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WHEAT PRICES AND MILLING COSTS IN CLASSICAL ROME

N. Jasny

The primary aim of this study was to ascertain the price of wheat in classical antiquity, and specifically the price or prices that correspond to the flour prices mentioned in Pliny's *Natural History*. It is concluded that the wheat price corresponding to Pliny's flour prices was at least 8 sesterces per modius for the cheaper of the two principal types of Roman wheat, rather than 3–4 or 5 sesterces for wheat as such—the interpretation hitherto commonly accepted. In other words, the free-market price of wheat in Rome at the end of the Republic and at the beginning of the Empire is likely to have been considerably higher than classical scholars have been assuming. Attention is also given to the price of wheat in certain other parts of the ancient world and an attempt is made to appraise the probable price spread between surplus and deficit areas.

To reach conclusions on prices required the intensive consideration of wheats, flours, milling techniques and costs, and related matters in classical antiquity. A further objective of the study has been to bring order out of the chaos that has characterized the available information on these subjects. If the work contributes only a little to reliable knowledge of the price of wheat in the ancient world, so important for its bearing on purchasing power and cost of living, it goes farther toward settling questions about flour grades and milling costs in classical antiquity.

A Roman flour with only bran separated, widely used during that period, was "discovered" in the course of the study. Extraction percentages of flour in antiquity appear to have been substantially higher than some prominent scholars have believed. It was also found that the high cost of power for grinding at that time was largely offset by the coarseness of the grinding, and that the total cost of producing flour, while higher than at present, represented only a small part of the flour price.

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N. Jasny

For the distant past, for which no detailed statistics are available, it is quite customary to determine the price of money from the prices of grain. Economic activities were centered upon food production and the diet consisted largely of grain. The prices of other foods, especially dried legumes and meats, stood in a certain more or less definite relation to the price of grain. Hence, the price of grain largely determined also the wage level, the cost of living, and so on. Grain prices are therefore the key to an analysis of the economic life of ancient times.

Unfortunately, the evidence on grain prices in classical antiquity is meager, particularly so for classical Rome. Rome certainly had a dual price system throughout most of its history. The prices at which the government distributed grain mostly were not even close to free-market prices and were sometimes even nominal. While government prices in Rome are known, not a single free-market price is transmitted to us which would have pertained to normal conditions rather than to times of either great abundance or scarcity.

Every scrap of information, however uncertain or indirect, must be used under these conditions. Among the scraps of indirect evidence are Pliny's prices of wheat flour. Since Pliny stated that those prices prevailed at times of average food prices, his evidence figures prominently in every study devoted to grain prices in classical Rome, and also in almost every study of the economics of classical antiquity, since grain prices largely served to determine wages, standards of living, and so on.

However, none of the important studies of grain prices in classical Rome made use of Pliny's flour prices as the basic evidence. The procedure has rather been to reach conclusions from other material and then to show that Pliny's flour prices do not contradict conclusions so reached. This relegation of Pliny's evidence to an auxiliary role is mainly due to the difficulties involved in converting the flour prices to wheat prices. The reluctance is fully justified. A correct result could not be obtained while knowledge of milling techniques, flour grades, and milling costs was such as to permit widely divergent and therefore in some degree very incorrect interpretations.

Five years as a flour-mill manager, two years in a grain-export organization, and many more years spent on research pertaining to grain have made those obstacles less serious for the present writer. Indeed, the specific character of the difficulties renders the problems particularly intriguing. While this study would have been warranted merely as finding the correct level of wheat prices corresponding to Pliny's flour prices, it is all the more justified if it serves to clarify knowledge of milling techniques, flour grades, and milling costs in ancient times.

Pliny's flour prices are commonly interpreted as corresponding to a wheat price of 5 sesterces per modius or less, even much less. But according to the analysis made in this study, the lowest prices to which they correspond are 8 sesterces per modius of the cheaper of the two principal types of Roman wheats and almost 10 sesterces per modius of the more expensive type.

Sicilian and Egyptian wheats were both of the cheaper type. The average market price of wheat in Sicily shortly before the beginning of our era was probably considerably higher than 3 sesterces per modius. In Egypt, wheat may have cost slightly less than 3 sesterces, both at this time and a century later

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when Pliny made his statement on flour prices. However, Egyptian exports may not have been entirely free. The high costs of transportation and storage and the heavy risks involved in the grain trade may well have brought the price of Sicilian and Egyptian wheats in Rome close to a price that would correspond to Pliny's flour prices. In any case, the free-market price of wheat in Rome probably was considerably higher than 3–4 sesterces per modius—the price hitherto commonly accepted by historians.

The flour used for bread in classical Rome was much poorer than is commonly assumed. Wheat was not thoroughly cleaned before grinding, and grinding and sifting, if any, were very coarse; in fact, much flour was simply whole-grain meal. Among sifted flours, one of about 80 per cent extraction was probably the most common. The practice of grinding wheat into three grades of flour, described in detail by Pliny and commonly assumed to have been the standard type in antiquity, probably was found only in the largest cities, and even there only to a moderate extent. As in the production of one-grade flour, the extraction of flour in the three-grade grinding was considerably higher than the present extraction rate.

Animal power was utilized inefficiently in Roman mills, which may partly account for the fact that human labor was largely used for grinding even after the invention of the rotating animal mill. Milling costs, though considerably higher than in modern times, nevertheless were small relative to the free-market price of wheat, because of the high price of the wheat, the cheapness of slave labor, and especially the small amount of power utilized per bushel of the coarsely ground wheat.

Pliny's Flour Prices

Pliny the Elder, the author of the famous *Natural History*, was born A.D. 23 and perished in Pompeii during the eruption of Vesuvius A.D. 79. The *Natural History* was published A.D. 77. Among the tremendous amount of evidence of all kinds and of greatly varying reliability assembled in it, there are 16 words pertaining to the prices of wheat flour:[1]

> *Pretium huic annona media in modios farinae XL asses, similagini octonis assibus amplius, siligini castratae duplum* [When food prices are average, a modius of *farina* costs 40 asses; of *similago* 8 asses more, and of bolted *siligo* twice.]

The customary interpretation of this statement is that those prices corresponded to a price of 5 sesterces per modius of wheat, or less.[2] This interpretation is almost a century old. Repeated over and over again, it attained the position of a definitely established truth. The interpretation that Pliny's flour prices correspond to 5 sesterces per modius was made, for example, by Hugo Blümner[3] (who devoted his life to study of the economics of classical antiquity) in his comments on the *Edict* of Diocletian on maximum prices. Corrado Barbagallo[4] first computed a price of 5–6 sesterces for *triticum*, the cheaper of the two Roman wheats;[5] but then he said that the wheat price could not have been so high because of the high milling costs. In his comprehensive work on the economy of ancient Rome, Tenney Frank[6] writes: "Pliny (xviii, 90) gives the price of flour in his day at forty asses which means a rather high price of five sesterces the modius for wheat." Thus in Frank's opinion the normal price of wheat in Rome in Pliny's time was less than 5 sesterces.

[1] *Naturalis Historiae Libri XXXVII* (Bibliotheca Scriptorum Graecorum et Romanorum Teubneriana, Leipzig, 1892), Book 18, chap. 10, sec. 90, pp. 166–67.

[2] The modius, the Roman unit of volume, was equivalent to 8.47 liters or 0.24 Winchester bushel; 1 sextarius was one-sixteenth of a modius. The denarius, the Roman unit of money, was subdivided into 4 sesterces and 1 sesterce was subdivided into 4 asses.

[3] *Edictum Diocletiani de Pretiis Rerum Venalium*, ed. by Th. Mommsen (interpreted by H. Blümner) (Berlin, 1893), p. 63.

[4] "Il prezzo del frumento durante l'età imperiale Romana in Grecia e in Italia," *Rivista di Storia Antica*, 1905, n.s., X, 53.

[5] The price computed by Barbagallo for *siligo*, the higher-priced type of Roman wheat, was 10 sesterces per modius. This price was reached by an incorrect interpretation of the word *duplum* in Pliny's statement as meaning a price twice as high as 40 asses. If Barbagallo had interpreted the word *duplum* as meaning duplication of the additional 8 asses (see p. 156 for proof that this is likely to be the correct interpretation), he would have arrived at a price of 7 sesterces for *siligo*.

[6] *Economic Survey of Ancient Rome* (Baltimore, 1933–40), I, 403.

For the time of Cicero (about a century before Pliny), when wheat was unlikely to have been materially cheaper than at the time of Pliny, Frank[7] accepts 3 sesterces as the normal price of wheat in Rome. Rodbertus,[8] in his important study of the real value of money in antiquity, arrived at the conclusion that the price of wheat corresponding to Pliny's flour prices was much less than 4–5 sesterces. M. Rostovtzev[9] thought that Pliny's flour prices can be "well brought in agreement with a price of wheat of 3 to 4 sesterces which is known to us from other sources." Alberto Oliva[10] uses 3 sesterces as the market price of wheat in Rome at the time of Caius Gracchus (the end of the second century B.C.) and of 3–4 in the period from Cicero to Nero.

It is the contention of the present writer that the lowest prices to which Pliny's flour prices could have corresponded were 8 sesterces per modius of *triticum* (in the narrow sense), the cheaper of the Roman wheat types, and slightly less than 10 sesterces per modius of *siligo*, the higher-priced of the Roman wheat types. The price of 8 sesterces per modius of *triticum* in the narrow sense corresponds to about 1.60 pre-1933 gold dollars per Winchester bushel, while slightly less than 10 sesterces per modius of *siligo* corresponds to almost 2 dollars of the same value per Winchester bushel.[11]

It must be conceded that those prices are high. But if Pliny's flour prices are interpreted as free-market prices[12]—and they obviously could not have been anything else—they do not seem to the present writer so enormously high as to most students of Roman economic history. In fact, they compare well with normal prices of present times. The comparison of course must not be with prices in the United States or any other surplus country, but with prices in highly deficit countries of which Rome was one, and not with prices in periods of deflation such as that which began in 1931, because Pliny's time was by no means one of such excessive production of agricultural products as characterized the period after 1931. The average wheat prices in the principal deficit countries of Europe in 1909–10 to 1913–14 and 1925–26 to 1929–30 were as follows (in cents per bushel of 60 pounds):[13]

Country	Type of wheat	1909–10 to 1913–14	1925–26 to 1929–30
United Kingdom...	Imported wheat, average of all imports	108	150
France.....	Domestic wheat in Paris	142	164
Germany.....	Domestic wheat in Berlin	135	170
Italy.....	Domestic common ("soft") wheat in Milan	150[a]	196

[a] Calendar years 1910–14.

At $1.60 per bushel the price of *triticum*, the most widely grown wheat of antiquity, as computed from Pliny's flour prices, was much higher than was the price of imported wheat in Britain before the first world war; but it was only moderately higher than the prices of domestic wheat in Berlin and Paris or the price of domestic common wheat in Milan.

[7] *Ibid.*, p. 98.

[8] "Zur Frage des Sachwerths des Geldes im Alterthum," in *Jahrbücher für Nationalökonomie und Statistik*, ed. by Bruno Hildebrand (Jena, 1870), XIV, 413.

[9] "Frumentum," in *Paulys Real-Encyclopädie der classischen Altertumswissenschaft* (new ed., Stuttgart, 1894–1938), Vol. VII, col. 149.

[10] *La politica granaria di Roma antica* (Piacenza, 1930), pp. 95, 168.

[11] The writer accepts the conversion of the Roman money to United States currency used by Frank (*op. cit.*, I, 422). The Roman silver denarius first was converted to gold by using the ratio 12:1 and then the conversion to United States currency was made. A direct conversion to the silver denarius, without bringing in gold, would yield a dollar value only about 40 per cent as high as that computed in the text. But silver must be considered a devalued metal now. With the accepted mode of conversion, a sesterce per modius is equivalent to about 20 cents of the pre-1933 gold dollar per Winchester bushel.

[12] The very important distinction between free-market prices and prices at which the government distributed or sold the grain in Rome is hardly ever made with sufficient clarity. The government obtained a portion of the harvest (mostly one-tenth) of the subject countries as a tax. Grain was also received by the government free as rent for government-owned land. Transportation within the individual countries frequently was performed as a compulsory service and ship owners were induced by privileges to transport government grain cheaply. Under these conditions the cost of the grain to the government was only a fraction of that to a private merchant.

[13] Official data compiled by the Food Research Institute, Stanford University. See J. S. Davis, "The World Wheat Situation, 1934–35: A Review of the Crop Year," WHEAT STUDIES, December 1935, XII, 181.

Domestic durum ("hard") wheat in Italy usually costs more than domestic common ("soft") wheat. *Imported* wheat of every kind cost substantially more than domestic wheat in all three of the big deficit countries of the European continent. Hence before the first world war the prices of *imported* wheat in those three countries were closer to the computed price of *triticum* in Rome than was the price of domestic wheat, and the price of durum in Milan practically coincided with the computed price of *triticum*.

In the period preceding the deflation of the 1930's, only in Britain was the wheat price less than the price computed for *triticum*. The price of domestic common wheat in Milan was almost as high as the price of *siligo* computed from Pliny's flour prices, while the price of durum wheat was as high as the latter. Of course, both before and after the first world war, the German, French, and Italian wheat prices were raised by rather high import barriers; but in antiquity the high cost of transportation operated as a very effective barrier.

The history of wheat prices over a long period of time cannot be analyzed here. It must be conceded that wheat prices as they were before the deflation of the 1930's represented the high point of a rise which had lasted for decades.[14] Yet the prices of 1925–29 are not high and those of 1909–13 are low, if they are compared with prices in import markets in more distant periods—for example, with the prices in those markets in the eighteenth century.

The idea of the historians that wheat was cheap in terms of other goods or gold in antiquity has its origin in the assumption that improvements in grain-production techniques since classical times have been negligible as compared with improvements in the techniques of producing other goods, and that grain consequently became gradually more and more expensive. Actually, however, the past century may have been the only period of very large changes in the price relationship between grain and other goods. These changes were brought about by a revolution in transportation facilities, and on the deficit markets grain was the commodity which had become cheaper relative to many other goods. Even if it could be proved that improvements in the techniques of grain production were less than improvements in the production techniques for other goods, the great reduction in transportation costs is a big offsetting factor so far as concerns the price of such a cheap commodity as grain on importing markets. The very high cost of transportation in antiquity is a factor which does not receive due attention from the analysts of Roman wheat prices.

The free-market price of wheat is the one at which Italian producers sold their surpluses. The common idea that these prices were low in Rome seems to agree well with the shift from grain to wine and olives which occurred in Italian agriculture at the end of the Republic and during the early Empire.[15] But this shift indicates only that wine and some other foods particularly expensive to transport, successfully competed with wheat for the land. The difference in transportation and other marketing costs made it profitable to produce these products in the vicinity of Rome and to bring wheat from distant countries. But wheat was not cheap in Rome. Transportation and other marketing costs of foreign wheats in Rome, though much lower than those of wine, were nevertheless very high. Free-market wheat would have been cheap in Rome only if the government had regularly and heavily subsidized its importation, but apparently such measures were taken only in emergencies.

It will be shown later that the free-market prices of grain in Rome were undoubtedly subject to violent variations, far exceeding in this respect anything observed now. Prices jumped up and down greatly from year to year and within the same year, and even five-

[14] This statement is true if the very high prices during the first world war are disregarded. If they are included, the peak of prices was reached during that war.

[15] The extent of the shift is frequently greatly exaggerated, and occurred on a large scale only in the vicinity of Rome. Available evidence leaves no doubt that imports covered only a small proportion (10 per cent or less) of the total grain requirement of Italy and probably did not exceed 15 million bushels, even including shipments from Sicily and Sardinia. About 150 million bushels were needed solely to feed the population, which at the time of Pliny is usually estimated at about 15 millions. Seed and feed had to be provided additionally.

year averages are likely to have differed very substantially one from another. These violent price variations may have been an important contributing inducement for the farmer near Rome not to rely merely on grain for his money income, even though the long-time average prices were rather high. The wide and highly important implications of the idea that the free-market prices in Rome might have been much higher than is commonly believed are recognized by the present writer, but cannot be discussed here.

In a subsequent short statement an attempt is made to show that, so far as free-market prices are concerned, the evidence on Roman wheat prices other than that given by Pliny by no means conclusively points to the price level commonly accepted by the historians. But even if it be granted that free-market prices of wheat in Rome may have been substantially less than those which correspond to Pliny's flour prices, this may have been true only with reference to long-time averages. Owing to the very large price variations, it is not impossible that, while the long-time average prices of wheat were materially less than the prices which corresponded to Pliny's flour prices, the free-market prices of wheat in Rome approximately reached the level indicated by our conversion of Pliny's flour prices for a period of time sufficiently long to have enabled Pliny to say that his flour prices were those of years with normal food prices.

But the present writer does not insist that the free-market prices of wheat as he computes them from Pliny's flour prices existed for a considerable length of time. He is only certain that his conversion of Pliny's flour prices is reasonably correct, and hopes that a step forward will have been made toward finding the truth by proving that Pliny's flour prices cannot properly be cited in support of wheat prices of only 5 sesterces per modius or less. The price of 5 sesterces per modius of wheat in Rome may be correct after all, but it ought to be substantiated by evidence other than Pliny's flour prices. The position of those defending this wheat price would be especially strong if, in addition to proving it by other evidence, they would find a way to explain why Pliny gave prices of flour which are so much higher than those which would correspond to a wheat price of 5 sesterces. But this is by no means indispensable. Pliny's *Natural History* contains so many statements the incorrectness of which is beyond any doubt that such an explanation would not be essential.

The conversion of Pliny's flour prices to a grain basis is not difficult, but it is partly a highly technical task. This accounts for the fact that a correct interpretation was not made long ago by some of the many brilliant scholars who have attacked the problem.

The first thing which needs to be known for the conversion of Pliny's flour prices to wheat prices is the type of flours to which Pliny's prices pertain. Existing knowledge of the flour of classical antiquity suffices for this purpose, but further clarification of that knowledge is useful not only for the problem at hand but also for its own sake.

The most important item in need of clarification is the weights per modius of flour and of meal in antiquity. This problem is easily solved on the basis of existing evidence. But owing to its very technical nature it is the one which tends to cause the most confusion.

Knowledge of milling costs in classical antiquity is not indispensable, if only a rough figure for the wheat price is sought. But familiarity with the general level of milling costs and of their effect on the price relation between flour and wheat is pertinent. As a rule, milling costs are equivalent to only a small proportion of the wheat price; with the prices of wheat as high as they were in Rome even very high milling costs (relatively) would not have affected the level of the flour prices materially. But this very fact of the low cost of milling a bushel of wheat relative to the cost of the wheat itself is not recognized by interpreters of Pliny's flour prices. Since the cost of milling in antiquity is of considerable interest for itself and apparently never has been discussed before, it is undertaken here in some detail, at a later stage.

Other Evidence on Wheat Prices

It is beyond the scope of this study to analyze all the evidence pertaining to wheat prices in Rome, but it seems desirable to show that

the most pertinent evidence is by no means conclusive. Rostovtzev,[1] in his basic study of grain in classical Rome, wrote:

> We have good evidence [on grain prices] only for the early empire and about the last century B.C. It is proven that as in the surplus countries as Sicily and Egypt, so in Rome, prices in normal conditions were about 3 sesterces [per modius]; somewhat higher in Rome, somewhat lower in the surplus countries.

Let us consider the countries mentioned by Rostovtzev, and also Greece, the second largest grain-deficit market of antiquity.

Price in Sicily.—Cicero's[2] evidence on the prices of grain in Sicily at the time of Verres' governorship (73–71 B.C.) was the principal source of information on which Rostovtzev based his statement about prices in surplus countries. The lowest price mentioned by Cicero was 2 sesterces per modius of wheat, but Cicero accused Verres of pushing the price that low;[3] that price, moreover, pertained to a year with an exceptionally large harvest.[4] The prices which by law the governor had to pay the Sicilian farmers were 3, 3½, and 4 sesterces per modius of wheat, according to Cicero. The price of 3 sesterces should have been paid for the *decumatum*, the second tithe, delivered for money in addition to the first tithe delivered as a tax. The price of 3½ sesterces was for the *imperatum*, certain quantities ordered in addition to the first two items. In both cases the price was at the farm. The price of 4 sesterces was that for small additional quantities ordered to be delivered to the storehouse designated by the governor (*frumentum in cellam*). The *decumatum* delivered at 3 sesterces per modius and the *imperatum* delivered at 3½ sesterces per modius were for the needs of Rome; the grain ordered at 4 sesterces per modius was for the needs of the Roman administration in Sicily. Cicero's oration[5] seems to indicate that the wheat purchased for Rome was charged to the Roman government at 3½ sesterces per modius.

It is important to emphasize that the prices of 3, 3½, and 4 sesterces per modius were prices for compulsory deliveries to the government. Scramuzza[6] correctly considered it a great disadvantage that:

> farmers of the 57 subject cities [of Sicily] were compelled to sell one-tenth of their crop to the Senate at 3 sesterces the modius, irrespective of the market price, [while] those of the privileged cities, if not hard pressed for cash, could wait until the following winter or spring, when the market price was twice or three times higher than in the summer months.

While nobody knows exactly the seasonal price spread, it was undoubtedly large.[7] The average yearly market price is likely to have been considerably higher than 3 sesterces, even if the market price which prevailed directly after harvest was not higher than the compulsory price of the second tithe.

Thus, while Cicero's evidence does not indicate the average market price of wheat in Sicily, it leaves no doubt that this price was not "somewhat less than three sesterces" as believed by Rostovtzev, but considerably above 3 sesterces.

Price in Egypt.—In spite of the relatively great number of individual grain prices in Egypt which have been transmitted to us, the evidence is inadequate for definite conclusions. Moreover, while one cannot be certain of the prices themselves, an additional uncertainty is involved in the conversion of the prices to Roman money and measure.

Heichelheim[8] compiled the prices of grain

[1] *Paulys Real-Encyclopädie . . . .*, Vol. VII, col. 149.

[2] *The Verrine Orations* (Loeb Classical Library, Cambridge, Mass., and London, 1935), Vol. II, Book 3, chap. 70, par. 163, pp. 199, 201; chap. 75, par. 174, p. 215; chap. 80, par. 188, p. 233; and others. See also Jérome Carcopino, "La Sicile agricole au dernier siècle de la République Romaine," *Vierteljahrschrift für Social- und Wirtschaftsgeschichte*, 1905, IV, 142–47; and V. M. Scramuzza, "Roman Sicily," in Frank, *op. cit.*, III, 261–68.

[3] *Op. cit.*, chap. 75, par. 174, p. 215.

[4] Frank, *op. cit.*, III, 265–66.

[5] *Op. cit.*, chap. 75, par. 174, p. 215.

[6] Frank, *op. cit.*, III, 263.

[7] In the spring of 78 B.C., before the harvest, the market price was as high as 20 sesterces per modius in Sicily (Cicero, *op. cit.*, chap. 92, par. 214, p. 263).

[8] Fritz Heichelheim, *Wirtschaftliche Schwankungen der Zeit von Alexander bis Augustus* (Beiträge zur Erforschung der Wirtschaftlichen Wechsellagen, Aufschwung, Krise, Stokung 3, Jena, 1930), pp. 118–22. Since we speak of Heichelheim's compilations of Egyptian grain prices, it may be useful to express our doubts of his idea (*op. cit.*, pp. 61–62) that in Egypt the penalty price on grain-loan contracts, which commonly was twice the market price for loans of wheat, was four times this price for loans of ὄλυρα (ὄλυρα was emmer, although it is commonly but inexactly translated "spelt"). There was no economic or other

in Egypt for a long period, but for the very time of Cicero the evidence is exceedingly meager. The author believes that his data indicate that the price of wheat in Egypt at Cicero's time varied from 1,000 to 2,000 copper drachmae or from 2½ to 5 silver drachmae per artaba. The Egyptian drachma was worth about ⅘ of a denarius at that time.[9] Artabas of various sizes were used in Egypt but the artaba equal to 3⅓ modii is believed to have been the most common one.[10] With a silver drachma equal to ⅘ of a denarius and an artaba equal to 3⅓ modii, the price of 2½–5 silver drachmae per artaba was equivalent to 2⁴⁄₁₀–4⁸⁄₁₀ sesterces per modius.

Pliny released his *Natural History* A.D. 77. For A.D. 78–79 an Egyptian source indicated wheat prices of 10 and 11 silver drachmae per artaba; the prices were for small quantities (2 to several artabas) sold by the producer in a small interior town during the time the new crop was growing. There is no certainty that this price was a normal one; indeed the normal price is likely to have been lower. Still, Johnson[11] uses the price of 10 silver drachmae in his computation of the cost of living in a whole period. If the artaba was equivalent to 3⅓ modii, 10 silver drachmae per artaba was equivalent to 3 sesterces per modius.[12]

The above computations closely agree with those by Segrè,[13] an expert in Egyptian economics. He computed the price of wheat in Egypt at the end of the reign of Cleopatra and in the first years of Augustus, converted to Roman measure and money, at 2⅔–3⅗ sesterces per modius. The average of these prices is 3 sesterces.

The above prices were domestic prices, indeed, prices on interior markets. It is not known whether exports of grain from Egypt were freely permitted. Johnson[14] believes that, while grain exports may have been un-

justification for such differentiation. It is much more likely that in the cases which Heichelheim had in mind, the commodity involved was hull-free emmer rather than emmer in hulls. It is absolutely improbable that emmer, which for a long time was very important in Egypt, was not bought, sold, and borrowed in hull-free form. Hull-free emmer also certainly was mentioned in documents. Hence it was referred to under one name or another. If the fact that in some cases the emmer was hull-free emmer rather than emmer in hulls has escaped the attention of the students, this may have occurred because the term ὄλυρα may have been applied to both emmer in hulls and hull-less emmer. All transmitted Egyptian prices of emmer have to be looked over carefully to ascertain whether they pertain to emmer in hulls or hull-less emmer.

[9] [F.] Hultsch, "Drachme," in *Paulys Real-Encyclopädie . . . .*, Vol. V, cols. 1613–33.

[10] A list of the various sizes of the artaba is given by Angelo Segrè, in *Metrologia e circolazione* (see A. C. Johnson, "Roman Egypt in the Reign of Diocletian," in Frank, *op. cit.*, II, 466), but Segrè himself believes the artaba of 3⅓ modii the most common one ("Inflation and Its Implication in Early Byzantine Times," *Byzantion*, 1940–41, XV, 277–79). Dr. Segrè kindly advised the writer to use this size specifically for the times of both Cicero and Pliny, which are involved in the present analysis. The conversion factor 3⅓ modii to the artaba is given in L. Mitteis and U. Wilcken, *Grundzüge und Chrestomathie der Papyruskunde* (Leipzig, 1912), Vol. I, p. lxviii; and also by Rostovtzev (*Paulys Real-Encyclopädie . . . .*, Vol. VII, col. 145), although with the reservation that this is in no case certain; Michael Schnebel (*Die Landwirtschaft im Hellenistischen Ägypten*, Münchener Beiträge zur Papyrusforschung und Antiken Rechtsgeschichte 7, Munich, 1925, I, 127); and others. Johnson (Frank, *op. cit.*, II, 466) first reproduces the long list of various artabas from Segrè's *Metrologia e circolazione* and then adds that "Hieronymus (*Comm. in Dan.* XI. 5) gives the equation of an artaba to 3⅓ Roman modii. Probably this was the standard used for the collection of tribute and in foreign trade." But Heichelheim, while not stating the conversion factor used by him, apparently applied one of about 4½ modii to the artaba. One specific consideration seems to point toward a higher conversion factor than 3⅓ modii. The standard quantity of seed wheat used in Egypt was 1 artaba per aroure (Schnebel, *op. cit.*, p. 126). The present seeding rate on soil which was not in crops through the summer in Egypt is 6 kelahs per feddan, according to a very authoritative source (W. Cartwright, "Cereal Crops," in *Text-book of Egyptian Agriculture*, ed. by G. P. Foaden and F. Fletcher, Egypt Ministry of Education, Department of Agriculture and Technical Education, 1910, II, 432). This quantity is equivalent to about 2.35 hectoliters per hectare, while 1 artaba, equivalent to 3⅓ modii per aroure, equivalent to 1,975 square meters, equals only about 1.4 hectoliters. It is true that less seed in general seems to have been used in classical antiquity than now. One artaba, equivalent to 3⅓ modii per aroure, works out to around 4½ modii per yugerum and hence agrees with the recommendation of Columella (*On Agriculture*, Loeb Classical Library, Cambridge, Mass., and London, 1941, Vol. I, Book 2, chap. 9, par. 1, p. 145) who advised the use of 4 modii per yugerum of rich soil and 5 modii on poor soil. The Egyptian soil should certainly be classed as rich.

[11] Frank, *op. cit.*, II, 311.

[12] The silver drachma in this period is commonly assumed to have been equivalent to ¼ of a denarius.

[13] *Circolazione monetaria e prezzi nel mondo antico . . . .* (Rome, 1922), quoted by Oliva, *op. cit.*, p. 166.

[14] Frank, *op. cit.*, II, 440.

controlled, the currency obtained may have had to be delivered at fixed rates to the government.

Price in Rome. — Rostovtzev's statement that a price of somewhat more than 3 sesterces prevailed in Rome under normal conditions is not based on factual evidence. It is largely an inference from Cicero's evidence for Sicily as interpreted by Rostovtzev. Rostovtzev's price for Rome in any case implies the improbability that the difference between somewhat less than 3 sesterces—the price he accepted for Egypt and Sicily—and somewhat more than 3 sesterces—the price he accepted for Rome—sufficed in classical antiquity to cover all transportation and other marketing costs from the producers in Sicily and Egypt to the consumers or at least to the wholesalers in Rome. That statement indeed contradicts what Rostovtzev himself has to say on the difficulties and high costs of transportation and marketing in antiquity.[15]

Computations of the marketing costs involved in the transfer of goods from surplus to deficit countries seem to have been made only by Heichelheim. His conclusions are that transportation and some other costs were very high. For 211–110 B.C. he computed the cost of transporting wheat from Egypt to Rome at 4⅔ sesterces per modius, considering in this computation only three items, freight rate on the sea, unloading, and risk.[16] The freight rate alone on the relatively short distance from Alexandria to Delos was 2–2⅓ times higher than the price of wheat in middle Egypt, in the period from 270 B.C. to 250 B.C., according to that author.[17]

Heichelheim's computations were not acceptable even before the very valuable fragment of the *Edict* of Diocletian was recently found which gives freight rates on the sea. Both of Heichelheim's methods of computing freight rates for sea transportation are incorrect. One is to apply the freight rates for short distances (40–150 kilometers) to long distances by increasing the rates[18] in proportion to the distances. For example, starting from an incorrectly computed (exaggerated) freight rate of 2½ drachmae per medimnos for a distance of 150 kilometers, and increasing this rate in the proportion of 1,000:150, he feels that he has computed the freight rate on wheat from Egypt to continental Greece, and is somewhat surprised that the computed freight rate alone turns out to be 67 per cent above the highest probable price of wheat in Greece (Delos). The freight rates of the famous *Edict* of Diocletian show that, as now, the per mile rate in antiquity declined rapidly with increase in the distance.

Not less objectionable is it to apply a sea-freight rate for a volume unit of vegetable oil to the same volume unit of grain.[19] In antiquity oil was transported in earthen jars which may have weighed more than the oil itself; the jars also occupied considerable space and needed very careful stowage. The freight rates per given volume of oil were certainly several times higher than the rates for the same volume of grain. Such a rate on oil for a distance estimated at 700 kilometers (Asia Minor–Egypt)[20] Heichelheim raises in the proportion 3,600: 700 (applying the erroneous principle that freight rates are proportionate to the distance) and feels he has obtained the freight rate on wheat from Egypt to Italy, the distance between those two places being in his opinion 3,600 kilometers. It matters little in such a computation that the distance between Alexandria, Egypt, and Ostia near Rome—the places Heichelheim has in mind—is actually only about 2,000 kilometers.

Heichelheim estimates the cost of unloading in Delos and Alexandria,[21] or even only Delos,[22]

[15] *Paulys Real-Encyclopädie . . . . .*, Vol. VII, cols. 139–43.

[16] *Op. cit.*, p. 73.

[17] *Ibid.*, p. 95. In "Sitos" (in *Paulys Real-Encyclopädie . . . . .*, Supp. Vol. VI, col. 859), Heichelheim stated that the wheat prices in Greece were at least twice as high as in surplus countries, and most frequently three to six or more times as high. The period discussed in "Sitos" preceded the one analyzed in this study, but no very large changes in transportation costs and price spreads are likely to have occurred in the intervening time.

[18] Heichelheim, *Wirtschaftliche Schwankungen . . . .*, pp. 92–93.

[19] *Ibid.*, pp. 73, 93.

[20] C. C. Edgar, "Zenon Papyri," Vol. I, in Service des Antiquités de l'Egypte, *Catalogue général des antiquités égyptiennes du Musée du Caire* (Cairo, 1925), No. 59015, lines 45–46. Thanks are expressed to Dr. J. A. Larsen, of the University of Chicago, for transmitting the text of the two lines, and, even more, for his detailed comments.

[21] *Ibid.*, p. 95.

[22] *Ibid.*, p. 96.

at two-thirds of the cost of the wheat in middle Egypt, although nowadays the cost of unloading is very small relative to the cost of wheat and may have been even less at a time when ships were very small and unskilled labor was obtainable for a few pounds of bread per day. On the other hand Heichelheim neglects to consider the costs of storing and distributing, which certainly were high then. Navigation was very slow and stopped entirely for many months in the winter. Indeed, only one trip was apparently made per year (in the summer) from Egypt to Italy. Communication between export and import regions was also very inadequate. Per acre yields of grain, however, varied greatly from year to year. Under such conditions the deficit areas undoubtedly swung from deficiency to overabundance, and this involved great trade risks and consequently high trade margins.[23] All this is most elementary, and yet Heichelheim's computations are often trusted.[24]

Although the freight rates for the transportation of grain by sea were much lower in antiquity than Heichelheim believes them to have been, two recently discovered fragments of the *Edict* of Diocletian containing freight rates (unfortunately not fully preserved)[25] leave no doubt that the rates were high in antiquity as compared with the present time. No rate from Sicily to Rome or one of its harbors was given. Some typical maximum rates from the *Edict* are listed in the tabulation below. They are in denarii per castrensis modius; but, since the maximum price of wheat was established by the *Edict* at 100 denarii per castrensis modius, the figures also express the freight rates as percentages of the wheat price:

Source	Destination	Denarii per castrensis modius
Alexandria	Rome	16
Alexandria	Africa or Sicily	10
Alexandria	Thessalonike	12
Alexandria	Aquileia	24
Alexandria	Dalmatia	18
Nicodemia (northwestern Asia Minor)	Rome	18
Roman Africa	Achaia	12
Roman Africa	Sicily	6

The stated rates to Rome may actually have been to Ostia, the adjacent Portus, or any other sea harbor of Rome.

All the rates of the *Edict* were at least three times as high as present ones. The distance from Alexandria, Egypt, to Ostia near Rome is only slightly more than a third of the distance from the Russian harbor of Novorossisk on the Black Sea to London. Yet the freight rates from Novorossisk to London were only around 6 and 5 per cent of the wheat price in London in 1909–13 and 1935–39 respectively. The distance from Australia to London is almost ten times longer than that from Alexandria to Ostia, but the average freight rate in 1925–29 was less in terms of wheat (15 per cent of the price of Australian wheat in London)[26] than was the freight rate from Alexandria to Ostia according to the *Edict* of Diocletian.

The preamble to the *Edict* insisted that the maximum prices were valid "anywhere," "in the whole of our empire," and that they should not be exceeded even "in those places where supplies are seen to abound," and the like. Still, in fixing the actual price level, prices of wheat may have been chosen that were too low for Rome, which probably had the highest wheat prices in the whole empire, or for similar places with very high wheat prices. If such was the case, it is obvious that the freight rate from Alexandria to Rome or Ostia must have been less than 16 per cent of the price of wheat in Rome. Even so, the freight rates at the time of Diocletian (the end of the third century A.D.) may well have been about three times higher

[23] Heichelheim (*loc. cit.*) provides for risk, but he has in mind the risks of navigation, mainly those from piracy, rather than the risks involved in disproportions between supplies and requirements. Hence, his provision for risk is in direct proportion to the distance by sea from the place of shipment to the place of destination.

[24] Frank (*op. cit.*, I, 191) quotes Heichelheim as saying that the freight rate from Athens to Delos, about 100 miles, was about 1½ sesterces per modius. On page 402, however, Frank computes the difference in the price of wheat in Sicily and Rome only at ¼–½ sesterce per modius.

[25] Giulio Jacopi, "Gli scavi della Missione Archeologica Italiana ad Afrodisiade nel 1937, XV–XVI," *Monumenti Antichi*, 1939, XXXVIII. Thanks are due to Miss Elsa Graser for a copy of the portion pertaining to freight rates.

[26] Successive issues of WHEAT STUDIES, especially V. D. Wickizer, "Shipping and Freight Rates in the Overseas Grain Trade," *ibid.*, October 1938, XV, 119.

in terms of the price of wheat than are present freight rates.[27]

At the time of Pliny, in which we are specifically interested at the moment, freight rates may have been even higher relatively than at the time of Diocletian, owing to the improvement in navigational practices over the intervening time. This is especially probable of the rates to Ostia and even more of the rates to Rome directly, owing to improvements of the harbor facilities of Ostia by the Emperor Trajan in the years A.D. 101–104.

Before the construction of the harbor of Ostia by Claudius in A.D. 43–46, Puteoli, about 130 miles from Rome, was the principal harbor for shipment of goods to and from Rome. Oliva[28] says that Puteoli played a role of the first order in the procurement of the *annona* (grain distributed free to the poor). Specifically, Puteoli was the place where the Alexandrian fleet from Egypt arrived.[29] It is unfortunately not known how the grain, which was the principal cargo of the Egyptian fleet, ultimately reached Rome. The fact that Puteoli had government and private warehouses[30] does not prove that even part of the grain was hauled the whole distance to Rome. This would have increased the price of wheat by 50 per cent or more.[31] But all other means of reaching Rome are also likely to have been rather expensive.[32] Puteoli continued to be used also after the winter harbor in Ostia was constructed by Claudius, especially for larger ships.[33] Indeed, Seneca's *Epistulae Morales*, in which the arrival of the Egyptian fleet in Puteoli was described in such lively terms, were not written before A.D. 63–64, i.e., about 20 years after the construction of the winter harbor in Ostia. Puteoli did not lose its importance until after Trajan had made an adequate harbor in Ostia in A.D. 101–104, and also built a harbor in Civitavecchia.[34]

Especially before the annexation of Egypt, the Roman price of wheat necessarily included enormous storage costs. Roman Africa, a very important source of grain supplies for the city of Rome, is an area with large year-to-year variations in precipitation and yield. The situation was aggravated by the fact that the ups and downs in African yields largely coincided with those in Sicily, another important source of Rome's grain supplies. Immense amounts of grain had to be, and apparently had been, kept in storage to protect Rome against the frequently recurring crop failures in the principal supplying countries. Septimus Severus was praised by Aelius Spartianus[35] for accumulating grain stocks to the amount of seven years' tribute.

In addition to high transportation and other marketing costs, the following factor must have tended to raise materially the average free-market price of wheat in Rome. In the form of rents for state land and of taxes the Roman government took a substantial portion of the harvest of the dependent countries,

[27] There is a small degree of uncertainty in our comparison of the present freight rates with those of the *Edict*. The rates for the present time are specifically for grain. Those of the *Edict* are only very likely to have been specifically for grain.

[28] *Op. cit.*, p. 233.

[29] Seneca, *Ad Lucilium Epistulae Morales*, with . . . . translation by R. M. Gummere (Loeb Classical Library, London and New York, 1917–25), Vol. II, Letter LXXVII, secs. 1–2, p. 168. See also Charles Dubois, *Pouzzoles antique (Histoire et topographie)* (Bibliothèque des Écoles Françaises d'Athènes et de Rome, fasc. 98, Paris, 1907), pp. 70–71.

[30] Oliva, *op. cit.*, p. 233.

[31] According to the *Edict* of Diocletian, the maximum charge for a wagon with a maximum loading capacity of 1,200 Roman pounds was 20 denarii per Roman mile. Since the maximum price of wheat established by the *Edict* was 100 denarii per castrensis modius, equivalent to about 42 Roman pounds of wheat, transportation of this grain over 133⅓ miles would have consumed its price in full. Thus, the price of wheat in Puteoli, if the wheat were taken to Rome by wagon at the above rate, would have been nil. The prices of the *Edict* were probably intended only for the eastern part of the Empire. Furthermore, the freight rates of the *Edict* may have been intended for more expensive or more bulky goods than grain, as well as for goods shipped in small quantities. They nevertheless give an idea of the cost of land transportation at that time.

[32] This is specifically true of transshipment via Ostia. Part of the grain was probably also reshipped from Puteoli to Tarracina, and taken to Rome by the small boats which navigated the canal running alongside the Via Appia. The fact that the boats were small is indicated by Strabo's statement that they were hauled by one donkey. See Strabo, *The Geography*, Book V, sec. 3, subsec. 6.

[33] Larger than 150–200 tons, according to Oliva, *op. cit.*, p. 233.

[34] Frank, *op. cit.*, V, 132, 241.

[35] "Severus," in *Scriptores Historiae Augustae* (Loeb Classical Library, London and New York, 1922), Vol. I, chap. 8, sec. 5, pp. 388–89, and chap. 23, sec. 2, pp. 426–27.

whether or not the remainder sufficed for the needs of the farmers themselves. Out of this remainder, moreover, the needs of the nonfarm population of the producing areas had to be covered before merchants could obtain grain to supply the free market of Rome. Owing especially to the great year-to-year variations of yield in important surplus areas, exorbitant risks must have been involved in the free-grain trade under such conditions, and great risks always imply large margins between producers' and consumers' prices.

The collected grain was used by the Roman government for feeding the army but primarily for distribution to the poorer population as *annona*. Part of the wealthier population obtained their food from their own farms. The rest of the population had to be provided for out of the residual grain through free-trade channels. It is elementary in the light of modern knowledge on demand elasticity that free-market prices tend to be very high whenever well-to-do people compete for a limited supply of goods of prime necessity. The enlargement of the year-to-year variations in marketable supplies caused by the compulsory deliveries, and the distribution of these through other channels, were aggravating factors.

Such interference in the free market as sales at rather frequent intervals by the Roman government at low prices may have been a further contributing factor in increasing the risk of grain merchants. Such actions could not have reduced the average free-market price unless the government had such a huge "ever-normal granary" that it could cover all requirements in poor crop years, although in these very years the quantity of grain obtained by the government in the way of taxes and rents must have declined in proportion to the crop. All other measures to reduce the free-market price of wheat in Rome also seem to have been inadequate for attaining more than moderate results towards lowering grain prices on the free market.

Offhand we would expect that, so far as concerns wheat purchased by private traders in Sicily, brought by them to Rome, and sold to the consumer with all the risks involved in such a trade at that time, the margin between the average price paid to the producers in Sicily and the price paid to the traders by the actual consumer in Rome may well have considerably exceeded half the farm price in Sicily even after the construction of the winter harbor in Ostia. At the time of Cicero, i.e., before this event, that margin and the price obtained by the farmer may have been approximately equal. The margin naturally was larger for wheat from Egypt.

It is impossible to analyze here the direct evidence pertaining to the wheat price in Rome. Although this evidence is by no means revealing, to analyze it would require a great amount of space. It suffices to remark that most of the grain prices available for Rome were similar to those given by Cicero for Sicily in that they were government prices. The few prices which might have been free-market prices pertained to times of either abundance or scarcity. For example, in 211–210 B.C., wheat cost 15 drachmae per Sicilian medimnos, or 10 sesterces per modius, in Italy.[36] The price certainly was abnormally high, but on the other hand, the normal grain requirements of Rome were much smaller in 211–210 B.C. than later; she did not then need to import wheat regularly from very distant markets, so that there was less justification for high prices than a century or two later.

Price in Greece.—Unfortunately we do not have grain prices in Greece, the only other grain-importing market of antiquity, for the period here analyzed. The compilation of Heichelheim[37] shows that in the fourth century B.C. the typical price of wheat in Athens was about 5–6 drachmae per medimnos. The Athenian drachma is commonly accepted as equivalent to the Roman denarius. The Attic medimnos is believed to have been equivalent to about 4⅞ modii.[38] Hence the wheat price in Athens in the fourth century B.C. was equivalent to 4⅜–5⅛ sesterces per modius. But occasionally prices as high as 32 drachmae per

[36] Polybius, *The Histories* (Loeb Classical Library, London and New York, 1925), Vol. IV, Book 9, sec. 11*a*, pp. 29, 31.

[37] *Paulys Real-Encyclopädie* . . . . , Supp. Vol. VI, cols. 887–90.

[38] Viedebantt, "Μέδιμνος," in *ibid.*, Vol. XV, Pt. 1, cols. 86–91, esp. col. 87.

medimnos (about 26 sesterces per modius) were reported for Hellas.[39]

The typical wheat price in Delos in the third and second centuries B.C. varied from 6 to 10 drachmae per medimnos with the average probably above 8 drachmae. The size of the Delphian medimnos is uncertain; Viedebantt believes 46.11 liters a probable figure. If this is correct, the Delphian medimnos was equivalent to about 5⅗ modii. Delos had the same drachma as Athens. Hence the typical wheat price in Delos varied between 4½ and 7⅕ sesterces per modius. The weighted average may have been somewhat above 6⅕ sesterces, the simple average of the two figures.[40]

Thus the average wheat price in Greece in the third and second centuries B.C. was around 6 sesterces per modius, but 8 sesterces may have repeatedly prevailed for several years. Thus the Greek price was higher than that commonly assumed for Rome in the first century B.C. and the first century A.D., although Athens and especially Delos are much nearer to Egypt, the granary of classical antiquity, than is Rome.

The foregoing discussion may suffice for the conclusion that a free-market price of wheat as low as 3–4 sesterces per modius is very unlikely to have existed in Rome in the last century B.C. and the first century A.D. At the time of Cicero (i.e., shortly before the beginning of our era) it may well have been 7 or more sesterces per modius of *triticum*, the type of wheat produced in Roman Africa and Egypt (see next section). The same price may also have prevailed in Rome when Pliny wrote his *Natural History* (about A.D. 77) for a sufficiently long time to permit him to consider the price normal.

[39] Aristotle, *The Oeconomica* (Loeb Classical Library, London and Cambridge, Mass., 1935), Book 2, chap. 2, sec. 33, p. 391. The measure was not stated by Aristotle, but the only possible alternative is the Egyptian artaba, in which case the price would have been even higher in Roman measure and money than the one stated in the text.

[40] On the price of wheat in Greece, see also the discussion by J. A. O. Larsen, "Roman Greece," in Frank, *op. cit.*, IV, 383–86.

The Wheat Flours of the Romans[1]

The wheats of the Romans.—The Romans distinguished two principal types of wheat (of *triticum* in the wide sense): *triticum* in the narrow sense, and *siligo*. *Triticum* in the narrow sense, in this study referred to simply as *triticum*, mostly fall-sown, belonged to the two closely related botanical subspecies, durum and poulard. It was the predominant type of wheat throughout the Mediterranean region in classical antiquity. Most *triticum* grown in the area around Rome probably was poulard; while the corresponding Greek wheat (σεμιδαλίτης) was durum. The wheats of Egypt, North Africa, Syria, and other Mediterranean countries, referred to as *triticum* by the Romans, also probably were durum.

Siligo was grown as either a winter or a spring crop. It probably belonged to the two closely related botanical subspecies, common and/or club wheat. When grown as a spring grain, *siligo* was called three-month wheat (*trimestre*).[2] Most of the *siligo* wheat was grown in central Italy and the Po Valley, where it was rather important. Some *siligo* was grown in Sicily, Greece, and adjacent portions of Asia Minor. The other Mediterranean countries apparently grew only *triticum*.

Common and club wheats are much softer and yield a whiter flour than durum or especially poulard. The latter wheats indeed are better adapted to the production of pastes than of bread. *Siligo* was therefore greatly preferred to *triticum* in antiquity. The fact that this wheat cost less to grind than *triticum* may also have played a certain, though minor, role in the preference for *siligo*. The grinding of hard grain requires additional power; and human and animal power, the two types used for grinding in antiquity, both are expensive.[3] But no classical source mentioned the difference between the types of wheat in the amount of power needed for their grinding. *Trimestre* was preferred to fall-

[1] To avoid misunderstanding, let us state here that the term "flour" is used in two different senses. Flour in the wide sense is every ground product used for food; in this sense it includes whole-grain meal. Flour in the narrow sense means a ground product with all or part of the bran removed; in this sense it is the reverse of bran.

[2] Some sources mention also a two-month wheat, but this may have been the same or practically the same wheat as *trimestre*.

[3] Water mills did not become important until the end of the classical era.

sown *siligo* because it yielded a particularly white flour.

Milling techniques.—From wheat, a modern mill produces flour weighing 70–75 per cent of the weight of the wheat; practically all of the flour is white. The remainder is feed. Hardly any really white flour was produced in antiquity. Praises of the whiteness of certain flours and breads in classical sources ("Bread as white as snow," in Juvenal)[4] perhaps need not be taken literally; such flour, in any case, was rare then. The flour of classical time was much inferior not only in color but also in other respects, some of which may have been more important than the color. For example, the flour of that time contained all or most of the impurities always present in wheat. Some of these impurities are poisonous; others are harmful for the teeth. It was noticed long ago that surprisingly well-preserved Egyptian mummies have their teeth rubbed off, apparently by the sand contained in bread.

The reasons for the poor quality of the flour in antiquity were two: the state of knowledge and the ability to afford. People eat, dress, and house according to their means. Such adaptations can be observed also with reference to milling. The Romans, of course, could not produce as refined a flour as that of modern times. Although in Pliny's day milling was several thousand years old, it was very primitive, and except for the mill proper —the grinding machine—Italy was not then the place of the most advanced milling techniques. But not even as much of the most refined product was produced as was then technically possible; the cost of processing would have been too high.

A modern mill contains a multitude of rather complicated machines, which operate as a unit, in which the function of the men is limited to supervision. A well-equipped Roman animal mill, however, contained, in addition to the stone mill proper, only a very primitive hand sieve, vessels for measuring the grain and grain products, a ruler to be used with these vessels, a basket, and similar simple appliances. To see the difference, it suffices to compare the Roman mill shown on the relief reproduced in Figure 5 (a poorly equipped mill would hardly be shown in a relief) with a partial view of a modern mill shown in Figure 7 (p. 153). Everything except the grinding proper (pouring the wheat into the mill, collecting the meal, as well as cleaning and sifting, if these operations were performed at all) was done by hand in a Roman animal mill.

There is little doubt that the rotating mill is a Roman invention.[5] In Pliny's day the rotating animal mill[6] (see Figures 5 and 6) was only about 200 years old, and the rotating hand mill (quern) (see Figures 3 and 4)[7] was perhaps only a hundred years older.[8] The animal mill especially was very primitive then, requiring more power and doing a much poorer job than a stone mill did several hundred years later. Even the most "modern" stone mill was ultimately replaced by roller steel mills.

In a modern mill wheat is thoroughly cleaned by a variety of processes before it is ground. Not only is practically all foreign matter removed in this process, but even part of the outer skin, together with the dirt which adheres closely to the kernels. In many countries the grain is washed and cleansed in addition to dry cleaning. The dry-cleaned grain is then conditioned. Conditioning or tempering is meant to bring the grain into such condition that, in grinding, the skin of the kernels strongly resists pulverization, while the interior of the kernels pulverizes readily. The pulverized interior can then be easily separated by sifting from the coarsely crushed skin. The most simple and also the most common method of conditioning is to moisten the wheat with water some time before grinding. In the grinding process proper, the grain is ground (broken) several times with the stock being divided after each grinding into several sizes by sifting; all of the better stocks are then purified and repurified in special machines

[4] *D. Iunii Iuvenalis Saturae XIII* . . . . , ed. . . . . by C. H. Pearson (Oxford, 1892), Satire V, lines 70–71.

[5] A lengthy discussion would be needed to prove this.

[6] An animal mill was necessarily a rotating mill.

[7] The best collection of pictures of rotating mills of the Roman and post-Roman periods is in E. C. Curwen, "Querns," *Antiquity*, June 1937, XI, 133–51.

[8] Before the rotating principle had been applied to stone mills, the grain was rubbed between bruising stones (the lower of these is commonly called the saddle stone) by moving one of them to and fro by hand (Figure 2) or by pounding the grain in a mortar (Figure 1), also by hand.

before being finally ground into very fine flour. Two hundred intermediate products or more are involved in this process, although the final product may consist only of one grade of flour and one grade of millfeed.

Surprisingly little is known about the cleaning of grain in the mill in antiquity. The Egyptian reliefs indicate that sieves may have been used for cleaning the grain before the grinding in the mill proper long before the classical era. But interpretation of the Egyptian reliefs involves great uncertainty, and the life they described was mostly that of the Pharaoh's court and high dignitaries. The meager additional evidence on cleaning the grain in the mill, or in any case of the cleaning other than on the threshing floor, pertains to a time after Pliny and to areas other than Italy. The Mishnah[9] prescribed that pebbles be hand-picked from grain used in sacrifices. Galen,[10] a famous physician of the second century A.D., described in detail the washing of grain in baskets before grinding; but he stated positively that the washing was practiced only in many cities of Asia, where as well as in Egypt milling techniques were more refined than in Greece and Rome.

The cleaning of the grain is unlikely to have been a regular part of the treatment of the grain in the Roman mill at Pliny's time; the winnowing on the threshing floor was probably believed sufficient except on rare occasions. Neither Pliny nor any other Roman or Greek writer of his day or before him mentioned the cleaning of grain in the mill. Nor is it indicated by the reliefs transmitted to us, as for example, by the reliefs on the monument to the miller-baker Eurysaces in Rome which present the whole process in great detail from taking in the grain to selling the bread. So far as grain was cleaned in the Roman mill at Pliny's time, this is unlikely to have consisted of anything else but sifting through a very coarse sieve.

Tempering of wheat may have been common practice in Babylonia, Palestine, and Egypt at Pliny's time. According to the Babylonian Talmud,[11] a miller even was liable to pay compensation if he took wheat to grind but did not moisten it, with the result that the flour contained much bran. Galen,[12] in describing the washing of wheat, displayed full understanding of the effect of conditioning on the grinding process. But the discussion of the different flours by Pliny seems to indicate that moistening wheat before grinding, though known, was not yet common in Rome.

The wheat, mostly with all the dirt it contained when it reached the mill and unmoistened, was ground very coarsely and probably only once in Rome. It is difficult for a modern scholar, who is naturally inclined to take the present fine flour for granted, to realize to what extent grain was coarsely ground in antiquity, and this easily leads to other wrong conclusions. Everything we know of the sieves used for the sifting of ground products indicates that the sieves were very coarse. The *farinarium*, a sieve used for separating bran from flour, was undoubtedly a very coarse sieve because it was used also in the production of *alica* (a kind of farina or semolina), and this consisted of very large bits even for *farina*. Cato[13] spoke of the use of the *farinarium* for forcing through cottage cheese, an operation for which a very coarse sieve is needed. We do not have equally reliable evidence on the size of the *pollinarium*, the linen sieve used for separation of the first flour grades (*pollen, flos*) from the second flour grades. Although much finer than the *farinarium*, the *pollinarium* probably was not a fine sieve according to our standards. *Angustissimum*, a sieve similar to *pollinarium*,[14] was used for sifting off chalk from *alica* and

[9] See j. Schabb. 10[b], quoted from Gustaf Dalman, *Arbeit und Sitte in Palästina* (Schriften des Deutschen Palästina-Instituts 6, Gütersloh, 1933), III, 147 and others. The Mishnah was a collection of Jewish laws pertaining mostly to the second century A.D.

[10] *Claudii Galeni Opera Omnia*, ed. by D. C. G. Kühn (Medicorum Graecorum Opera quae Exstant, Leipzig, 1829), Vol. XVIII, Pt. 1, chap. 41, pp. 470–71.

[11] *Der Babylonische Talmud* . . . . , trans. by Lazarus Goldschmidt (Berlin, 1930–36), VIII, 260, Baba Bathra, sec. 6, par. i (fol. 93*b*).

[12] *Loc. cit.*

[13] *On Agriculture* (Loeb Classical Library, Cambridge, Mass., and London, 1934), chap. 86, sec. 3, p. 82.

[14] Moritz Voigt ("Die Verschiedenen Sorten von Triticum, Weizen-Mehl und Brod bei den Römern," *Rheinisches Museum für Philologie*, 1876, n.f., XXXI, 118) even believed that those names were different names for the same sieve, but there is not sufficient justification for this assumption.

therefore could not be a really fine sieve,[15] according to modern standards.

The great probability that the wheat was ground only once is another strong indication that the grinding was very coarse in classical Rome. Much less power is needed to produce fine flour by repeated than by a single grinding. The flour produced by repeated grinding is also of considerably better quality (fine flour produced in one grinding is uneven and overheated).

A statement in the *Problems,* ascribed to Aristotle but written much later,[16] is the only evidence that grain may have passed more than once through the stone mill in antiquity. Repeated grinding is too important not to have been mentioned by many, if it were practiced. It would certainly have been mentioned in the Mishnah in which repeated sifting was spoken of more than once. Dalman[17] probably is right when he insists that the grain was ground only once even in the preparation of *sōlet*—probably the most refined product of grinding in antiquity. There seems to be even less reason to assume that repeated grinding was practiced in Rome in Pliny's time.

When the product of grinding was sifted at all in Rome, all of it was probably sifted once in one operation (one-grade flour) or twice in three operations (three-grade grinding) as against the almost endless number of times that various products of grinding are sifted and resifted in modern mills before the final products are reached. When, as in the case of *sōlet,* repeated sifting was involved,[18] this fact was strongly emphasized. Moreover, the methods of producing *sōlet* were much more elaborate than those commonly followed in flour production in Rome. *Sōlet* was used for sacrifices, and Babylonia and the Near East generally were farther advanced in sifting techniques than either Rome or Greece.

Meal.—Even if one disregards such writers as the famous gourmet Athenaeus,[19] who have been mainly interested in the upper thousand, classical sources seem to indicate a much smaller role of wheat meal than it probably had. This is also true of Pliny, our best source of information on the flours in classical Rome. Meal was the old type of flour; it was mainly consumed by the masses and entered the trade channels only to a relatively small extent, having been largely ground by the producers themselves for their own use. Pliny, however, was mainly interested in what was new, not known to everybody; he also paid special attention to goods entering trade channels. Whole-wheat meal may well have been the dominant type of ground product from wheat in Italy outside of Rome and may have been rather important even in that great city. The fact that Pliny, in enumerating the prices of ground products, mentioned first the price of wheat meal is one of many proofs for our contention.[20]

Pliny's *farina,* the price of which was given by him first, was certainly a whole-grain meal. Some students even believe that the term *farina* always meant whole-grain meal.[21] In any case it always meant whole-grain meal if the term was used to indicate not flour in general, a ground product used for food,[22] but a definite grade of flour. There is furthermore no doubt that in Pliny's statement *farina* was

[15] Evidence on sieves mainly in Pliny, *op. cit.,* chap. 11, sec. 108, p. 172, and sec. 115, p. 174.

[16] *Problems* (Loeb Classical Library, Cambridge, Mass., and London, 1936), Vol. I, Book 21, secs. 3 and 7, pp. 443, 445, 447. Some students date the completion of the *Problems* in the fifth or the sixth century, A.D.

[17] *Op. cit.,* p. 293.

[18] *Sōlet* was sifted 11–13 times, according to some Talmud authorities; it was sifted an adequate number of times, according to another Talmud authority, *The Mishnah,* trans. . . . . with introduction and brief explanatory notes by Herbert Danby . . . . (London, 1933), Menahoth, sec. 6, par. 7.

[19] *The Deipnosophists* (7 vols., Loeb Classical Library, London and New York, 1927–33).

[20] The fact that in *Moretum* (see *The Copa and Moretum* . . . . , ed. . . . . by E. H. Blakeney, Winchester, 1933, line 40), a very small farmer with only one female servant used a sieve for sifting his barley meal would be a proof that sifting was in common use in at least a part of Italy for some time before Pliny, if *Moretum* really were by Vergil. However, *Moretum* is commonly listed among Vergil's dubious and spurious works. It is noteworthy, moreover, that the farmer in *Moretum* sifted off the bran from barley meal, which contains much more fiber than wheat meal. He might not have done this, if his grain were wheat. He probably would have been happy to make his bread from wheat meal rather than from barley meal with the bran sifted off from the latter.

[21] See, for example, Voigt, *op. cit.,* p. 114.

[22] As for example in Pliny, *op. cit.,* chap. 9, sec. 87, p. 166, or chap. 11, sec. 104, p. 170.

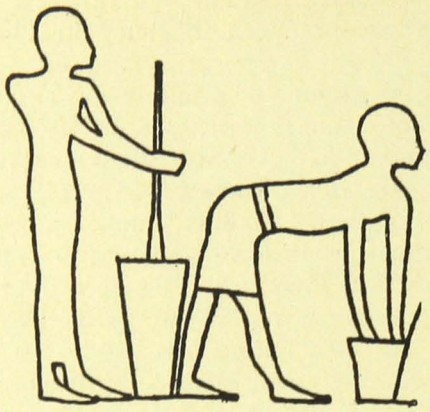


FIG. 1.—Wooden mortar of ancient Egypt. Reproduced from Richard Bennett and John Elton, *History of Corn Milling* (London, 1898), I, 89.

FIG. 2.—A saddle stone of ancient Egypt. Reproduced from Richard Bennett and John Elton, *History of Corn Milling* (London, 1898), I, 42.

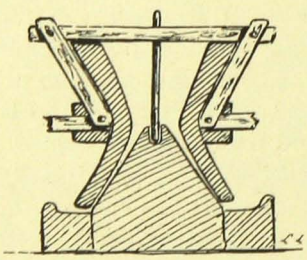


FIG. 3.—Cross section of a Roman hand mill. Reproduced from L. Lindet, "Les Origines du moulin à grains," *Revue Archéologique* (Paris), January–February 1900, 3d ser., Vol. XXXVI, p. 23.

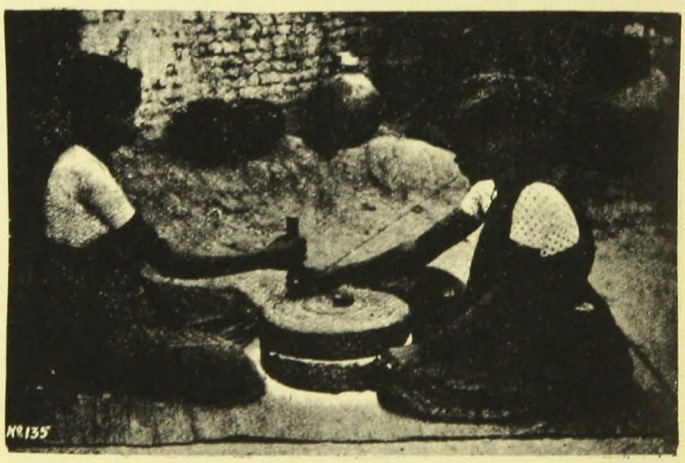


FIG. 4.—A quern in modern India. Reproduced from Richard Bennett and John Elton, *History of Corn Milling* (London, 1898), I, 165.

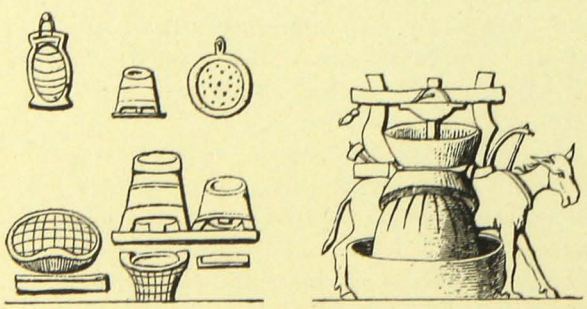


FIG. 5.—Mill utensils and Roman animal mill. Reproduced from Theodor Schreiber, *Kulturhistorischer Bilderatlas. I. Altertum* (Leipzig, 2d ed., 1888), Plate LXVII, fig. 10.

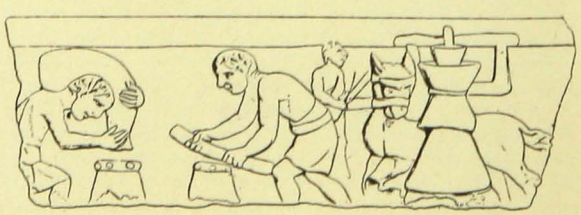


FIG. 6.—Dumping and measuring flour, and a Roman animal mill. Reproduced from Hugo Blümner, *Technologie und Terminologie der Gewerbe und Künste bei Griechen und Römern* (Leipzig, 2d ed., 1912), I, 43.

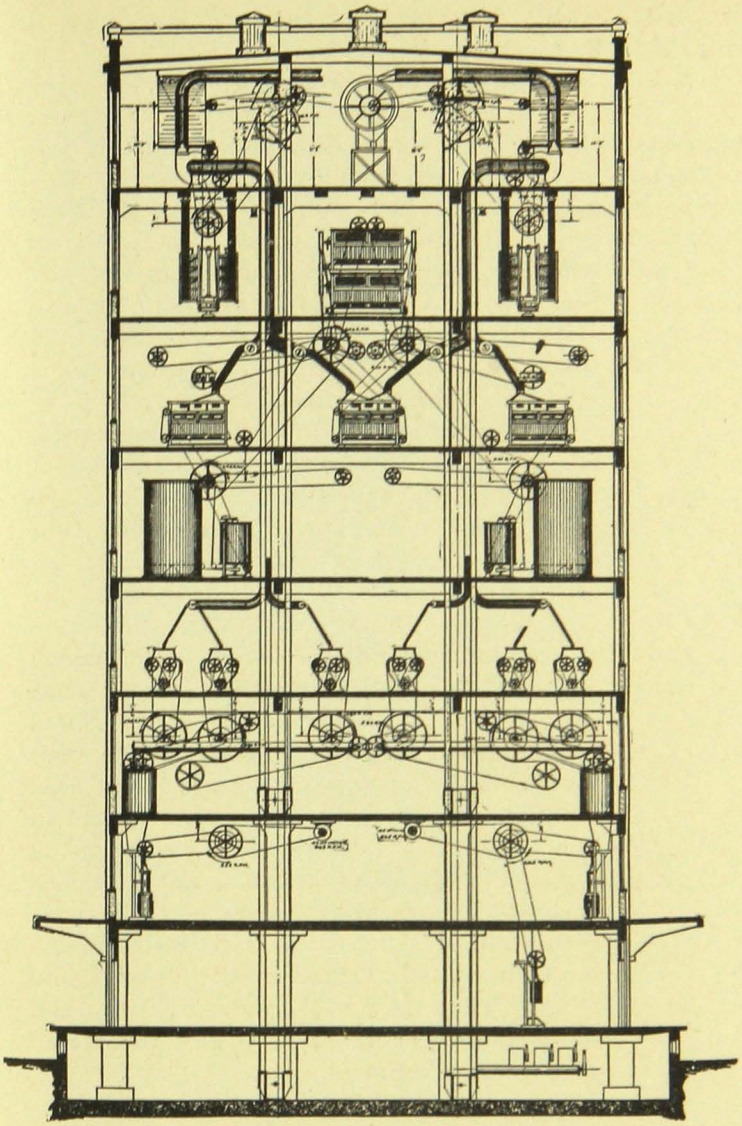
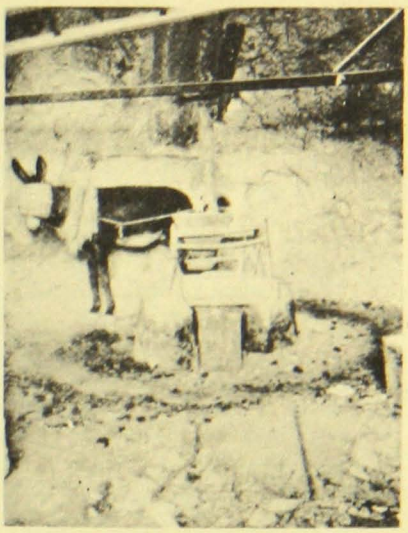


FIG. 7.—Cross section of a modern flour mill. Reproduced, by permission, from B. W. Dedrick, *Practical Milling* (Chicago, 1924), p. 429.



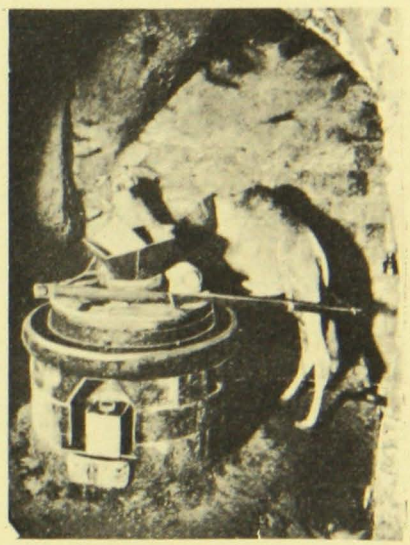


FIG. 9.—Two mills of ancient type in modern Palestine. Reproduced from Gustaf Dalman, *Arbeite und Sitte in Palästina* (Schriften des Deutschen Palästina-Instituts 6, Gütersloh, 1933), Vol. III, figs. 54 and 55.

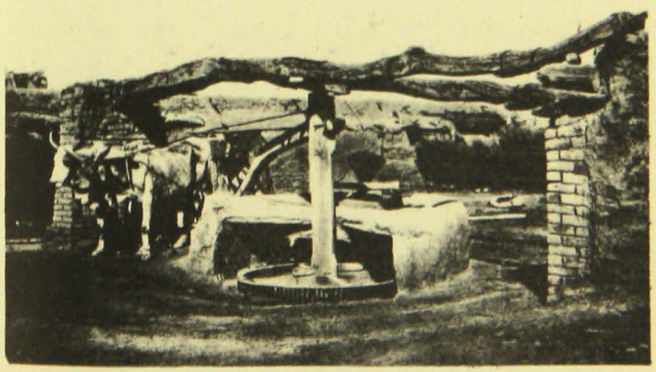


FIG. 8.—A bullock mill in modern India. Reproduced from India, Agricultural Marketing Adviser, *Report on the Marketing of Wheat in India* (Agricultural Marketing in India, Marketing Series 1, 1937), facing p. 60.

specifically whole-wheat meal. The fact that the price of *farina* was lower than the prices of the two other wheat flours mentioned by Pliny is also an indication of this.

Three-grade grindings.—It is the commonly accepted opinion of scholars that, so far as wheat was ground to products other than meal in classical Rome and Greece, it was ground into three grades of flour and one grade of bran.[23] The Latin names of the various products obtained from the principal types of Roman wheats in this type of grinding were as follows:[24]

Type of wheat	*triticum*	*siligo*
First flour grade	*pollen*	*flos*
Second flour grade	*similago*	*siligo*
Third flour grade	*secundarium* or *cibarium*	
Bran	*furfur*	

Pliny not only mentioned the names of the various products obtained in the three-grade grindings, but gave also the extraction rates of these products for several wheats. The extraction rates are naturally in terms of a measured unit. Their conversion to a weight unit is made here for the first time with due consideration for the differences in the weight per modius of the different ground products (see table above). The weight per modius was highest for the best flour and lowest for coarse bran, but even the best flour weighed less per modius than wheat. To attain the same per modius weight for the best flour as for wheat, the flour would have to be pressed tightly into the modius, but actually it was merely dumped from a very low height. (This is clearly seen in Figure 6.) That none of the ground products was packed as tightly as wheat is even more obvious from the fact that a modius, equal to 16 sextarii of wheat, yielded 20–22 sextarii of ground products in the three-grade grindings of unmoistened wheat according to Pliny.

EXTRACTIONS IN THE THREE-GRADE GRINDINGS OF UNMOISTENED WHEAT IN ROME*

From *triticum*			From Pisan *siligo*		
Ground product	Sextarii per modius of wheat	Percentage in terms of weight of the wheat	Ground product	Sextarii per modius of wheat	Percentage in terms of weight of the wheat
pollen	5	27	*flos*	8	44
similago	8	44	*siligo*	5	27
secundarium or *cibarium*	4	15	*cibarium* or *secundarium*	4	15
Bran	4	11	Bran	4	11
Waste	..[a]	3	Waste	..[a]	3
Total	21	100	*Total*	21	100

* The figures in sextarii (a measured unit) are by Pliny (*op. cit.*, chap. 10, sec. 89, p. 166, and chap. 9, secs. 86–87, p. 166); the percentages in terms of weight are computed by the present writer.

[a] Not stated by Pliny.

The correct computation of the extractions in terms of weight also puts into correct light the social position of the consumers of the second grade, frequently referred to as the intermediate grade. These consumers are commonly assumed to have had a relatively high social position because of the very fact

[23] Voigt, *op. cit.*, pp. 115–18; Hugo Blümner, *Technologie und Terminologie der Gewerbe und Künste bei Griechen und Römern* (2d ed., Leipzig, 1912), I, 53–54; A. Mau, "Bäckerei," in *Paulys Real-Encyclopädie* . . . . , Vol. II, col. 2736.

[24] The names of products are those for grinding of unmoistened wheat. In addition to the three-grade grindings of unmoistened wheat, Pliny spoke of similar grindings of moistened wheat, but we need not discuss these because it is probable that the moistening of wheat was not yet common in Rome in Pliny's time.

that the second grades of the flour were assumed to have been of fairly good quality. But from our analysis the second grade of the three-grade grinding emerges as a materially lower grade than is commonly assumed. Indeed, from the modern point of view the second grade of the Roman three-grade grindings was the lowest grade of flour.

Since it is the common assumption that the three-grade grindings were the only ones which existed in classical Rome in addition to the grinding of wheat to meal (*farina*), it is also commonly accepted that the terms *similago* and *siligo* were used exclusively in the sense of the second grades of the three-grade grindings and therefore that *similago* and *siligo*, for which Pliny gave his prices, also were the second grades obtained in those grindings. Actually, however, those terms were also widely used to designate any flour from *triticum* and *siligo* respectively except whole-wheat meal and *cibarium*, and specifically to designate one-grade flours from the same wheats.[25] Pliny himself used the terms *similago* and *siligo* in those differing senses. Moreover, he did this in the same section in which he designated the second grade of flour from *triticum*, ground without preliminary moistening, as *similago*. This is the section containing Pliny's principal discussion of flours from that type of wheat. With reference to none of the three cases in which the term *similago* is found in that section is it likely that the second grade was involved. The statement, *"Similago e tritico fit, laudatissima ex Africo"* (*similago* is made from *triticum;* the most praised one is from Africa), with which the section begins, makes sense only if *similago* is interpreted as meaning either flour from *triticum* in general or one-grade flour from the same wheat. The statement, *"panis vero e modio similaginis, p. XXII, e floris p. XVI,"* in the same section makes the best sense if *similago* is interpreted as one-grade flour from *triticum*. The third case where the term *similago* is mentioned in the section is the statement on flour prices analyzed in this study. It is most likely that in this statement the term *similago* and also the term *siligo* likewise refer to one-grade flours. If Pliny in stating the prices of *similago* and *siligo* had in mind the second grades of the three-grade grindings, he probably would also have mentioned the prices of the first grades, which were as important as the second grades. Indeed, more first-grade than second-grade flour was obtained according to Pliny's own evidence in the three-grade grinding of *siligo* wheat (see table, p. 154).

One-grade flours.—The three-grade grindings seem to fit well into the social organization of the city of Rome. The upper layer ate "bread as white as snow," the middle class got the "second" grade, while the third grade of "flour," actually bran middlings or largely bran middlings, was eaten by the poor and slaves. Yet the probability is great that the three-grade grindings were almost as rare as the feasts described in detail by Athenaeus. The stratum of those who could afford bread from the first-grade flour was relatively thin. Hence the wheat processed to such flour also made up only a relatively small proportion of the total wheat ground.

The natural development from meal to the type of grinding in which more than one grade

[25] It is not intended to present the rather extensive evidence on which the statement in the text is based. The principal reason for the assumption is that the names of the first grades of the three-grade grindings, *pollen*, its Greek equivalent, γῦρις, and *flos* were mentioned very rarely. Chiro, in his medicinal recipes for animals (*Claudii Hermeri Mulomedicina Chironis*, ed. by Eugenius Oder, Bibliotheca Scriptorum Graecorum et Romanorum Teubneriana, Leipzig, 1901, 467 pages), who naturally wanted to be exact, is almost the only one who used them; but he used the terms *similago* and *siligo* as qualifying factors and by no means in the sense of second grades. The expressions involved in his recipes were *pollinem siliginis, flos similaginis, similaginis pollen, flos similae* (sec. 912, p. 274; sec. 846, pp. 257–58; sec. 674, p. 213; and sec. 912, p. 274). For the first grade from their σιτανίας the Greeks even did not have a name which would have roughly corresponded to the Latin *flos*. It is evident, therefore, that the first-grade flours were referred to in common language in some other way. It is our contention that they were normally referred to under the names *similago*, its Greek equivalent, σεμιδαλίτης, and *siligo*, and its Greek transcription, σιλιγνίτης. Oribasius (*Oribasii Collectionum Medicorum Reliquiae*, Leipzig, 1928, Book IV, sec. i, par. 3) stated on the authority of Galen that if the product of grinding is separated into flour and bran, the flour yields the σεμιδαλίτης or σιλιγνίτης bread, the bran the πιτυρίας bread. Juvenal (*op. cit.*, line 70) used the term *siligo* to designate the best flour available, and by no means in the sense of a second grade. If the term *flos* for the best flour from *siligo*, the best wheat, were in common use, Juvenal would have wanted to use it at that particular place.

of flour is produced is through a processing consisting in the separation of only one grade of flour and one grade of bran, or, more precisely, consisting in the elimination from the meal of a certain quantity of the coarsest stock as bran. Such one-grade flour is still produced, to greater or lesser extent, everywhere, especially from the coarser grains such as corn and rye, even when wheat is generally further processed into a more refined product. This rather primitive type of one-grade flour is found to be increasingly common as one goes back into history. Such one-grade flours also existed in both Rome and Greece. It is, moreover, the opinion of the present writer that, so far as sifted flour was produced at all, the one-grade rather than the three-grade grinding was the predominant form. The extraction of these one-grade flours was around 80 per cent. Space prevents showing that this inference is reached from Pliny's evidence[26] that one modius of *similago* and *flos* yielded 22 and 16 pounds of bread respectively, and from a statement in the *Geoponica*.[27]

The likelihood is great that Pliny had in mind exactly such one-grade flours of about 80 per cent extraction in stating his prices of *similago* and *siligo*. As was pointed out, the fact that Pliny did not mention the prices of the first grades of the three-grade grindings indicates that in his statement of prices *similago* and *siligo* were not the second grades of the three-grade grindings. But if they were not prices of these grades, and since they also were not prices of meal, they were most likely prices of one-grade flours. It will be shown that Pliny's flour prices make the best sense when *similago* and *siligo* are interpreted as one-grade flours and specifically such of about 80 per cent extraction. Thus Pliny's flour prices themselves serve as proof of the existence of one-grade flours and of the approximate extraction rate of these.

The qualification "castrata." — Teubner's edition of Pliny, which now is accepted as standard, has the qualification *castrata* only with reference to *siligo* in the statement on flour prices analyzed here. Those who interpret that Pliny's statement "*castrata siligo* twice" meant 80 asses per modius of *siligo* flour[28] may argue that *castrata siligo* was a particularly fine flour from the highly favored *siligo* wheat, while *similago* was either the second grade of the three-grade grinding or a one-grade flour of about 80 per cent extraction from the less desirable *triticum* wheat. But the present writer believes it improbable that a first-grade flour could have cost almost twice as much as a second-grade flour, even though the first-grade flour was from the more desirable wheat and the second-grade flour from a less desirable wheat. He interprets the price of *siligo* as given by Pliny at 56 asses and the qualification *castrata* as pertaining to both *similago* and *siligo* and meaning "sifted."

By qualifying *siligo* as *castrata,* Pliny probably wanted to put it beyond doubt that flour rather than whole-wheat meal was involved.[29] There was no need to qualify the term *similago* in the same manner. The fact that *similago* cost 8 asses more per modius than *farina* made it certain that the first one was *castrata* (sifted). Some editions of Pliny, moreover, have the qualification *castrata* for both *siligo* and *similago.*

Milling Costs

The cost of milling is usually small when related to the price of wheat, and even a relatively high cost of milling in Rome would not have greatly affected the price of wheat corresponding to a certain price of flour. Actually, however, the cost of milling in classical Rome was not much higher than it is now, in spite of the fact that milling was done by animal and human power, which was not only expensive but in the case of animal power was also used very inefficiently. The crude nature of the milling and especially the small amount of power used in it were the main reasons for the low milling costs.

[26] *Op. cit.*, chap. 10, sec. 89, p. 166.

[27] *Geoponica, ... (Agricultural Pursuits)*, trans. by T. Owen (London, 1805), Vol. I, Book 2, chap. 32, p. 80.

[28] Dr. R. D. Harriman, of Stanford University, has informed the present writer that this is the grammatical meaning of Pliny's statement.

[29] A cause for such an incorrect interpretation of *siligo* might have been found in the term *farina siliginea* used by Pliny in the paragraph immediately preceding the one where he gave his flour prices. The correct meaning of the term *farina siliginea* was whole meal from *siligo*.

Little power used.—The difference between the milling systems of our days and classical times is clearly reflected in the much smaller total power used for milling in antiquity, as well as in the fact that all or almost all power was then used for the grinding proper, while now more than half of it is used for other operations. According to B. W. Dedrick,[1] in a modern mill the total power requirement varies between 0.26 and 0.40 horsepower per barrel of 196 English pounds in 24 hours. This is equivalent to 1½–2 horsepower-hours per bushel of wheat. Not less than 60 per cent of this power is used for the wheat-cleaning machinery, sifters, purifiers, elevators, and transmissions.[2] The 40 per cent used for the grinding proper is equivalent to 0.6–0.8 horsepower-hour per bushel of wheat.

The amount of animal power used in a Roman mill is estimated, probably too high, by Dedrick at one-third of a horsepower-hour, or about one-third to one-half of the power used for the grinding proper in a modern mill.[3] While 60 per cent of the total power spent in a modern mill is used for machinery other than that performing the grinding proper, the power spent in a Roman animal mill for operations other than the grinding proper consisted exclusively or almost exclusively in the man power used for driving the donkey which did the actual grinding. Sifting, so far as it was done, required an appreciable amount of work only in the production of the first-grade flour, where a relatively fine sieve had to be used; little such flour, however, was produced in antiquity. If it is assumed that one man could take care of two donkeys (this is equivalent to one two-donkey mill or two one-donkey mills) and sift the flour ground by them, the total animal and human power needed to mill a bushel of wheat in a Roman mill may have been equivalent to 1/10–5/10 horsepower-hour—as against 1½–2 horsepower-hours in a modern mill.

Contemporary cost of refined milling.—According to the United States Federal Trade Commission,[4] operating costs of 37 companies in the United States in 1913–14 were equivalent to 22 cents per barrel of flour or to 5.6 per cent of the cost of wheat. The evidence could be multiplied almost indefinitely—for this and other countries. If comparisons between contemporary wheat and flour prices appear to indicate higher milling costs than those, it is because charges are included in the flour prices which have nothing to do with milling proper. The price of wheat is commonly for the grain in bulk; flour, however, is sold packed; the cost of packages to the quoted 37 American concerns was higher than their total operating costs. Wheat is bought for cash; the flour price is frequently for deferred payment or subject to discount for cash.

Cost in classical antiquity. — The Roman mill was inexpensive. The *Edict* of Diocletian gave the following maximum prices of mills, which for convenience are expressed in Winchester bushels of wheat by using the maximum prices of wheat (50 denarii per modius) of the same *Edict*:[5]

Type of mill	Price of mill in bushels of wheat
Horse mill with stones	7½
Ass mill	6¼
Water mill	10
Hand mill	1¼

These prices are obviously too low to pertain to complete mills. Although the prices of mills in the *Edict* are found among the prices of goods made mainly of wood, Blümner[6] interpreted them as the prices of the stones only. Miss Graser, who translated and commented upon the *Edict*,[7] kindly informed the writer that she shares the opinion of Blümner. It is, indeed, very probable that, at least so far as

[1] *Practical Milling* (Chicago, 1924), p. 309.

[2] *Ibid.*, p. 298.

[3] Dedrick, an expert in modern milling, may have underestimated the coarseness of Roman grinding as many others do. But the amount of power declines rapidly—up to several times—with increase in the coarseness of the ground product. Compare the interesting grinding experiments under conditions of antiquity made by M. A. Heron de Villefosse of Paris and reported also by Max Ringelmann, *Essai sur l'histoire du génie rural* (Paris, 1910), III, 546–56, and "Essai sur l'histoire du génie rural. ... La Judée," *Annales* (Institut National Agronomique, Paris), 1910, 2d ser., IX, 309–10.

[4] *Report . . . . on Commercial Wheat Flour Milling* (Sept. 15, 1920), p. 90.

[5] "The Edict of Diocletian," trans. and interpreted by Elsa Graser in Frank, *op. cit.*, V, 318, 365–66. The maximum price for wheat of 100 denarii is for a castrensis modius, which is equal to two modii.

[6] *Edictum Diocletiani . . . .*, p. 114.

[7] Frank, *op. cit.*, V, 305–41.

animal-driven and water mills were concerned, only the stones and iron parts were purchased, the wooden parts having been made by a carpenter on the spot. This practice is still common where stone mills are used. Moreover, the prices of the *Edict* may not have included transportation of the stones to the mills. Still, the price of the stones at the quarry probably made up a large part of the price of the complete mills, installed in the mill.

According to Cato,[8] an oil mill or press (*trapetus*) brought to the place of destination and assembled, cost complete either 629 sesterces (from Suessa) or 724 sesterces (from Pompeii). At 5 sesterces per modius of wheat, the mills were equivalent in price to 31½–36 Winchester bushels of wheat. The Roman oil mill was rather large; six men in addition to the oxen were needed to haul the mill from Suessa to the place of destination.[9] If the price of a donkey-driven grain mill was the same as that of an oil mill, the grain mill driven by two donkeys in three shifts could have ground the equivalent of its price in wheat in 36–48 hours.

The sieves were simple hand sieves and therefore inexpensive. A hand sieve for fine flour (σιμιδάλια) cost as much as 2 bushels of wheat according to the *Edict*.[10] A large woven sieve, also apparently for flour, cost as much as a bushel of wheat.

Turning now to the cost of the Roman grinding, we shall first examine the cost of hand grinding. A grown man can be expected to expend ¾ horsepower-hour in a day's work. Assuming that 3 bushels of wheat were ground per horsepower-hour in Rome, a day's work of a man would yield in excess of 2 bushels.[11]

The maximum wage of a *pistor* (miller-baker) was established in the *Edict* at 50 denarii per day and subsistence. But the *Edict* naturally neglected to state a wage rate for workers grinding grain by hand, for at the time of Diocletian and for several hundred years before, no free man was hired for this work. Even if free labor had been used, it would obviously have been unskilled labor. The maximum daily wage of such a laborer, for example a water carrier, was 25 denarii, the price of one-eighth of a Winchester bushel of wheat, and subsistence—according to the *Edict*. The food customarily provided to such a worker was very simple; 5 English pounds of wheat would have covered it amply. Thus, the cost of such a laborer may have been equivalent to the cost of about 12–13 English pounds of wheat.[12] Depreciation of the hand mill and of the sieves, if any, can be neglected, and frequently no special building space was needed. Thus, the total cost of grinding by hand, even when performed by free labor, would have been only about 10 per cent of the cost of wheat if no sifting was involved, and only a little more in the latter case; the cost of a special working place, if such were needed, would have increased this cost somewhat.

However, little if any grinding was performed with the use of hired free labor for turning the mill in classical Rome; hand grinding was done either by women and slaves in homes, or by slaves and criminals in commercial establishments. Animal power must have been even cheaper than slave labor; otherwise, animals would not have been used. The computation of the cost of grinding by hand with hired free labor is nevertheless use-

[8] *Op. cit.*, chap. 22, sec. 3, pp. 40–41.

[9] The fact that the oil mill was rather large is indicated also by the fact that the moving stones were 1 foot and 3 fingers thick and had a diameter of 1 foot according to Cato (*loc. cit.*).

[10] Frank, *op. cit.*, V, 366.

[11] The quantity is larger, according to Barbagallo (*op. cit.*, p. 54). He reports: "In the countries where the old hand mills still exist, we find that 4 hours' work of one person is sufficient to furnish at least 33 kilograms . . . . of flour." On this count, at least 82 kilograms, or slightly more than 3 bushels, would be ground in 10 hours. Yet according to Dr. Johnson (*London Magazine*, 1774, quoted by Richard Bennett and John Elton, *History of Corn Milling*, London, 1898, I, 169), "it employs two pair of hands four hours to grind only a single bushel of corn." According to the *Report on the Marketing of Wheat in India* (India Agricultural Marketing Adviser, Agricultural Marketing in India, Marketing Series 1, 1937, p. 293), the productivity of a hand mill is merely 2 seers (4 pounds) per hour. The work is done by women in India and Indian women weigh less than 100 pounds. In addition to the variations in the power exerted by different persons, the considerable variations among the above figures may be largely due to the fact that the output per man is greatly affected by the fineness of the flour produced.

[12] This figure is undoubtedly too high for a man operating a hand mill; it is used advisedly to provide for the eventuality that the labor requirement was larger than that assumed in the text.

ful, indicating the upper limit of the cost actually involved; even the cost of grinding by hand was far below the figures visualized by many interpreters of Pliny's flour prices as the cost of grinding in antiquity.

The animals in Roman mills were attached to the stone directly by means of a sweep and, therefore, had to make a very small circle (Figures 5 and 6). The power developed by them under such conditions must have been considerably less than the same animals would have been able to develop under better conditions. This inefficient use of animal power was an important contributing factor. But the principal factor was cheapness of slave labor. Because of this, human labor was used for turning even relatively large mills long after the invention of animal mills. In this connection, the row of mills of a large bakery excavated at Pompeii is of interest, for illustrations of it are frequently used to show Roman animal mills; Bennett and Elton,[13] however, plausibly argue that these mills could have been turned by men alone.

A conservative estimate seems to be that the total power transmitted per day by a donkey of a size typical for the Mediterranean countries to a Roman mill was 1¼ horsepower-hours;[14] then the quantity of wheat ground per donkey-day is likely to have been about 3½ bushels. In addition, some human labor was needed for driving the animal and for sifting, if the latter operation was performed.

Donkeys are satisfied with the poorest food. Indeed their owners frequently leave them to find their own subsistence, and the cost of keeping a donkey in the country is therefore almost negligible. It is assumed that 10 English pounds of wheat per working day would have taken care of the cost of food, housing, interest, and depreciation of a donkey in Rome.[15] Since the maximum daily wage of a *pistor* was established by the *Edict* at 50 denarii (the equivalent of ¼ bushel of wheat) and maintenance, or a total of about 20 English pounds of wheat, and one free man could probably have taken care of two donkeys and sifted the flour ground by them,[16] the total cost of grinding and sifting 7 bushels of wheat would have been equivalent to 40 pounds of wheat or 9.5 per cent of the wheat ground. Adding to this figure the interest and depreciation on the mill proper, and on the building and sieves, if any, as well as the profit, we find that the total cost of grinding would have been a little more than 10 per cent of the cost of the wheat.

Thus the costs of grinding with a donkey mill and of grinding by hand with free labor come to approximately the same. But the upkeep of a donkey may have been less than assumed above, or the animal may have been able to grind more than 3½ bushels of wheat per day. An exact computation of the costs is impossible anyway, and we are interested only in the order of magnitude. That the above figures are within the correct order can be demonstrated by other evidence.

The cost of grinding as computed above is difficult to express in money, for no agreement exists as to the price of wheat. The cost of grinding which would have corresponded to the high prices of wheat implied in Pliny's

[13] *Op. cit.*, p. 18.

[14] This is ⅕–⅙ of what a horse weighing about 1,500 pounds can develop per day in continuous work (E. V. Collins and A. B. Caine, *Testing Draft Horses*, Iowa Agr. Exp. Sta. Bull. 240, 1926, p. 221; and Naum Jasny, *Der Schlepper in der Landwirtschaft, seine Wirtschaftlichkeit und weltwirtschaftliche Bedeutung*, German Reichsministerium für Ernährung und Landwirtschaft, Berichte über Landwirtschaft, 1932, n.f., Sonderheft 62, pp. 20–24). Lighter horses develop proportionately more power, and donkeys are more hardy than horses of the same weight. According to Nicolà Bochicchio, an Italian student (*Manualetto di economia rurale ad uso degli studenti delle scuole agrarie e degli agricoltori*, Biblioteca d'Agricoltura ed Industrie Affini IX, Catania, 1907, p. 104), the work of a donkey is scarcely equal to ½–⅓ that of a horse. The average weight of a horse is given by him at 350–450 kilograms (770–1,000 English pounds), and the power developed by it at ½–⅔ horsepower per hour. In the *Edict* of Diocletian a donkey load of fuel was assumed to have been equivalent to half a camel load.

The estimate of 1¼ horsepower-hours per donkey-day includes an allowance, probably too high, for the loss of energy through the inconvenient attachment of the donkey to the mill.

[15] It is noteworthy that on the basis of the *Edict* vetch hay cost 40 per cent, and hay or chaff 20 per cent, as much as wheat.

[16] Actually few of the workers in the mill-bakeries were free men; most—if not all—of them were slaves. The customary wage of a city slave was 5 modii (probably wheat or hulled emmer; perhaps meal from either of them) and 5 denarii per month (Seneca, *op. cit.*, Letter LXXX, sec. 7, p. 216). These quantities were equivalent to 3 English pounds of grain plus the value of at most 2.4 English pounds of grain in money or a total of 5.4 English pounds of grain per working day.

flour prices would be about 4 asses per modius, or even somewhat less. But if the normal price of wheat in Rome was 5 sesterces, as many believe, the approximate cost of grinding a modius of wheat would have been 2½ asses or somewhat less.

Cost in classical Egypt.—The only evidence of the cost of grinding in classical antiquity which has come to the attention of the writer is a few rates for custom grinding in Egypt about the first year of our era[17]—all of them for grinding small quantities in the same city, at the same time, and probably also in the same mill. The charge was 3 and 4 obols per artaba of wheat. When the charge was 4 obols grinding was probably finer.[18] Related to the price of wheat in Egypt (about 20 obols),[19] the Egyptian charge for grinding was high—15 and 20 per cent respectively. Three factors may have been responsible for this:

(1) Wheat was cheap in Egypt. The cost of grinding performed by man or animal power, and especially the cost of custom grinding, was in general greatly affected by the price of the grain, but it was unlikely to have been exactly proportionate to this. Human labor in terms of grain was much more expensive in Egypt than Greece and probably was more expensive than in Rome. (2) The quantities involved in the available evidence (each time only 1 artaba was ordered to be ground) were so small that the transactions had the character of a more or less retail business. And (3), with the almost endless number of monopolies in ancient Egypt, there is a probability that a state monopoly also existed for commercial grinding.

If one applies the relationships of 1 Egyptian drachma = ⅘ of a denarius and 1 artaba = 3⅓ modii, the Egyptian milling rates are equivalent to 1⁹⁄₁₀ and 2⁹⁄₁₀ Roman asses per modius. The rate for grinding in Rome as computed above was about 4 asses per modius; this is a rate for grinding on a larger scale and does not include the cost of retailing the flour.

The difference between 1⁹⁄₁₀ and 2⁹⁄₁₀ asses computed as the cost of grinding small quantities in custom in Egypt and 4 asses computed as the cost of grinding large quantities in Rome seems about adequate to compensate for the lower operating costs in terms of money in Egypt as compared with Rome.[20]

[17] The *Oxyrhynchus Papyri* . . . . , ed. with trans. by B. P. Grenfell and A. S. Hunt (Egypt Exploration Fund, Greco-Roman Branch Memoirs, London, 1904), Pt. 4, p. 232.

[18] The higher rate was perhaps for grinding to flour, the lower for grinding to meal or groats.

[19] See tabulation of wheat prices in Frank, *op. cit.*, II, 310–12.

[20] The only other material related to the problem of milling costs in antiquity is Friedrich Hrozný's discussion of the cost of hulling emmer in ancient Babylonia, but his conclusions are based on an incorrect interpretation of an obscure Sumerian term (*Das Getreide im alten Babylonien; ein Beitrag zur Kultur- und Wirtschaftsgeschichte des alten Orients, I. Teil,* Sitzungsberichte der Kais. Akademie der Wissenschaften in Wien, Philosophisch-Historische Klasse, 173, 1914, Abhandlung 1, p. 110, and others). Hrozný believes that he has proved that the Sumerian term *bal,* usually equivalent, when expressed in and related to emmer in hulls, to one-seventh of the emmer intended for hulling, represented "the payment in kind for the hulling, and unlikely (perhaps only in exceptional cases) in part the loss in material accompanying the hulling." The cost of hulling is unlikely to have been more than a fraction of that account. Hrozný's interpretation of the term *bal* is not accepted by the leading linguists (e.g., Anton Deimel, *Sumerisches Lexikon,* Scripta Pontificii Instituti Biblici, Rome, 1932, Pt. 2, Vol. 3, p. 689, letter 367, note 40, and Allotte de la Fuye, "*En-e-tar-zi* patési de Lagas," in *Assyriologische und archeologische Studien, Hermann V. Hilprecht . . . . , Hilprecht Anniversary Volume,* Leipzig and London, 1909, p. 131). Any payment for the hulling is unlikely to have been involved in the accounts analyzed by Hrozný; the accounts were those of storekeepers in households of kings, churches, and the like; the hulling was done in the mill-bakery which was part of the same household. The storekeepers and miller-bakers were slaves belonging to the head of the household.

Although Hrozný's analysis does not contribute anything to the knowledge of the cost of grinding or hulling in antiquity, we find it very intriguing. The Babylonian accounts seem to be the only available means to get an idea of the price relationships between different grains, as well as of the milling, baking, and brewing techniques in so remote an era as the third and second millennia B.C., and Hrozný certainly succeeded in taking an important step toward the understanding of these accounts. It seems to be in line with Hrozný's reasoning, if the *bal,* consisting of a quantity of emmer in hulls and related to another quantity of such emmer, the latter usually six times larger than the *bal,* is interpreted as a device to convert emmer into barley, the basic grain of the old Babylonian accounts. Then one measured unit of barley was equivalent in value to 1⅛ units of emmer in hulls in Babylonia. Hrozný's interpretation of the relation in value between wheat and hull-less emmer, and emmer in hulls, becomes: 1 unit of wheat or hull-less emmer = 2⅛ units of emmer. The whole equation of grain values in old Babylonia may have been: 1 unit

Contemporary costs of primitive grinding. —Even today large amounts of grain are ground by animal and even by human power. While the continued use of human power indicates primarily that enormous amounts of women's work are expended for a very low reward, the existence of animal-drawn mills bears witness that the work of such mills is not exorbitantly more expensive than that of the mills driven by mechanical power; otherwise they would have disappeared long ago. The high cost of animal power is not an obstacle to the existence of such mills, because little power is used per given quantity of grain; this is of course equivalent to very coarse grinding. Other deficiencies of animal mills are large amounts of labor and slowness of the whole process. But the consumers in very poor countries have to be satisfied with such coarse flour; the large amount of human labor and slowness of the process also do not count much there. All these drawbacks are offset by the advantage that the mills are small and consequently near the consumers. The large reduction in the distance to the mills is an especially important factor where the producers do not possess means of transportation.

In British India, animal mills are still in wide use, along with hand grinding.[21] The animal mills are equipped with gears, the animals make a large circle, and the stones are likely to have the optimum speed (see Figure 8). Two bullocks are generally employed with each mill, though there are also camel mills. "The normal grinding fee or charge is 2 seers of wheat per maund. . . ."[22] Since a maund has 40 seers, the charge is equivalent to 5 per cent of the wheat—a very moderate fee especially since grain is not expensive in India (it was dear in ancient Rome). The cost of grinding in animal mills may be unusually low in India owing to the very low wage level, the frequent combination of milling and carpentry in one business, the use of the mill bullocks for plowing (the most urgent farm operation in wheat-producing regions of India), and the unhoused mills. But the evidence for India nevertheless dispels any suspicion that very high costs are involved in grinding with animal power, so long as wages are low and the consumers are satisfied with a primitive product like whole-wheat meal or the flours known to the Romans. It may be of interest to add that the charge in British India is higher if the grinding is by mechanical rather than by animal power.[23]

According to Dalman,[24] the customary rate for grinding grain (without sifting) in modern Palestine is 1¼–1½ units for each 20 units, or 6¼–7½ per cent of the grain ground. At this rate both water and animal mills operate. It is of particular interest that mills with the animal directly attached to the stone (Roman fashion) still exist there (see Figure 9). These are apparently able to operate by collecting as fees only about 7 per cent of the grain ground.

Erroneous Interpretations of Pliny

When Frank[1] speaks of the wheat price corresponding to the prices of flour given by Pliny, he considers only the price of 40 asses

of wheat or hull-less emmer = 2 units of barley = 2⅓ units of emmer in hulls—all in measured units.

Hrozný's analysis of the extraction of the various flours needs to be fully reconsidered. He fails to take into account the fact that flour occupies more space than the grain from which it is produced. For example, Hrozný (p. 103) analyzes five items, four of which according to him were quantities of various flours, two emmer flours and two barley flours, while the fifth item is supposed to have represented the equivalent of all those flours in barley. If the quantities of emmer flours are summed and doubled (because 1 unit of hull-less emmer was considered equivalent to 2 units of barley), the total quantity of all flours is 20 per cent higher than the quantity of barley supposed by Hrozný to be their equivalent in barley. But Hrozný fails to notice this and handles both figures as if they were equal. Some of Hrozný's inferences from the Babylonian accounts seem highly improbable—for example, that one of the emmer flours then produced was so fine that only 3⅓ pounds of it were obtained from 100 pounds of hulled emmer, and that in the preparation of a specific kind of beer 3½ units of barley were used for 1 unit of beer. Similarly, data on breads and beer have to be reconsidered by taking into account important technical details which escaped Hrozný's attention—for example, the fact that both the weight and the volume of the flour change when it is made into bread. Unfortunately the present writer cannot undertake the needed revisions of the very interesting Babylonian material, at least at present.

Asked to comment on this footnote, Dr. G. R. Hughes of the Oriental Institute of the University of Chicago kindly informed the writer that he does not find anything in it with which he would disagree.

[21] *Report on the Marketing of Wheat in India*, p. 60.

[22] *Ibid.*, p. 293.

[23] *Ibid.*, p. 294.

[24] *Op. cit.*, p. 282.

[1] *Op. cit.*, V, 144.

per modius; the fact that Pliny gave two more prices is neglected. The other writers, with the exception of Barbagallo,[2] made the same omission. The failure to take into consideration the two other prices of Pliny would have done no harm, if the price of 40 asses per modius had been taken for what it really was, namely, the price of *farina* or whole-grain meal from wheat. This price, however, has been persistently treated as if it were a price of bran-free flour. However, only *similago* and *siligo*, the prices of which were likewise given by Pliny, were flour in the narrow sense obtained by removing the bran (only part of it, in fact) from the meal.

To the erroneous idea that the price of 40 asses per modius was for wheat flour rather than whole-wheat meal, a further error was added by assuming that the extraction of flour was low in classical antiquity. One of the reasons for this assumption was that Rodbertus and everyone after him treated the evidence on the extraction of wheat products as given by classical authors as if it pertained to weighed quantities. Thus their analysis implied that the weight per modius was the same for wheat and all products obtained by grinding it. The error caused by the confusion of weights and measures is particularly conspicuous in the study by Barbagallo,[3] who made detailed tabular computations of the yield of the various ground products as stated by Pliny[4] for several types of wheats. Implying equal weights per modius for wheat, all kinds of flour, and even bran, he came to the conclusion that the yield of bran from *triticum* in the narrow sense was equivalent to 19 per cent, while the computation in the table on page 154, which takes into consideration the difference in the weights per modius between wheat flour and bran, leads to 11 per cent as the extraction percentage of bran.

Still, even according to Barbagallo, the total extraction of all products other than bran from *triticum* was 81 per cent (actually it was equivalent to about 86 per cent), while the now-usual extraction of flour, except in emergencies like wars, is only 70–75 per cent. To arrive at the conclusion that the total extraction was low in ancient Rome, the students of Pliny's flour prices, in addition to their failure to consider the differences in weight per modius between the various ground products, had to disregard the fact that *cibarium*, although actually bran middlings or largely bran middlings, was flour in ancient Rome, because all ground products used for food are flour in the wide sense.[5] With *cibarium* excluded in addition to bran proper, the remaining ground products of Pliny's three-grade grindings correspond to an extraction of only 60–61.9 per cent according to Barbagallo. It is obvious from the computation in the table on page 154 that the correctly computed extraction of flour other than *cibarium* was 71 per cent, i.e., that it was about equal to the present *total* extraction of flour, yet the incorrectly computed extraction of flour other than *cibarium* of 60 per cent, or only slightly more, is applied by Rodbertus and many other interpreters of Pliny's flour prices to *farina*, a whole-wheat meal.

After the price stated by Pliny for *farina* was applied to flour and the extraction of flour in ancient Rome accepted as very low, a further error was introduced by assuming very high milling costs in classical antiquity. The price relationship between flour and wheat of approximately 1.5:1, assumed by the interpreters for modern conditions, was declared unsuitable to the conditions of ancient times, owing both to the lower extraction of flour and the higher costs of milling then. A ratio of 2:1 was believed more representative of conditions in classical Rome. Rostovtzev went even further. In his opinion, the ratio of 2:1 between the prices of flour and wheat would have existed in classical Rome if the milling costs were the same as now, but since they were much higher in Rome, the price of wheat must have been less than half the price of flour.

To what extent one can go astray in the analysis of milling costs is obvious from the fact that the renowned Rodbertus quoted the

[2] *Op. cit.*, especially pp. 49–50. Barbagallo interprets the term *farina* as meaning flour of second quality.

[3] *Ibid.*, pp. 47–48.

[4] *Op. cit.*, chap. 9, secs. 56–57, and chap. 10, sec. 89, p. 166.

[5] Students who study the Roman flours without reference to Pliny's flour prices treat *cibarium* as flour. See, for example, Voigt, *op. cit.*, p. 117, and Blümner, *op. cit.*, p. 54.

evidence by Michel Chevalier[6] that the productivity per man was 144 times higher in a modern mill at Chevalier's time than in hand grinding in ancient Rome and then stated that, on the basis of this relationship, the price of a modius of wheat corresponding to Pliny's flour price of 40 asses would have been merely 1⅛ asses (or 1/30 the flour price). Rodbertus did not accept this absurd figure, but it sufficed that he mentioned it. Chevalier's figures may be found reproduced by several other prominent writers discussing Pliny's flour prices.[7] The productivity per man in a modern mill has risen to perhaps 1,000-fold that of hand grinding since Chevalier's time, but no conclusions from this can be drawn regarding the cost of grinding by hand or animal power in classical Rome. Even comparisons of the productivity per man in milling in classical antiquity with the productivity in other economic pursuits in the same era—the only permissible ones—may easily mislead.

As with reference to extractions, the students of the Roman wheat prices applied modern price relationships between flour and wheat, which are in terms of weight, to the price relationships of antiquity, which were in terms of measured units. But the weight of flour per measured unit is commonly and considerably less than that of wheat. Hence the prices of wheat and flour *ceteris paribus* must have been considerably closer in antiquity than they are now.

It is especially unfortunate that all such incorrect assumptions and confusions tended in the same direction of reducing the price of wheat corresponding to a given price of flour or meal. It is this cumulation of several errors that accounts for the fact that the wheat price corresponding to Pliny's flour prices as computed by Rostovtzev turned out to be less than half of what it actually was.

Pliny's Flour Prices Converted to Wheat Prices

Prices of farina and wheat.—Surprising as it may seem to many, the price of a modius of whole-wheat meal in Rome was no higher and was probably even less than the price of a modius of wheat.[1] A modius (equal to 16 sextarii) of wheat produced about 19–20 sextarii of whole-wheat meal.[2] The extra bulk of the meal must have more than covered milling costs. Hence, the price per modius of wheat corresponding to a price of *farina* of 40 asses or 10 sesterces per modius could not have been less than the same 40 asses or 10 sesterces and may have been slightly higher.

Similago and siligo, one-grade flours. — Since it is impossible to ascertain definitely what Pliny meant by *similago* and (bolted) *siligo*, two possibilities will be analyzed, namely (1) that those flours were one-grade flours of about 80 per cent extraction from *triticum* and *siligo* respectively, and (2) that they were the second grades obtained in grinding these wheats into three grades of flour without moistening.

A weighed quantity of the one-grade flour may be assumed to have filled 10 per cent more space than the same weighed quantity of wheat. Hence, a modius of wheat produced 14⅒ sextarii of one-grade flour of 80 per cent extraction, and, at the prices stated by Pliny, the flours produced from a modius of *triticum* and *siligo* were worth 42⅗ and 49⅒ asses respectively. Bran may be assumed to have cost half as much as wheat in terms of weight; hence 17 per cent of bran obtained as the residual in this type of grinding cost as much as 8½ per cent of wheat and the return for the bran obtained from a modius of wheat was about 3 asses. Hence the total return for the ground products obtained from a modius of *triticum* was about 45 asses; the corresponding figure for the products obtained from a modius of *siligo* was about 52 asses. After the milling costs are deducted, we have about 40

[6] Michel Chevalier, *Cours d'économie politique fait au Collége de France* (2d ed., Paris, 1855), I, 316–18.

[7] Barbagallo (*op. cit.*, pp. 53–54) also accepts Chevalier's procedure but reduces the ratio between the productivity of labor in milling in classical antiquity and now from 1:144 to 1:15.

[1] The Roman flour prices are assumed to have been prices in bulk. The practice of including the value of the containers in the flour price is of recent date.

[2] Pliny's extraction data for the three-grade grindings indicate a total of 20–22 sextarii of three grades of flour and one grade of bran from a modius of wheat. The ground products, mixed as they are in a whole-wheat meal, occupy somewhat less space. Moreover, whole-wheat meal was probably more coarsely ground than were the flours in the three-grade grinding, and a coarser product occupies less space than a finer one.

and 47 asses as the return for a modius of *triticum* and *siligo* respectively. The reader will have noticed that this return for the *triticum* wheat is the same as that computed for the grinding of wheat into whole-wheat meal. This is a good indication that both computations are correct in substance.

Similago and siligo, second grades.—Turning to the second possibility with reference to *similago* and *siligo,* namely that they were the second grades of the three-grade grindings, we again assume that the price of a certain quantity of bran was equivalent to half the price of the same weighed quantity of wheat.[3] The price of *cibarium* may be assumed to have been equivalent to approximately two-thirds of the price of wheat—also in terms of weight. Since there were 15 per cent of *cibarium* and 11 per cent of bran (see table, p. 154), these two items represented the value of approximately 15 per cent of the wheat ground. Milling costs were probably less than that. But disregarding this possibility, we arrive at the conclusion that the value of the flour, obtained by sifting off the bran and *cibarium,* represented the return for the wheat.

It is an old rule of thumb with millers of many countries that business is good when all the flour obtained pays in full for the wheat, and the miller has the millfeed to cover milling costs, sacks, marketing costs, and to provide for his profit. It will be shown later that in general millers are in such position only in countries with low to moderate wheat prices. Yet the above rule is applied here to the situation in classical Rome, although the Roman wheat prices were high and the Roman millers did not provide the containers for the flour.

For our second possibility, i.e., for the assumption that Pliny's *similago* and (bolted) *siligo* were the second grades, we have yet to estimate the prices of the first grades (*pollen* from *triticum* and *flos* from *siligo*). These prices are assumed to have been higher than the prices of the second grades of the respective grindings by 8 asses per modius. This implies that the price per modius of the second grade from *siligo* wheat (extraction percentages 44th–71st) was the same as that of the first grade from *triticum* wheat (extraction percentages 1st–27th)[4]—a rather improbable situation. But any other prices of the first grades do not fit in better.

With all the above assumptions we arrive at the following net returns (excluding milling costs) per modius of wheat if it be supposed that *similago* and *siligo* were the second grades of flour obtained from *triticum* and *siligo* respectively:

Triticum		
5 sextarii of *pollen* at 56 asses per modius	17½	asses
8 sextarii of *similago* at 48 asses per modius	24	
Total	41½	
Siligo		
8 sextarii of *flos* at 64 asses per modius	32	asses
5 sextarii of *siligo* at 56 asses per modius	17½	
Total	49½	

The results are again very close to those obtained in the preceding computations. The price of wheat corresponding to Pliny's price of *similago* slightly exceeded 40 asses, while the corresponding price of *siligo* wheat was close to 50 asses.

Recapitulation.—It may be useful at this stage to recapitulate the different interpretations of Pliny's flour prices:

The common interpretation is that 40 asses was Pliny's price of flour produced from wheat with very high milling costs and with the yield of flour equal to about 10 sextarii per modius of wheat; the type of wheat has not been specified by the interpreters.

The suggested interpretation is as follows: (1) Forty asses was Pliny's price of meal produced from *triticum* with low milling costs and with the yield of meal equal to 19–20 sextarii per modius of wheat. (2) Forty-eight asses was Pliny's price of one-grade flour produced from *triticum* with low milling costs and with the yield of flour equal to about 14

[3] Actually the bran in the three-grade grindings was somewhat poorer in quality than that obtained in the one-grade grindings.

[4] Extraction percentages from table on p. 154.

sextarii per modius of wheat; or of the second flour grade (28th–71st extraction percentages) produced from *triticum* with low milling costs and with the yield of this grade of flour equal to 8 sextarii per modius of wheat. (3) Fifty-six asses was Pliny's price of one-grade flour produced from *siligo* wheat, with low milling costs and with the yield of flour equal to about 14 sextarii per modius of wheat; or of the second flour grade (45th–71st extraction percentages) produced from *siligo* with low milling costs and with the yield of this grade of flour equal to 5 sextarii per modius of wheat.

Flour and wheat price relationships in Palestine. — *Sōlet* was the ground product used by the Jews in sacrifices. The term is commonly translated to mean fine or finest flour; but Dalman[5] made it appear very probable that *sōlet* was something resembling the American farina or semolina. *Sōlet* was made reasonably free of bran by a large number of resiftings (perhaps as many as 13). In Russia a similar product made from durum, the type of wheat from which *sōlet* was made, is still believed to yield the finest bread. *Sōlet* was the most refined product of grinding not only of the Jews, but, so far as evidence is available, of all ancient peoples. Hence the price of *sōlet* in relation to the price of wheat is likely to have been higher than was the price of the first grade of the Roman three-grade grinding in relation to the price of wheat in Rome.

According to the Mishnah,[6] 1 seah of wheat cost 1 denarius in Palestine in the second century A.D., while for 4 denarii 3–4 seah of *sōlet* could have been obtained. Herzfeld,[7] who apparently believed that flour was twice as high in price as wheat in antiquity, commented, "Hence it [*sōlet*] surprisingly was almost not more expensive than wheat." After the preceding analysis, the reader will not share in Herzfeld's surprise but on the contrary will find the price relationship fairly reasonable.

The evidence of the Mishnah is of course inexact; the prices of wheat and *sōlet* do not pertain to the same time. If the ground products were packed in Palestine as tightly as in Rome, we would expect for *sōlet* a slightly higher price relative to wheat than that indicated by the evidence. But we are interested only in the order of magnitude here, and the price relationship stated in the Mishnah is well within this order.

Price difference between triticum and siligo wheats. — The considerable preference for *siligo* wheat over *triticum* in classical Greece and Rome is common knowledge. Students may nevertheless find useful the numerical expression for this preference. As this is revealed by our analysis of Pliny's flour prices, *siligo* wheat appears to have cost 17–20 per cent more than *triticum* in Rome at Pliny's time.

Pliny's flour prices as evidence of one-grade flours.—The analysis of Pliny's flour prices furthermore provides contributory evidence for existence of one-grade flours in classical antiquity and for the assumption that the extraction of this flour was high. In favor of the existence of such flours is the fact that the price relationships implied in Pliny's flour prices are much more reasonable if in his statement *similago* and *siligo* were one-grade flours. For the possibility that in that statement *similago* and *siligo* were the second grades, we had to accept the view that *pollen* (the first grade of flour from *triticum*) cost as much as the second grade of flour from *siligo*, although this price relationship does not seem probable. It is also doubtful that the price of *siligo* or a flour representing the extraction percentages 45th–71st was 16⅔ per cent higher than the price of *similago* representing the 28th–71st percentages. On the contrary, one finds very reasonable the line of prices: 40 asses per modius of the meal from *triticum;* 48 asses per modius of one-grade flour from the same wheat; and 56 asses per modius of one-grade flour from the preferred *siligo* wheat. This speaks strongly for Pliny's *similago* and *siligo* having been one-grade flours.

Furthermore, on the same possibility that *similago* and *siligo* were one-grade flours, *similago*, a one-grade flour from *triticum*, cost 20 per cent more than *farina*, a whole-grain meal

[5] *Op. cit.*, pp. 292–96.

[6] *The Mishnah*, Peah, sec. 8, par. 7, and other places, and Shekalim, sec. 4, par. 9. See also Levi Herzfeld, *Handelsgeschichte der Juden des Alterthums* (Braunschweig, 1879), pp. 185–86.

[7] *Loc. cit.*

from the same wheat. This is the price relationship in terms of volume. Since the one-grade flour packed more tightly, the price difference between them was not much more than 10 per cent in terms of weight. This is a strong indication that, providing *similago* was a one-grade flour, its extraction was high. The return for the wheat ground into *similago*, a one-grade flour, would have been less than for the same wheat ground into *farina* (whole meal), if the extraction of *similago* were materially lower than around 80 per cent.

Were Pliny's flour prices retail prices?— So far as the present writer is aware, the question has not been raised whether Pliny's flour prices were wholesale or retail prices. But the price of wheat computed from Pliny's flour prices has always been treated as a wholesale price, and in computing the milling costs no provision has been made for retailing. Hence, one must conclude that Pliny's flour prices have also been considered as wholesale prices.[8]

There is, however, some indication that Pliny's flour prices may or might have been retail prices. Every figure given by Pliny, when divided by 16, yields a whole number or a whole number plus one-half. Was this mere chance? Pliny's price of 40 asses for *farina* is a round figure adequate for a broad estimate, as Pliny may have wanted it to be. But why should the wholesale price of *siligo* have been exactly 8 asses higher than that of *similago?*

The procedure would not have been very rigorous from the modern statistical point of view, but Pliny may have started from prices of *farina, similago,* and *siligo* of 2½, 3, and 3½ asses per sextarius. These probably were retail prices because bakers, who now are commonly the principal and frequently the only local wholesale buyers of flour, produced their own flour in classical antiquity. An extensive interstate or intrastate trade in flour was also unlikely. The principal transactions in flour may have been between the miller-bakers and the consumers, the latter buying—along with their bread — small quantities of flour for cooking.

If Pliny's flour prices were retail prices, wholesale prices for wheat corresponding to them must have been less than those computed above. The margin between wholesale and retail prices, of course, is not easy to estimate. But it could not have been large, because the flour probably was mostly sold in the city where it was produced and indeed was probably retailed by the miller himself, and because the individual milling establishments were very small. A margin of 15–20 per cent of the wholesale price, accepted here, appears certainly to be too high. In estimating the retailing margins, we sought to provide for a possible overestimation of the price of bran and *cibarium* and a possible underestimation of the milling costs in our computation. Another and much stronger desire was to bring down the computed price of wheat as much as seemed consistent with the evidence.

With this final assumption that Pliny's flour prices were retail prices, the wholesale price of *triticum* wheat corresponding to Pliny's prices of *farina* and *similago* becomes equivalent to about 8 sesterces and the price of *siligo* wheat corresponding to Pliny's price of *siligo* flour to about 10 sesterces.[9]

Price Relationship between Flour and Wheat

The wheat prices reached in the preceding analysis were obtained directly from the prices of flour without reference to the relationships between flour and wheat prices, the procedure usually employed by other students of the classical evidence. Conclusions obtained from such price relationships necessarily yield very

[8] In the main, the nature of the evidence for so remote a period as classical antiquity does not justify raising the question whether a certain price was at retail or at wholesale. But the question is seldom raised in historical studies even when the nature of the price can be specified. The difference between wholesale and retail prices is frequently so large as to destroy much of the value of conclusions drawn from prices of unspecified nature.

[9] In the effort to find a reasonable way toward further downward interpretation of Pliny's flour prices, the possibility has been contemplated that in the Roman retail trade it was customary to give to the customer a good measure of flour as is usual in this country in retail sales of fruits and vegetables by the measure. But this would have meant that a modius contained less than 16 of such retail sextarii. Pliny would hardly have failed to know this, and the procedure of arriving at prices per modius by multiplying retail prices per sextarius by 16 would have been even more objectionable.

inexact results and indeed are superfluous when the more exact direct method can be used. Yet for the benefit of those who are accustomed to think in terms of flour-to-wheat price relations our study may be concluded with a short analysis of these relationships. To avoid misunderstanding, let us emphasize that the following analysis is in terms of weight.

It was stated that some students who analyzed Pliny's flour prices considered the price ratio of 1.5:1 between flour and wheat as standard for the present time. This ratio is correct as an approximation; in countries with low to moderate wheat prices, flour may even cost relatively more. Where wheat is expensive—and it was expensive in Rome—the present-day price relationship between flour and wheat tends to be somewhat less than 1.5:1.

Prices of flour and wheat and the ratios between these in a few important countries are compiled in the following table. Years preceding the big depression of the 1930's were used advisedly, because such low prices as were observed during this depression in countries with no or little government protection have no precedent in the known history of grain prices. Another reason is that in some countries with high protection of wheat prices the price relationship between flour and grain during the depression was narrowed by government action, such as the raising of flour-extraction rates, admixture of coarse grain with wheat, and the like.

Most of the ratios computed in the table are unfortunately not really suitable for our purpose. For this, the prices ought to be of a given wheat and of the flour made from it. Also, the flour price ought to be that of one-grade flour such as the "straight run" of London or that of a flour grade equivalent in quality to such a "straight run." Only a few market prices satisfy both requirements.

The price relationship at Melbourne in the table is the only one fully adequate for our purpose. The Melbourne flour is a "straight run" made from the local wheat to which the price used in the computation pertains. But the Budapest flour price is too high for our purposes because grade 0 is the best flour grade among many. The flours of Minneapolis and Kansas City were also of higher-than-average grade, while the prices used in Berlin and Paris are for flour of lower-than-average grade. As to the other flours, we must reserve judgment. Owing to the admixture of expensive foreign wheats, the wheats used in the production of the Berlin and Paris flours cost somewhat more than the domestic wheats, the prices of which were used in the computation. It may be noted that the inaccuracies in the prices of flour and wheat used in the computation of the price relationship for Berlin and Paris tend to offset one another. But no such compensation occurs in the case of Kansas City and Minneapolis.

PRICE RELATIONSHIP BETWEEN FLOUR AND WHEAT IN SPECIFIED COUNTRIES, AVERAGE 1925–29*

Market	Grade of flour	Type or grade of wheat	Ratio of flour price to wheat price (wheat price: 100)
Berlin, Germany	000	Local	128.4
Paris, France	....	Domestic	130.0
Budapest, Hungary	0	....	167.7
Milan, Italy	....	Soft	133.4
United Kingdom	London, straight run	All imported	148.0
Kansas City	Winter patent	No. 2 Hard Winter	174.2
Minneapolis	Standard patent	No. 1 Hard Spring	178.3
Buenos Aires, Argentina	00	Barletta	142.9
Melbourne, Australia	Export grade	Standard grade	130.8

* Official data reproduced from *Revue de l'Institut International de Statistique*, 1933, 1 année, p. 90, and similar sources. The wheat price in Germany is increased by 11 German marks per metric ton to bring it to the basis of free-on-rail Berlin—the basis to which the price of flour pertains. The price of all imported wheat in Great Britain is taken from the customhouse returns.

According to the table above, the flour price in Kansas City and Minneapolis exceeded the wheat price by 74 and 78 per cent, respectively. Yet the detailed analysis of the accounts of many mills by the United States Federal Trade Commission[1] revealed that in 1913–14[2] millers' receipts per barrel of flour averaged $4.15, while their outlay for 4.42 bushels of wheat used per barrel of flour amounted to $3.96. These figures indicate that the price of the average flour was only 42 per cent

[1] *Op. cit.*, pp. 43, 97.

[2] That year was quite as representative as any other.

higher than the corresponding wheat price.

After allowing for all such discrepancies, we conclude that in countries with high wheat prices, such as France, Italy, or Germany, the flour price, in terms of weight, tends not to exceed the wheat price by more than a third. In countries with low to moderate wheat prices, the flour prices tend to be higher than the wheat price by more than a third, but a ratio of 1.5:1.0 is rarely exceeded.

The prices of millfeed and sacks, the quantity of flour extracted, and interest rates are factors other than the level of the wheat prices which affect the price ratio. The highest price ratios are probably those observed in the United States and Canada. High wages, and especially the practice of selling a barrel of flour in two relatively small new sacks (98 lbs. each) are responsible for this. The price relationship in Great Britain may also be relatively high, owing to the low extraction of flour.

With the usual amount of the extracted flour varying from 72 to 74 per cent of the wheat, a price of flour equivalent to 139–135 per cent of the wheat price implies that the return for the flour covers the cost of the wheat. Thus, in countries with high wheat prices all costs of milling, including sacks, marketing, bad debts, and profits, are less than the return for the millfeed. As shown by the price relationship between flour and wheat in Melbourne, mills manage to work for less than the cost of millfeed, even in some countries with rather low wheat prices. The millers of North America are among the few which need more, though not much more.

In the conversion of Pliny's flour prices to wheat prices in which *similago* and *siligo* were supposed to have represented one-grade flours with an extraction of 80 per cent from *triticum* and *siligo*, respectively, the computation leads to a price ratio between wheat and flour of 1:1.33⅓ (80 weight units or 88 volume units of *similago* cost 42.24 asses while 100 weight units of wheat cost 40 asses). In comparing this ratio with the present-day ones, one should not forget that several factors tended to depress the price ratios in antiquity: the extraction of flour in ancient Rome was considerably higher than the common extraction of all flour is now—80 per cent as against 70–75; the flour prices were in bulk; and marketing costs—not including retailing, taken care of separately—probably were veritably absent.

The first draft of this study was written in 1940 when the writer was on the staff of the Division of Statistical and Historical Research, Bureau of Agricultural Economics, United States Department of Agriculture. The writer is very grateful to the Social Science Research Council for a grant-in-aid used in finishing this and continuing other studies on grain in classical antiquity. Professor F. C. Lane of The Johns Hopkins University made very valuable critical suggestions concerning the form of presentation. The co-operation of Dr. M. K. Bennett and Dr. V. P. Timoshenko, of the Food Research Institute, were greatly appreciated. Thanks are due to Miss Helen E. Hennefrud of the United States Department of Agriculture Library for a very careful verification of quotations and references.

Since Professor M. Rostovtzev, Yale University, in his fundamental study "Frumentum" in Paulys Real-Encyclopädie . . . . *summarized all the principal findings on grain in classical Rome that were generally accepted at the time of writing, his responsibility for the opinions criticized in this study is much smaller than may be suggested by the foregoing pages. His sincere and strong encouragement of the writer to proceed with historical studies and specifically to publish the present one, which he was the first to see, is the more appreciated and admired.*

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