the sample which had been dried *in vacuo* was 5507 calories per gram, calculated to an ash- and water-free basis as determined by drying *in vacuo*, whereas the heat of combustion of the sample dried at 110° and afterwards *in vacuo* was 5629 calories per gram, calculated to the ash- and water-free basis as determined by drying at 110° and then *in* *vacuo*. If the first determination of the heat of combustion is recalculated on the assumption that the difference in water determinations by the two methods is due to moisture still present in the sample dried only *in vacuo* we find the heat of combustion to be 5630, which agrees exactly with the second determination, 5629 calories per gram. In confirmation of this result four other samples of edestin were dried in the two ways and the following results obtained, calculated to an ash- and water-free basis; *a*, moisture determined *in vacuo; b*, moisture determined by heating at 110° for 12½ hours and then drying in vacuum desiccator for 5 weeks. The result given under *a* is calculated under *c* on the assumption that the difference in moisture found between *a* and *b* was due to moisture still retained in the samples dried by method *a*.

	a	*b*	*c*	
Edestin No. 40	5500	5622	5623	calories per gram.
" " 1	5570	5658	5575	" "
" " 2	5575	5655	5600	" "
" " 3	5629	5668	5653	" "
" " 4	....	5644	....	" "

The difference in the moisture determinations in samples Nos. 1, 2 and 3, dried by the two methods, is much less than that found for Edestin No. 40 and the difference in the heats of combustion is correspondingly less.

In the following tables we give the results of the determinations of the heats of combustions of a large number of different vegetable proteins. The condition of these preparations as respects drying before using in this work is indicated in Column I by "dried at 110°" or "over H_2SO_4" respectively. Under VII is given the heat of combustion as found for the preparation dried only *in vacuo* calculated to a water-free basis, assuming that the slightly greater loss of weight after drying at 110° and then *in vacuo* is moisture.

Amandin. This is a globulin forming the greater part of the protein matter of the seeds of the almond (*Prunus amygdalus var. dulcis*).

Dried at 110° in air it has the following composition:[1]

C, 51.30; H, 6.90; N, 18.90; S, 0.43; O, 22.47 per cent.

[1] The composition of all these proteins was determined after drying in the customary way at 110° in air without subsequent drying in vacuo.

I. Previously Dried.	II. Dried.	III. Weight of Dry Substance.	IV. Weight of Substance when Burned.	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.	VII. Corrected for Difference in Moisture.
at 110°	in vacuo	1.8063 gm.	1.9787 gm.	5037	5527	5543
		1.8054 "	1.9784 "	5022		
	at 110° and then in vacuo	1.8001 "	1.9822 "	5022	5543	
		1.8002 "	1.9820 "	5018		

Corylin. This globulin constitutes most of the protein substance of the filbert or hazel-nut (*Corylus avellana*). Its composition, dried in air at 110°, is

C, 50.72; H, 6.86; N, 19.03; S, 0.83; O, 22.56 per cent.

I. Previously Dried.	II. Dried.	III. Weight of Dry Substance.	IV. Weight of Substance when Burned.	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.	VII. Corrected for Difference in Moisture.
over H_2SO_4	in vacuo	1.8237 gm.	1.9980 gm.	5036	5573	5583
		1.8238 "	2.0009 "	5053		
	at 110° and then in vacuo	1.8202 "	2.0046 "	5044	5597	
				5044		

Excelsin. Most of the protein of the Brazil or Para nut (*Bertholletia excelsa*) consists of the globulin excelsin which crystallizes in hexagonal plates. The preparation used for these experiments consisted entirely of hexagonal plates. Its composition is

C, 52.23; H, 6.95; N, 18.26; S, 1.09; O, 21.47 per cent.

I. Previously Dried.	II. Dried.	III. Weight of Dry Substance.	IV. Weight of Substance when Burned.	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.	VII. Corrected for Difference in Moisture.
at 110°	in vacuo	1.8552 gm.	2.0280 gm.	5224	5719	5737
		1.8552 "	2.0271 "	5212		
	at 110° and then in vacuo	1.8500 "	2.0312 "	5197	5736	
		1.8485 "	2.0307 "	5222		

Edestin. This is the principal protein constituent of the hemp-seed

(*Cannabis Sativa*). The preparations used for these combustions were all composed of octahedral crystals. The composition of Edestin is

C, 51.36; H, 7.01; N, 18.65; S, 0.88; O, 22.10 per cent.

I. Previously Dried.	II. Dried.	III. Weight of Dry Substance.	IV. Weight of Substance when Burned.	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.	VII. Corrected for Difference in Moisture.
Prep. No. 1 over H_2SO_4	in vacuo	0.8980 gm. 0.8980 "	0.9960 gm. 0.9961 "	5006 5008	5570	5575
	at 110° and then in vacuo	0.8972 " 0.8972 "	0.9867 " 0.9867 "	5126 5133	5658	
Prep. No. 2 over H_2SO_4	in vacuo	0.9092 " 0.9087 "	1.0083 " 1.0081 "	5018 5020	5575	5583
	at 110° and then in vacuo	0.9072 " 0.9024 "	0.9989 " 0.9925 "	5113 5165	5630 5681	
Prep. No. 3 over H_2SO_4	in vacuo	0.9098 " 0.9102 "	1.0289 " 1.0296 "	4973 4971	5629	5653
	at 110° and then in vacuo	0.9045 " 0.9077 "	0.9977 " 0.9985 "	5146 5136 5156	5673	
Prep. No. 4 at 110°	in vacuo	0.9182 " 0.9114 "	1.0086 " 0.9966 "	5138 5135 5135	5644	

Globulin of the Cotton Seed (*Gossypium herbacium*). Very nearly all of the protein matter of this seed consists of this globulin, the composition of which is

C, 51.71; H, 6.86; N, 18.30; S, 0.62; O, 22.51 per cent.

I. Previously Dried.	II. Dried.	III. Weight of Dry Substance.	IV. Weight of Substance when Burned.	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.	VII. Corrected for Difference in Moisture.
over H_2SO_4	in vacuo	1.8179 gm. 1.8181 "	1.9728 gm. 1.9741 "	5179 5113 5258	5657	5673
	at 110° and then in vacuo	1.8132 " 0.9054 "	1.9939 " 0.9966 "	5074 5059 5074 5044 5046	5596	

VIGNIN. The greater part of the protein substance of the cow pea (*Vigna sinensis*) consists of this protein which has the properties of a globulin and the following composition:

C, 52.64; H, 6.95; N, 17.25; S, 0.42; O, 22.74 per cent.

I. Previously Dried.	II. Dried.	III. Weight of Dry Substance.	IV. Weight of Substance when Burned.	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.	VII. Corrected for Difference in Moisture.
at 110°	in vacuo	0.9206 gm.	1.0292 gm.	5055	5668	5715
		0.9182 "	1.0268 "	5039		
	at 110° and then in vacuo	0.9118 "	0.9944 "	5202	5703	
				5210		
over H_2SO_4	in vacuo	0.9081 "	1.0242 "	5023	5688	
		0.9071 "	1.0240 "	5027		
	at 110°* and then in vacuo	0.4552 "	0.4991 "	5160	5691	5721
		0.4551 "	0.4999 "	5178		

* This was the only preparation which showed a greater loss of weight after drying in vacuo alone than after drying at 110° and then in vacuo. No reason for this exception is apparent. Were it not for the fact that the heats of combustion of the two samples agreed so closely it might be taken as indicating oxidation.

GLYCININ. This globulin forms the greater part of the protein matter of the soy bean (*Glycine soja*). Its composition is

C, 52.01; H, 6.89; N, 17.47; S, 0.71; O, 22.92 per cent.

I. Previously Dried.	II. Dried.	III. Weight of Dry Substance.	IV. Weight of Substance when Burned.	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.	VII. Corrected for Difference in Moisture.
yellow soy bean at 110°	in vacuo	1.8242 gm.	1.9620 gm.	5236	5667	5687
		1.8254 "	1.9655 "	5242		
				5255		
	at 110° and then in vacuo	1.8181 "	1.9938 "	5147	5672	
		1.8197 "	1.9979 "	5147		
Japanese soy bean over H_2SO_4	in vacuo	0.9184 "	1.0248 "	5056	5665	5680
		0.9187 "	1.0247 "	5016	5619	5636
	at 110° and then in vacuo	0.9170 "	1.0236 "	5048	5657	
		0.9151 "	1.0211 "	5048		

LEGUMIN. Most of the protein matter of seeds of the horse bean (*Vicia faba*), lentil (*Ervum lens*), vetch (*Vicia sativa*), and pea (*Pisum sativum*) consists of a globulin, the preparations of which have thus far appeared to be identical in respect to all their properties that have been examined. This agreement is now found for the heats of combustion of preparations from the three seeds first named. No preparation from the pea was available at the time this work was done. The composition of legumin is

C, 51.72; H, 6.95; N, 18.04; S, 0.39; O, 22.90 per cent.

Legumin, lentil.

I. Previously Dried.	II. Dried.	III. Weight of Dry Substance.	IV. Weight of Substance when Burned.	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.	VII. Corrected for Difference in Moisture.
at 110°	in vacuo	0.9094 gm. 0.9092 "	0.9771 gm. 0.9769 "	5224 5203 5202	5612	5619
	at 110° and then in vacuo	0.9082 " 0.9093 "	0.9835 " 0.9850 "	5177 5193	5630	

Legumin, horse bean.

I.	II.	III.	IV.	V.	VI.	VII.
at 110°	in vacuo	0.9122 " 0.9112 "	0.9820 " 0.9826 "	5203 5190	5625	5632
	at 110° and then in vacuo	0.9112 " 0.9107 "	0.9872 " 0.9869 "	5220 5172	5656	

Legumin, vetch.

I.	II.	III.	IV.	V.	VI.	VII.
at 110°	in vacuo	0.9088 " 0.9092 "	0.9830 " 0.9840 "	5156 5143 5143	5586	5600
	at 110° and then in vacuo	0.9063 " 0.9077 "	0.9878 " 0.9865 "	5132 5150 5166	5621	

PHASEOLIN. This is a globulin that forms the principal part of the protein substance of the white or kidney bean (*Phaseolus vulgaris*), and also that of the Japanese adzuki bean (*Phaseolus radiatus*). Its composition is

C, 52.57; H, 6.97; N, 15.84; S. 0.33; O, 24.29 per cent.

Phaseolin, kidney bean.

I. Previously Dried.	II. Dried.	III. Weight of Dry Substance.	IV. Weight of Substance when Burned.	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.	VII. Corrected for Difference in Moisture.
at 110°	in vacuo	1.8270	2.0409	5050	5675	5689
		1.8276	2.0403	5049		
	at 110° and then in vacuo	(1.8232	2.0273	5083	5679	
				5060		
				5086		

Phaseolin, Adzuki bean.

I. Previously Dried.	II. Dried.	III. Weight of Dry Substance.	IV. Weight of Substance when Burned.	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.	VII. Corrected for Difference in Moisture.
at 110°	in vacuo	0.9226 gm.	1.0213 gm.	5123	5709	5726
		0.9237 "	1.0227 "	5111		
	at 110° and then in vacuo	0.9213 "	1.0202 "	5095	5683	
		0.9225 "	1.0216 "	5088		
over H_2SO_4	in vacuo	0.9061 "	1.0070 "	5072	5681	5693
		0.9066 "	1.0072 "	5081		
	at 110° and then in vacuo	0.9045 "	1.0029 "	5097	5702	
		0.9040 "	1.0030 "	5112		

Conglutin. The substance formerly called conglutin, which forms almost all of the protein matter of the seeds of lupines (*Lupinus*) of various species consists in those of the yellow lupine (*Lupinus luteus*) of at least two distinct globulins. These are designated Conglutin α and Conglutin β. In the seeds of blue lupine (*Lupinus angustifolius*) the conglutin is similar to Conglutin α. The composition of conglutin from the blue lupine is

C, 51.13; H, 6.86; N, 18.11; S, 0.32; O, 23.10 per cent.

Conglutin α has a similar composition, namely,

C, 51.75; H, 6.96; N, 17.57; S, 0.62; O, 23.10 per cent.

Conglutin β has the following composition[1]

C, 49.91; H, 6.81; N, 18.40; S, 1.67; O, 23.21 per cent.

---

[1] Cf. Osborne and Harris: *Amer. Journ. of Physiol.*, xiii, p. 436, 1905.

Conglutin, Blue lupine.

I. Previously Dried.	II. Dried.	III. Weight of Dry Substance.	IV. Weight of Substance when Burned.	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.	VII. Corrected for Difference in Moisture.
over H_2SO_4	in vacuo	0.8902 0.8905	0.9916 0.9897	4893 4882 4904	5475	

Conglutin α, Yellow lupine.

I. Previously Dried.	II. Dried.	III. Weight of Dry Substance.	IV. Weight of Substance when Burned.	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.	VII. Corrected for Difference in Moisture.
at 110°	in vacuo	1.8551	2.0223	5040 5047	5528	5536
	at 110° and then in vacuo	1.8537	2.0203	5061 5067	5548	

Conglutin β, Yellow lupine.

I. Previously Dried.	II. Dried.	III. Weight of Dry Substance.	IV. Weight of Substance when Burned.	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.	VII. Corrected for Difference in Moisture.
over H_2SO_4	in vacuo	1.8530	2.0109	4873 4868 4888	5302	5376
	at 110° and then in vacuo	1.8278	2.0275	4808 4799	5341	

Vicilin. This is a globulin associated with legumin in the seeds of lentil (*Ervum lens*), horse bean (*Vicia faba*) and pea (*Pisium Sativum*). Its composition is

C, 52.29; H, 7.03; N, 17.11; S, 0.17; O, 23.40 per cent.

I. Previously Dried.	II. Dried.	III. Weight of Dry Substance.	IV. Weight of Substance when Burned.	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.
at 110°	in vacuo	0.8900 gm.	0.9727 gm.	5183 5200	5683

Legumelin. This is an albumin-like protein which is found in the extracts of most leguminous seeds. This preparation was from the lentil (*Ervum lens*). The composition of legumelin is

C, 53.31; H, 6.71; N, 16.08; S, 0.97; O, 22.93 per cent.

I. Previously Dried	II. Dried.	III. Weight of Dry Substance.	IV. Weight of Substance when Burned.	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.
at 110°	in vacuo	0.9154	0.9901 gm.	5209	5676

GLIADIN. This is a protein soluble in 70–80 per cent alcohol, which forms nearly one-half of the protein of wheat (*Triticum vulgare*) and rye kernels (*Secale cereale*). The composition of gliadin is

C, 52.72; H, 6.86; N, 17.66; S, 1.03; O, 21.73 per cent.

Gliadin from wheat.

I. Previously Dried.	II. Dried.	III. Weight of Dry Substance.	IV. Weight of Substance when Burned.	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.
I. over H_2SO_4	in vacuo	1.7786 gm. 1.7787 "	1.9596 gm. 1.9557 "	5229 5226 5242	5784
II. over H_2SO_4	in vacuo	1.8045 " 0.9023 "	1.9903 " 0.9928 "	5187 5181	5713
Gliadin from rye.					
over H_2SO_4	in vacuo	1.8095 " 1.8090 "	1.9925 " 1.9955 "	5184 5203 5177 5184	5717

GLUTENIN. This protein (Gluten-casein according to Ritthausen) forms about one-half of the protein matter of the gluten of most varieties of wheat, and is insoluble in neutral solvents. Its ultimate composition is nearly the same as that of gliadin but the structure of its molecule is very different, as shown by a comparison of the proportion of decomposition products yielded by these two proteins. The composition of glutenin is

C, 52.34; H, 6.83; N, 17.49; S, 1.08; O, 22.26 per cent.

I. Previously Dried.	II. Dried.	III. Weight of Dry Substance.	IV. Weight of Substance when Burned.	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.
at 110°	in vacuo	1.8072 gm.	1.9924 gm.	5134	5704
		1.8054 "	1.9977 "	5137	
				5111	5703
				5119	
				5116	

Globulin. Wheat (*Triticum vulgare*). This globulin forms only a very small part of the total protein of the wheat kernel. It is contained chiefly, if not wholly in the embryo of the seed. Its composition is

C, 51.03; H, 6.85; N, 18.30; S, 0.69; O, 23.13 per cent.

I. Previously Dried.	II. Dried.	III. Weight of Dry Substance.	IV. Weight of Substance when Burned	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.
over H_2SO_4	in vacuo	0.8925 gm.	0.9883 gm.	4759	5358
				4790	

Hordein. Barley (*Hordeum vulgare*). Hordein, which forms about one-half of the protein substance of the barley kernel, is readily soluble in 70–80 per cent alcohol. Its composition is

C, 54.29; H, 6.80; N, 17.20; S, 0.85; O, 20.86 per cent.

I. Previously Dried.	II. Dried.	III. Weight of Dry Substance.	IV. Weight of Substance when Burned.	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.	VII. Corrected for Difference in Moisture.
over H_2SO_4	in vacuo	1.8082 gm.	2.0025 gm.	5316	5902	5916
				5317		
	at 110° and then in vacuo	1.8043 "	1.9946 "	5349	5934	
				5361		

Bynin. Barley malt. Bynin is the alcohol soluble protein of barley malt. Its composition is

C, 55.03; H, 6.67; N, 16.26; S, 0.84; O, 21.20 per cent.

I. Previously Dried.	II. Dried.	III. Weight of Dry Substance	IV. Weight of Substance when Burned.	V. Heat of Combustion, Calories per Gram.	VI. Calculated to Ash- and Water-free Basis.
at 110°	in vacuo	0.9006 gm.	0.9899 gm.	5262 5293	5807

The results of these determinations are given in the following table:

	C	H	N	S	O	Calories per gram
Amandin	51.30	6.90	18.90	0.43	22.47	5543
Corylin	50.72	6.86	19.03	0.83	22.56	5590
Excelsin	52.23	6.95	18.26	1.09	21.47	5737
Edestin	51.36	7.01	18.65	0.88	22.10	5635
Globulin (Cotton seed)	51.71	6.86	18.30	0.62	22.51	5596
Vignin	52.64	6.95	17.25	0.42	22.74	5718
Glycinin	52.01	6.89	17.47	0.71	22.92	5668
Legumin	51.72	6.95	18.04	0.39	22.90	5620
Phaseolin	52.57	6.97	15.84	0.33	24.29	5726
Conglutin (Blue lupine)	51.13	6.86	18.11	0.32	23.10	5475
Conglutin α (Yellow lupine)	51.75	6.96	17.57	0.62	23.10	5542
Conglutin β (Yellow lupine)	49.91	6.81	18.40	1.67	23.21	5359
Vicilin	52.29	7.03	17.11	0.17	23.40	5683
Legumelin	53.31	6.71	16.08	0.97	22.93	5676
Gliadin	52.72	6.86	17.66	1.03	21.73	5738
Glutenin	52.34	6.83	17.49	1.08	22.26	5704
Globulin (Wheat)	51.03	6.85	18.30	0.69	23.13	5358
Hordein	54.29	6.80	17.20	0.85	20.86	5916
Bynin	55.03	6.67	16.26	0.84	21.20	5807

In general the higher heats of combustion are found for those proteins which have a higher carbon content and similarly for those with a lower oxygen content. Many irregularities, however, appear in the preceding table, which are doubtless due to the different proportions of the various amino-acids which constitute the molecules of the different proteins. As we have but little knowledge of the relative proportions of these amino-acids in the proteins burned, we are not able yet to draw any definite conclusions in regard to these differences.