TOOLS & TILLAGE

Edited by Grith Lerche, Alexander Fenton
and Axel Steensberg

Vol. VI:1 1988

NATIONAL MUSEUM OF DENMARK, COPENHAGEN

TOOLS AND TILLAGE

A Journal on the History of the Implements of Cultivation and other Agricultural Processes

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TOOLS AND TILLAGE has appeared once a year since 1968 and contains not less than 60 pages. The subscription price is 85 D.Kroner. If paid in another currency a fee equivalent to 30 D.Kr. should be added, postage not included. Payment, please, only on receipt of invoice. Subscription as well as single issues are obtainable from the address below.

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Address for all communications: International Secretariat for Research on the History of Agricultural
Alle Zuschriften erbeten an: Implements. National Museum, Brede, DK-2800 Lyngby, Denmark.

The Journal acts as a guide to research in every aspect of the subject, not only the implements themselves, but also field systems and methods of cultivation and cropping, including linguistic as well as functional aspects. Its coverage is from the beginnings of cultivation to the industrial era in every part of the world. The primary emphasis is on material relating to Europe and such areas as have influenced or have been influenced by Europe, by contacts within recent centuries, and with regard to the historical development of agriculture through its actual practice and through written theory. In this way TOOLS AND TILLAGE can consider, inter alia, links between China and Europe, and between Europe and the New World.

Die Zeitschrift wirkt als illustrierter Führer durch alle Sparten der einschlägigen Forschung und behandelt nicht nur die Geräte selbst, sondern auch die Feldwirtschaft und die Struktur der Felder sowie sprachliche und funktionelle Aspekte. Die ins Auge gefaßte Zeitspanne reicht von den Anfängen des Bodenbaus bis zur Industrialisierung in allen Teilen der Erde. Das Schwergewicht liegt auf Materialien mit Bezug zu Europa und solche Gebiete, die Europa beeinflußt haben oder von ihm durch Kontakte in vergangene Jahrhunderten beeinflußt wurden, und zwar im Hinblick auf die geschichtliche Entwicklung des Ackerbaus durch seine praktische Ausübung und die schriftliche Darstellung seiner Theorie. Dadurch kann sich TOOLS AND TILLAGE beispielsweise Verbindungen zwischen China und Europa und zwischen Europa und der Neuen Welt befassen.

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Grants from the Danish Research Council for the Humanities.

Printed and Published by
Poul Kristensen, DK-7400 Herning, Denmark
Printer to the Royal Danish Court

ISSN 0563-8887 ISBN 87-7468-451-5

A METHOD FOR IDENTIFYING GRAIN STORAGE TECHNIQUES AND ITS APPLICATION FOR EUROPEAN AGRICULTURAL HISTORY

By

*François Sigaut**

Except for a few special cases, staple foods, especially grain, have usually to be kept some time in storage before being consumed, so that their preservation is a matter of importance almost everywhere. Yet in comparison with the other stages in the acquisition of food – tillage, planting, harvesting, processing – storage seems to have been somewhat neglected by scholars. It was only in the mid 1970s, for example, that economists and other experts working in developing countries came to realize that losses due to bad storage conditions could make all their efforts to increase yields pointless.[1] As far as history and anthropology are concerned, Marceau Gast and I became aware of a similar discrepancy at approximately the same time. The social importance of food and grain storage had always been understood by some scholars, but serious studies were few and far between, with practically no comparative work to speak of. What were the causes of this situation, and what could we do about it?[2]

A full discussion of causes is not in order here, but some deserve to be mentioned briefly. Thus, the disappearance of famines in Western Europe was a factor: it is surprising to observe how quickly grain storage, as a matter of public debate, vanished after about 1850.[3] But the remoteness of scholars from grass-root realities may well have been more important yet. For example, V. Gordon Childe himself seems to have adhered to the widespread belief that the conservation of grains is "easy", only forethought, thrift, and convenient receptacles being necessary.[4] Granted, grains keep more easily than most other kinds of food, and technical improvements in the course of the last 150 years have made their conservation easier still. But it takes a complete ignorance of those very improvements to extend to all places and times a result that has been attained in the last decades and in areas of temperate climate only. Indeed, the prevailing opinion in the early 19th century was exactly the opposite of Childe's. Here are, for example, the first few lines of *Des fosses propres à conserver les grains* ..., a book published in 1819 by one of the main French industrial writer of the time, C.-P. de Lasteyrie:

"Grains being very susceptible of getting spoiled or lost by the effects of atmospheric variations, by moistness, and by the ravages of insects, the first agricultural peoples must have looked for the means to conserve a produce that was their only, or at least their main subsistence; so the invention of *fosses à blé* [corn pits], which seems, and indeed is, the simplest of all that have ever been tried, dates

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Errata: p. 4 col. 2 l. d-1
p. 6 col. 1 l. 1
p. 15 col. 1: appel fig. 6

p. 32 Rystedt (date)

back to the highest antiquity. But this method, which seemingly ought to have been adopted by all agricultural peoples, was concentrated in certain areas and could not extend farther, in spite of the advantages it presents and of the preference it deserves."

To this day, this excerpt is perhaps one of the best available statements of the problem of grain storage in a historical perspective. Grains are *not* easy to keep in storage, and no amount of thrift alone can ensure that they will be. Specific techniques (methods, equipment and skills) have to be resorted to. And these techniques, like all other cultural traits, show a distribution through time and space that cannot be explained away with the help of simple assumptions about climate, wars, traditions, or whatever more or less logical idea happens to be available.

Such, at least, was our starting point. The air-tight *fosses à blé*, vigorously advocated by Lasteyrie, contrasted so sharply with the traditional European granaries, where it was thought indispensable to ventilate the grain by frequent shovelings, that their functioning, and even their very existence, was open to question (most Europeans refuse to believe it possible today). To settle this question meant to ascertain the technology, not only of grain-pits, but also of the traditional granaries themselves – which is much less evident than we are inclined to believe – and finally of all the methods of grain storage that are known to have been used somewhere sometime. But it soon became obvious to us that such a task was beyond the means of one or a few researchers. As many colleagues as possible had to be called in for help. To that end, a conference was organized at the former abbey of Sénanque (Provence) in March 1978. The response was such that it was followed by two others, at Arudy (Béarn) in June 1978 and at Levroux (Berri) in November 1980. The proceedings of the conferences have been fully published: 76 communications by authors from 14 countries were gathered.[5]

This paper does not propose to summarize this, and the other publications on grain storage that have appeared before and after. The problems are so many and have so many aspects that just to list them would make a long and tedious paper.[6] Instead, what is intended here is to give an idea of the kind of details that must be taken into account together for unequivocally *identifying* grain conservation techniques, and to present some results of this approach for a better understanding of the agricultural past of Europe.

Identifying grain conservation techniques
To identify a thing is to learn how to differentiate it from other things that look more or less like it, or in other words, to find out not only what the thing is, but also what it is not. Techniques are no exception. A technique cannot be described by itself, in isolation as it were, because to describe it requires the knowledge of relevant criteria, which cannot be identified other than by comparison with other techniques. What I call identification is the specific task of finding out such criteria. For grain storage, as for many other techniques, it proves convenient to proceed by addressing the two following questions: exactly *what* is stored, and *how* is it kept in storage, i.e. what specific means and methods are used to ensure its conservation during that time?[7]

What is stored?

To answer this question is to tell the stage in the processing of grain between harvest and the final product (bread, porridge) when storage takes place.

Porridge, of course, cannot be kept more than a few hours. But dried bread was important locally, and for the use of armies and navies (*biscuit de mer* in French). Noodles and other pasta products are also conveniently storable, but they became important with industrialisation only.

Flour is usually not considered important as a stored item. However, letting it lie some time in storage may improve its baking qualities, and its conservation had also to be ensured under the difficult conditions of maritime transport when it was exported overseas. In the 18th century, large quantities of flour were sent from the French Atlantic ports to the West Indian colonies; after being dried, the flour was packed as tightly as possible into casks which were then hermetically sealed. But the mere fact that wheat, barley or rye flour can be conserved for a few weeks or months in temperate climates has been of primary importance for the history of machinery. By allowing each household to have about one month's provision of grain milled at once, it made profitable the development of bigger mills in Europe. Whereas in most millet- and rice-growing areas, the fact that dehusked grains or groats cannot be kept more than a few hours makes it necessary to process them daily, preventing a similar development. In western France, where water- and windmills are by no means less developed than anywhere else, millet continued to be pounded with the mortar-and-pestle well into the 19th century.[8]

However, dehusked grains and groats can be made much fitter for storage by parboiling, i.e. the soaking of the whole grain in hot water and its drying previously to pounding or milling. The technique of parboiling occurs in a strangely discontinuous pattern. Parboiled rice is standard in India, for example, but appears to be completely unknown in the Far East (China, Korea, Japan and the Indochinese peninsula). Parboiled wheat, *bulgur*, is standard in Turkey and neighbouring areas of the Near East and in Tunisia, but not in Iran nor in Egypt nor in Maghreb outside Tunisia. Finally, parboiled oats, *Talggn, Haberkern,* etc., occur in eastern and central Europe up to Switzerland in the west. The occurrence of *bulgur* in Tunisia may be explained by the historical links of that country with Turkey, but obviously, the general distribution of parboiling in the world cannot be understood without consideration of food habits as a whole. In wheat-consuming areas, parboiling is conspicuously absent from countries where the emphasis on bread is strongest. In western Europe, the traditional importance of both bread and beer may have prevented its adoption. Which reminds us that beer and malt are also stored items of primary importance in northwest Europe.[9].

Although this enumeration of cereal products as more or less storable items is far from complete, I shall not go into further detail here. Most processed cereal products are in fact beyond the scope of this paper, either because they are of local importance only, or because they do not require specific conservation techniques other than the processes to which they have been submitted. Just to keep out moisture, insects, rodents – and thieves – will do in most cases, especially for products like biscuit, pasta, bulgur, etc., that have been made more or less biologically inert. It is for such products that Childe's opinion is valid: a measure of care and the use of proper receptacles are about all that is needed to conserve them in storage.

Things are quite different with living grain, intended to be kept biologically active. It may well be asked why it is necessary to keep live grain at all, beyond what is needed as seed. The question is perhaps not as naive as it sounds. Actually, the most usual answers do not look very encouraging: grain is kept alive basically because it is kept unprocessed, and it is kept unprocessed either because the whole harvest cannot possibly be processed at once, or because the processed products themselves do not keep easily, or both. But there are most specific and interesting reasons. Grain has to be kept living for beer-making by malting, for instance. And to keep it living can also be a simple consequence of the development of commerce, since regular exchanges imply the existence of fixed quality criteria on which buyers and sellers can agree. We are prone to take such criteria for granted today, but we should perhaps pay more attention to them in a historical perspective. Finally, consider an element that is not frequently mentioned in connection with storage, the technique of sowing. Where broadcast sowing is the most common mode, as in Europe, Northern Africa and Western Asia, the yields lie between 3-4 and 10-15 times the seed sown, which means that a household of four, consuming one tonne of grain each year, may have to keep in store as much as 300 kg of seed. By contrast, in most other countries where cereals are either dibbled, drilled, or transplanted from a nursery, the yields lie between 30-50 and 200 to one, meaning that only 5 to 50 kg of seed may be necessary. Clearly, this changes the basis of the problem altogether.

However, living grain too, like processed grain, comes into consideration under a number of different forms for storage, the main ones being:

1, grain in bulk, i.e. threshed and winnowed,
2, grain in bulk with chaff, i.e. threshed but *not* winnowed,
3, ears, unthreshed but separated from the culms,
4, ears with the culms still attached, but not bound,
5, sheaves, i.e. ears with culms, bound together.

It is essential to distinguish all those different forms as specifically as possible, because each one has its specific physical constraints and requirements. Grain in sheaves is relatively protected against heating and insect damage (in a temperate climate), but it occupies a much larger volume than threshed grain, which conversely is much more liable to every kind of deterioration. As a rule of thumb, it may be said that the less voluminous the form under which grain is stored, the more work and skill it requires for its preservation. There is no clear-cut alternative, however, since the overall cost is a function of both. Volume can be costly inasmuch as it requires large buildings, but work and skill are costly too.

How is it stored?

As already said, this question relates to unprocessed grain mainly; from now on, processed cereal products will be left out of the discussion.

Before putting grain into storage, however, it is often necessary to submit it to some preparation. So it is convenient to distinguish two succeeding stages:

– operations taking place before storage proper, essentially drying,
– operations taking place during storage, in order to prevent any undesirable change within the stored grain.

The latter consist in a more or less effective control of the atmosphere surrounding the grain. The degree of control actually achieved is of course quite difficult to assert in many cases, but the means intended to achieve it are usually unambiguous. According to them, three methods of storage will be distinguished: a, storage with ventilation, i.e. the permanent or frequent use of the outer air to renew the atmosphere surrounding the grain,
b, hermetic storage, i.e. storage made as airtight as possible to preclude contact between the grain and outer air,
c, no-control storage, i.e. closed storage, but

without apparent devices for ensuring ventilation or airtightness.

Drying

Most frequently, drying occurs spontaneously as it were, as the harvested crop is waiting for transport or for further processing, etc. There are in addition many cases in which this "natural" drying is intentionally assisted by temporarily exposing the crop to the sun or wind, and in Europe at least, examples are numerous and quite well recorded in the ethnography. By contrast, artificial drying, i.e. the use of an artificial source of heat, seems rather infrequent. It is known from some of the moister rice growing areas of Western Africa (Guinea) and of Madagascar: the paddy spikes are stacked under the roof and over a fire kept more or less constantly burning, either in the kitchen itself, or in a separate room specially intended for the purpose. This "smoked" rice is said to acquire a taste not appreciated by people living outside the areas concerned. Similar practices are to be expected from the numerous regions of Southern Asia where climatic conditions are at least as humid as any in Africa, but I have no information about them. Finally, one of the largest areas of artificial grain drying may well be Northern Europe, but with an important difference between the eastern and western parts. East of the Baltic, the grain was dried in sheaves, that is *before* threshing; it was done in special buildings resembling barns, called *riga* in Russian, where a fire was kept burning. In Northern Britain on the other hand, grain was dried *after* being threshed and winnowed, in often beehive-shaped kilns. This process is basically similar to that used for drying malt, *touraillage* in French; with it, temperatures reached within the grain are such that both its germinating ability and, in wheat or rye, the elasticity of the gluten, can be destroyed.[10]

It would be misleading, however, to assume that the importance of grain-drying is simply a function of the humidity of the climate. Humidity is itself a seasonal variable, but other factors come into play, chiefly the maturity of the grain when harvested, and the form under which it is intended to be stored. It is well known, for example, that grain to be stored in bulk has to be drier than grain to be stored in the ear or in sheaves: this was one of the main factors that delayed for one century the adoption of the combine-harvester in the wheat-belt of North America. The consequences of the replacement of the sickle by the scythe in Europe are also well known: to avoid losses by shattering, the crops had to be mown earlier, before full maturity; the sheaves had to be left longer on the fields for ripening and drying, which made necessary the adoption of more elaborate forms of ricks, *moyettes* in French, specially contrived for the purpose. In a few cases, moreover, grain is harvested quite unripe, either intentionally as with the *Grünkern* (unripe spelt) of Würtemberg, or simply because the whole crop does not reach maturity at the same time, as with maize in Southeast Burgundy: in such cases, immediate drying is necessary, the grain being more or less parched or toasted in the process. Finally, seasonality is important, the more so since it is not infrequently overlooked. One cereal variety may need drying just because it matures a few weeks later than another. In Asturias, Northwest Spain, spelt is sown late, until Christmas, and it is also harvested late, in September: being stored in spikes, it is not artificially dried. But it is a question whether late-maturing cereals like spelt are not the simplest explanation for the presence of grain-drying kilns in Roman and medieval times in places where they have since disappeared. Seasonality is even more important in monsoon countries like China or India: cool season crops like wheat or barley are harvested just before the rains come, and may therefore be more difficult to store than millets or rice that ripen after the rains.[11]

To sum up, the importance of drying is a function of at least four factors: (a) the overall humidity of the climate, (b) the exact place of the harvest time within the seasonal cycle, (c) the stage of maturity of the grain at harvest, and (d) the form under which grain will be put into storage. Factor (a) is prevalent under rather extreme and infrequent conditions only. Factors (b) to (d) depend less on environmental than on technological conditions. Maize in France in the 1970s is a classic example. There was in those years an abrupt and massive development of maize-drying equipment, not because of any climatic change, but because the combine-harvester replaced the corn-picker, so that the maize harvest was increasingly delivered in bulk. With humidity ratios reaching 30% and more, maize ears can still be stored in cribs, but grain in bulk will heat and spoil in a matter of days or hours if not immediately dried.

Storage with ventilation

The basis of this method is the use of external air to stop heating, moulding, or any other unwanted phenomena likely to occur in a mass of stored grain. Of course, the method is appropriate only to fairly cool or dry conditions. In Europe, stormy weather was well known to be bad for stored grain, and people usually hastened to shut the windows of the granary as soon as a storm threatened. In tropical countries, stored grain is left exposed to air in the drier regions only.

There are two ways of putting grain into contact with air:

a, letting or making air circulate through the grain,

b, tossing the grain in the air, shoveling, French *pelletage.*

Shoveling is used with grain in bulk only, and examples of shoveling grain under other forms are of marginal importance (maize ears in Southwest France before 1950 ...). Shoveling has been the standard method of conservation used in urban, military and commercial granaries in non-Mediterranean Europe since early modern times and possibly earlier. But beside this nearly self-evident observation, the lack of reliable data is such that very little can be said. Shoveling does not appear to have been known by Roman agricultural writers, nor does it seem to be used outside the European culture area. But the chronology is rather obscure within Europe itself. Shoveling in peasant storage is an unanswered question: since it was so general within living memory, we are inclined to see it as ancient, but I wonder if it came into common use before the end of the 18th century.[12]

Aeration proper, i.e. the forcing of air through the grain with bellows or machine-fans, did not came into common use until well into the 20th century. It was first tried in

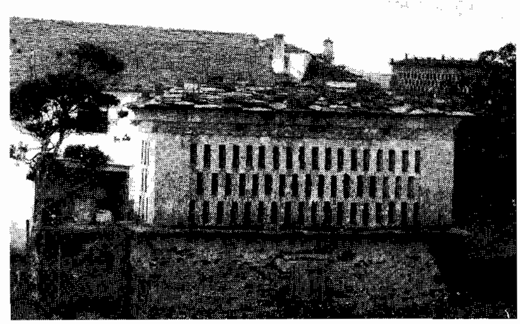

Fig. 1. Elevated granary, Galicia, Spain. Note the vertical openings for ventilation, and the overhang between the granary and its supporting basement to prevent climbing by rodents. Photo: F. Sigaut 1979.

Erhöhter Kornspeicher, Galizien, Spanien. Man beachte die vertikalen Lüftungsöffnungen und die herausragende Schürze zur Abwehr von Nagetieren zwischen Kellergeschoß und Speichergeschoß.

Fig. 2. Elevated granary, Asturias, Spain. Square plan, posts with rat-guards, wooden walls, no ventilating devices. Photo: F. Sigaut 1979.

Erhöhter Kornspeicher, Asturien, Spanien. Quadratischer Grundriß, die Pfosten mit Ratten-Abweisern, hölzerne Wände, keine Belüftungsvorrichtungen.

France by Duhamel du Monceau in the 1740s, and repeatedly throughout the 19th century, without really practical results. In fact, to force air through a thick mass of grain in bulk causes rather complex transfers of heat and dampness within it, that were not well understood before the 1950s. Lacking such knowledge, aeration procedures were either unduly expensive, or too hazardous to be practical.[13]

By contast, *ventilation,* i.e. allowing air and wind to circulate freely through the grain, was and still is quite widespread in pre-industrial agricultures. But it applies almost exclusively to grain stored in the ear; examples of ventilating devices for either grain in bulk or sheaves seem rather infrequent.[14]

From its very nature, ventilated storage is usually highly visible. Maize ears hanging from under the eaves are or were a common aspect of many landscapes, and ventilated granaries can be so inescapable as to become the emblem of a whole region, like the notorious *horreos* and *espigueiros* of Galicia and Northern Portugal (fig. 1). Their modern counterparts, *cribs,* still stand as interminable barriers across the plains of central France. In that country, cribs were introduced after World War II only, as part and parcel of the package of innovations coming from America with the new hybrid varieties of maize; their earlier history, in America as well as elsewhere in Europe, is unknown to me. However, cribs and espigueiros are substantially identical from a functional point of view: both are designed to hold maize ears between narrowly-spaced and permeable walls, so that the wind may pass through them freely. The main differences are the materials used – many espigueiros are masterpieces of wood or stone working, whereas cribs are makeshift wire-netting structures marring the landscape – and their position relative to the ground: cribs are set near ground level (in France at least), and espigueiros are built high above ground level on posts or on some other kind of basement. The etymology of Port. *espigueiro* (mediev. Lat. *spicarium*, "a granary for spikes") suggests that granaries especially designed for the storage of ears did exist well before the arrival of maize, for storing millets or spelt probably. And the fact that Germ. *Speicher* has the same Latin origin suggests that storing grain in the ear may have been much more widespread in ancient and medieval Europe than in modern times. We shall return to this discussion later.[15]

Finally, although all elevated post-granaries have some architectural features in common, it must be stressed that they are by no means functionally similar. Some "granaries" are not granaries at all, but are intended for the processing and storage of fish. In areas where houses are built on posts (Southeast Asia), granaries are built on posts too, but grain is stored there in bulk without any attempt at ventilation. African granaries are not designed for ventilation any more, although grain is kept there in ears rather than in bulk. In Europe, most elevated granaries known from recent sources are quite different from the "elevated cribs" of Portugal and Galicia. This has been pointed out long ago for the *paneras* of Asturias (fig. 2) and the *garaixe* of the Basque country: in contrast to the espigueiros, they are squarish and unventilated buildings, and they are designed for the storage of every kind of crop and other valuables. The same probably holds true for the elevated "granaries" known here and there in Europe (Sweden, England, the Netherlands, Hungary, etc.), although exact information on what is stored in them is often lacking. On the other hand, the *raccards* or *Stadel* of Switzerland can be unambiguously defined as barns, because they are specifically designed for the storage of sheaves, usually with a threshing floor inside.

A characteristic feature of most elevated granaries is the presence of wooden or stone discs between each post or other supporting point and the part of the structure in contact with it, in order to prevent climbing by rodents. Such discs – it is proposed here to call them *rat-guards* – are common in Europe and northern Asia, but they seem to be unknown in Africa and southern Asia. Several explanations can be imagined to account for this rather puzzling difference, the less idly speculative being perhaps the following. Let us assume that in northern Eurasia, most elevated storage structures are or were built so as to be freely ventilated, that is with walls highly penetrable by the wind; such walls would be almost necessarily penetrable by rodents also, so that specific obstacles to stop them before they could reach the walls would be indispensable. In most tropical countries on the other hand, elevated granaries are usually not ventilated, so that the walls have no built-in openings and are (or are supposed to be) sufficiently rodent-proof by themselves.[16]

Hermetic storage

This method still surprises most people in Europe today, including many cereal storage specialists. However, hermetic or air-tight storage in underground pits has probably been the most widespread method in the whole world until the 18th century for the conservation of grain in bulk. About 1800, it prevailed in an immense area extending from Morocco and Spain to India and China, and also in eastern Africa (Ethiopia, Somalia, Sudan), in Madagascar, in northern America west of the Mississipi Valley, and elsewhere. In Europe, underground pits were standard in Spain (the northwestern provinces excepted), in Italy (Tuscany and south of Na-

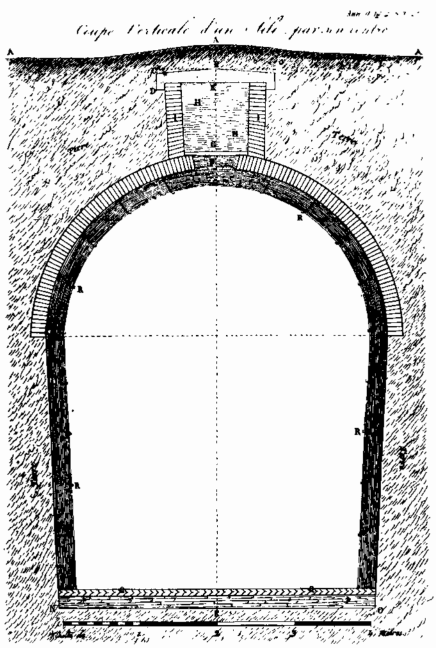

Fig. 3. Silo. Section through one of the silos dug by Ternaux near Paris for his experiments with airtight storage. Drawing of 1824 (Sigaut 1978, 10). Photo: Musée National d'Histoire Naturelle.

Silo. Schnitt durch eins der Silos, angelegt von Ternaux in der Nähe von Paris für seine Experimente für luftdichte Einlagerung. Zeichnung von 1824 (Sigaut 1978, 10).

ples), and in the Southeast (Danubian Plain, Balkan Peninsula, Ukraine ...); in France, they were formerly common in the Southwest (Gascony, Haut-Languedoc), where, however, they fell into disuse during the 17th century. In many European regions, underground grain pits continued in use well into the 19th and even the 20th century. They are still, or were quite recently used in some areas of Maghreb, of Turkey, of Ethiopia, etc.[17]

There is something very strange about the history of air-tight storage. Traditional underground pits are of course obsolete, but it must be stressed that as a method, air-tight storage is not. What is most striking about it, in fact, is its attractiveness for the scientifically minded. Biochemically speaking, a mass of grain in bulk in contact with air is in a state of unstable equilibrium: any biological activity starting up inside it (by insects, fungi, or both) produces heat and moisture, i.e. the very conditions for further propagation of that activity. So "heating" is a kind of chain-reaction, and can result in the spoilage of a whole mass of apparently healthy grain in a short time if not prevented by regular shovelings or cleanings. But the heating process cannot take place without a free supply of oxygen: in an airtight receptacle, it has to stop as soon as the oxygen initially present has been used up, that is usually well before any substantial damage has been done.[18]

Of course, things are not quite so simple, and a thick book would be necessary to account for all the details. But this short explanation is basically true, and it is sufficient for our present purpose. Only a few additional remarks must be made.

There is a long history of research on air-tight grain storage, beginning with the experiments by Ternaux, Lasteyrie and others in France in the 1820s (fig. 3). Those first experiments had an immense impact throughout Europe, due largely to the keen sense of publicity of the industrialist Ternaux. Scores of French and foreign distinguished visitors were invited by him to Saint-Ouen to watch the operations; the list includes two future kings, Louis-Philippe of France and Christian VIII of Denmark, the physicist Ørsted, and a number of generals, princes, dukes, and high officials from countries as far away as Egypt or Russia. It was in the 1820s with the Ternaux experiments that the word *silo*, borrowed from Castilian, was popularized throughout continental Europe.[19]

However, those first experiments were not as successful as expected, mainly because the importance of the moisture content of the grain was not properly understood. This was realized by Doyère in the 1850s, and his main conclusions remain valid today: airtight storage is safer than any other method for bulk grain, and it is quite safe provided the moisture level does not rise above a limit thought by him to be 15%. The details have been elaborated by subsequent research. The lethal conditions for insects and mites have been established more precisely, as have the conditions for the growth of fungi, the upper moisture limit has been raised from 15 to 18%, etc. But basically, Doyère's results still hold. The strange thing is that although the superiority of airtight (now controlled atmosphere) grain storage has been repeatedly proved by research programme after research programme for more than 130 years now, professionals have remained almost completely ignorant of it.

It is also in Doyère's writings that what is perhaps the only thorough study of an actually functioning system of grain storage in *silos* is to be found; a system he observed in the Tierra de Los Barros around the town of Almendralejo, Extremadura, Spain. It is there that the main problem of underground grain storage is best set out. The problem is that before industrialization, underground storage was the only practical way to achieve an approximately airtight storage. Now, a silo cannot be made more airtight than the earth into which it is dug and with which it is sealed; and the earth itself is only as impermeable as its composition (sand, loam, clay ...) and its moisture allow it to be. Here is a kind of double cleft-stick, as it were, that is perhaps the crux of the matter. For when the earth is quite dry, it is no longer airtight and insects can survive; and when it is moist, moisture slowly enters the grain, causing detrimental changes if given enough time. Both defects had been clearly described by Doyère in Spain. There, people tried to retard the process by drying the grain as thoroughly as possible before putting it into silos; in addition, they took it out each September to be dried afresh if it was to spend one year more in storage.[20]

So successful storage of grain underground very much depends on local factors. Much depends on local climate and topography, and on a proper choice of the ground where silos are to be dug. But much also depends on the local food habits, for they determine the quality required in the stored grain. In wheat to be made into bread, there is no doubt that any change occurring during storage is more or less detrimental, but with other grains or for other uses, things may be different. In North Africa, grain accidentally fermented during storage in a silo (called *hamum,* "hot") can fetch a higher price than ordinary grain for being consumed as couscous. In South India, paddy is intentionally put into silos, not so much for storage as to undergo a "curing" process said to improve its cooking and digestive qualities. There is no doubt that it will take careful analyses of all such factors acting in combination, from geology and climate to food habits and tastes, to clarify the often puzzling history and geography of underground grain storage.[21]

No-control storage

Ventilation and airtightness are two opposite methods of achieving the same end, i.e. checking undesirable processes in stored grain by exerting some sort of control upon the atmosphere within the storage receptacle. But there are many cases where different means are used to aim at the same end. There is even a number of cases where no specific conservation methods at all seem to be used. All these cases are somewhat arbitrarily bundled together here; short-term and small-volume domestic stores are not included in this study. Since information is often quite defective on these "no-control" storage techniques, the most convenient way to deal with them is to present them according to the stored materials (grain in bulk, ears, etc.) to which they are applied.

Grain in bulk (threshed and winnowed). The idea of leaving grain in bulk unprotected in the open seems absurd, except for emergency storage. However, large amounts of wheat were stored in that way in 18th century Egypt if we are to believe the Italian traveller P. Alpino (1735). The grain was just put into big heaps inside a walled enclosure. The outer layers of the heaps, alternately moistened by dew at night and dried by the sun during the day, progressively hardened into a thick protective crust. The grain was supposed to keep in such heaps for seven years (a Biblical reminiscence). What gives this story some degree of credence is that it is not unique. According to another Italian, F. Galiani, wheat was stored in the same way on the beaches of Basilicata, waiting for export. The difference was that in South Italy, the rains were sufficient to make the outer grains germinate, but the same kind of protective crust was obtained. A third instance of the same process is recorded from Poland, for grain being transported in open barges on the rivers. And finally, there are some stories about grain being kept under such a protective crust within fortresses or citadels in northern Europe.

Grain to be stored in that way was first put into an ordinary granary for a few years in order to settle down, so to speak. It was then heaped into underground cellars; the protective crust was said to develop naturally over the years, but it could also be made artificially, by covering the heap with a layer of quicklime and sprinkling it with water. Such stories were already looked on as fables by Béguillet, a French specialist in milling technology, in 1775. But during the Napoleonic wars, the French found in Silesia grain reserves that had been kept thus since the Seven Years War, that is for more than 50 years. Needless to say, we have no scientific (biochemical) studies on this mode of conservation.[22]

Of course, examples like these are more spectacular than frequent. Most often, grain in bulk was stored in "ordinary" granaries, that is in buildings more or less efficiently designed to preclude moisture, rodents, birds, and thieves, but with no special contrivances for ensuring either ventilation or air-tightness. "Ordinary" granaries are the rule in Southeast Asia, in India and elsewhere, and as already seen, the granaries of ancient Rome, Egypt and Mesopotamia certainly belonged to this category, if we are to judge by the lack of evidence for shoveling in all these cases. We have many detailed architectural descriptions of such granaries. But unfortunately, detailed evidence on the way grain is managed is usually lacking.[23]

There is a last important mode of storage for grain in bulk: *bykes* (to generalise a name from the North of Scotland). But since it is also used for grain with chaff, it will be dealt with in the following section.

Grain with chaff differs from grain in bulk by the mere fact that it is not winnowed (chaff may even be intentionally added to it). But from a biophysical point of view, it seems plausible that a bulk of grain mixed with chaff or similar material behaves quite differently from a bulk of cleaned grain. It has been claimed that the chaff impedes mice, and retards the propagation of insects and of the heating process, so that shoveling is less needed and may even be dispensed with. Some at least of these points may be valid, although hard evidence is lacking. What is certain so far is that keeping grain mixed with

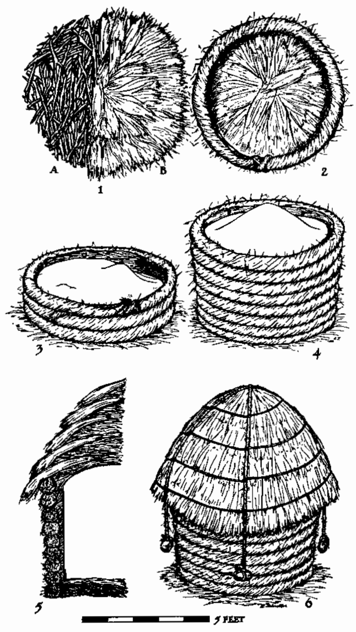

Fig. 4. Straw-rope granary, Ireland. Similar structures are named *bykes* in northern Scotland. (Fenton 1976, after Lucas 1956.)

Speicher aus Strohwülsten, Irland. Vergleichbare Gebilde im nördlichen Schottland werden »bykes« genannt. (Fenton 1976, nach Lucas 1956).

chaff is mentioned as a specific method of conservation in the French agricultural literature of the 18th century. Like grain in bulk, grain with chaff was stored in granaries, but unlike it, it could also be stored in barns; in southwestern France, there were buildings especially designed for the storage of grain with chaff, called *garde-pile*.[24]

A peculiar method of storing grain with chaff was to mound it inside straw-rope "granaries" such as were called *bykes* in northern Scotland (fig. 4). Bykes were no permanent granaries: they resulted from grain with chaff being heaped upon a platform within a round "wall" of straw set vertically, this wall itself consisting of, or held in place by, a straw rope tightly bound round and round it as the heap went higher. In Europe, bykes are reported from Ireland and Scotland only, but the *morai* of West Bengal (fig. 5) and the *puri* of Andhra Pradesh are built in an almost identical manner, and so are the straw granaries commonly used in China. However, it seems that in India and in China, the material stored in bykes is grain in bulk, without chaff: the data are not quite clear on that point.

A variant of the byke, differently built, is reported from Poland (but with no precise location) and from Fuerteventura (Canary Islands). It is a stack of straw built in the usual way, i.e. by laying down concentrically successive layers of straw, but with a hole arranged in the middle for the storage of grain. Again, it is not clear whether grain is stored with or without chaff; in Fuerteventura, grain is surrounded by chaff inside the straw

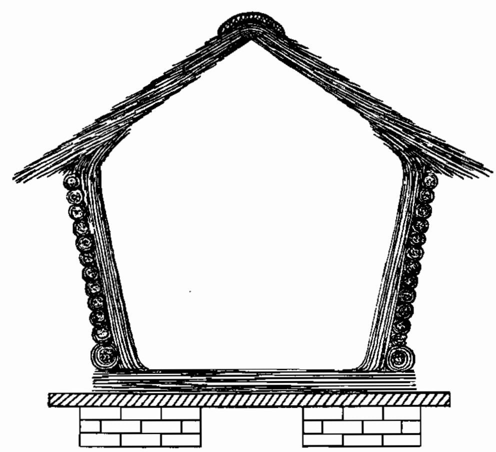

Fig. 5. Straw-rope granary, West Bengal, India. (Bainbrigge Fletcher & Gosh 1921, reprinted in Sigaut 1978.)

Speicher aus Strohwülsten, West-Bengalen, Indien. (Bainbrigge Fletcher & Gosh 1921, Nachdruck in Sigaut 1978).

"walls". The use of chaff, sometimes pressed down, as a protective wrapper for bulk grain

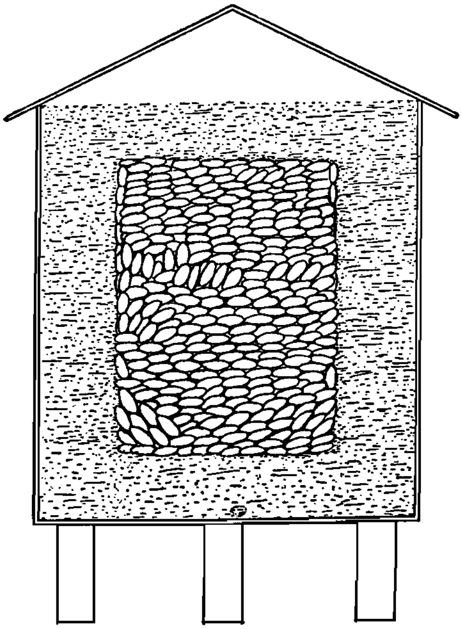

Fig. 6. Grain stored within chaff inside an elevated granary, Bihar, India. (Bainbrigge Fletcher & Gosh 1921, reprinted in Sigaut 1978.)

Getreide eingelagert in Kaff innerhalb eines erhöhten Speichers, Bihar, Indien. (Bainbrigge Fletcher & Gosh 1921, Nachdruck in Sigaut 1978).

inside ordinary granaries seems to be quite common throughout India. (fig. 6.)

Finally, an interesting mode of storage of grain with chaff has been reported from among the Serer (Senegal, ~~fig. 6~~). A few men stand inside the round wickerwork granary, and they pound and crush with long sticks the ears of millet that somebody throws into it little by little. When they have finished, the granary has been filled with a tightly compressed mixture of grain, broken straw and chaff, the men jump out, and the roof is put in place.[25]

The available descriptions of grain being stored with or within chaff often claim that such grain keeps for several years, that it is little if at all damaged by insects and rodents, etc. Since no scientific evidence is available, we can only take those claims at their face value. They are not unlikely in temperate countries for example, where storage insects are not able to breed in the open, and are therefore not present within the harvested grain as eggs or larvae; it can be supposed that a well-built straw byke is sufficient to keep them out. But it is certainly not so in hot countries; there, insects are already present in the grain before storage, so that the absence of insect damage, if true, must be explained in some other way.

Unthreshed grain: ears. As already seen, only maize, and probably millets and spelt have been stored in the ear in Europe in historic times, but always in ventilated conditions. Storage of ears in non-ventilated granaries is prevalent in Africa only, and possibly in some parts of the Australasian Archipelago, although I have no precise information on the latter. In Africa, traditional grain storage has been extensively surveyed of late, and these studies have shown that grain losses are much less than formerly thought. Actually, it is in "modern" storage that losses develop, owing to a number of causes ranging from poorly adapted techniques and equipment to careless management. In traditional storage, losses have also developed with the extension of new varieties more susceptible to deterioration than traditional ones (especially maize).

In the Sahelian and Sudanian zones of West Africa, a comparison between wickerwork and mud-wall granaries shows somewhat better results for the latter, which confirms that in such climates, ventilation during storage is more detrimental than profitable. For now, the best hypothesis on the functioning of grain conservation in tropical Africa is that it is based on the three following factors: varietal resistance to insects, storage in the ear, and thorough drying before storage (insects can only with difficulty attack grain at, say, 12% moisture and less).[26]

Unthreshed grain: ears with culms, sheaves. When the harvest is done with sickles, scythes or mechanical harvesters (the combine excluded), ears are cut with some length of the culm, usually to be bound into sheaves afterwards. The making of sheaves is not absolutely general, however: in 18th century England, there are examples of oats and barley being carried from field to barn and stored unbound. Although this mode of storage does not seem to have been important, it should not be left out of the picture.[27]

Since at least the Middle Ages and until the general adoption of the combine-harvester in the 1950s and 1960s, storage of sheaves has certainly been the dominant mode of peasant storage in non-Mediterranean Europe. Sheaves were stored either in permanent building, *barns* (fig. 7 and 8), or in the open, in *stacks* or *ricks*. The latter present an unsolved problem. Whereas barns are clearly medieval and possibly earlier, we do not really know whether storage in stacks is earlier than, say, the 17th century. In France for example, stacks were used in the central regions of the Paris Basin only and not on the periphery, which suggests a rather recent origin. The idea that storage in stacks should be ancient because it would be simple or cheap is very misleading. Stacks are no ordinary heaps of sheaves hastily arrranged: they are built so as to stand for up to two or three years, and special skills are required to make them (in France, they were built by specialist workers called *calvaniers* (fig. 9). Although supporting evidence is not available to me, it is likely that stacks were first an occasional addition to the barn for exceptionally plentiful harvests, and that they developed as a regular mode of storage in modern times only, when law and order were sufficiently established in the countryside. Moreover, I know of no region in Western Europe where sheaves would be stored in stacks while barns would be totally absent.

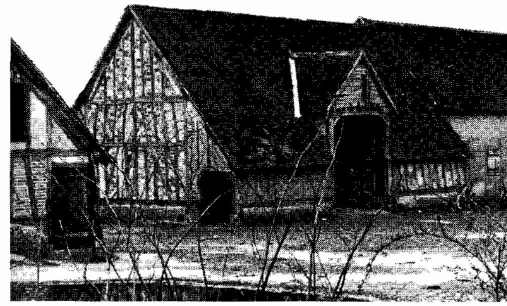

Fig. 7. Barn, Cerdon, Loiret, France. The barn is the centerbuilding with the wide gabled door. Photo: Pison, 1938, Musée National des Arts et Traditions Populaires.

Scheune, Cerdon, Loiret, Frankreich. Die Scheune ist das Gebäude im Bildmitte mit dem Einfahrtstor unter dem Spitzgiebel.

Grain was said to keep rather better in ricks than in barns, in France at least. Barns, like any permanent building, provide a shelter for rodents and weevils – it seems that the European weevil, *Sitophilus granarius,* the main insect pest in former times, cannot survive European winters outside granaries or barns – whereas in well-built ricks, being set on a new plot, the grain was not damaged by weevils and less by rodents than a layman might expect. In comparison with barns, however, stacks had one important drawback: the impossibility of taking out a few sheaves at a time (fig. 10). Once a stack had been opened, all the sheaves had to be threshed in a relatively short time. Before the coming of threshing machines during the 19th

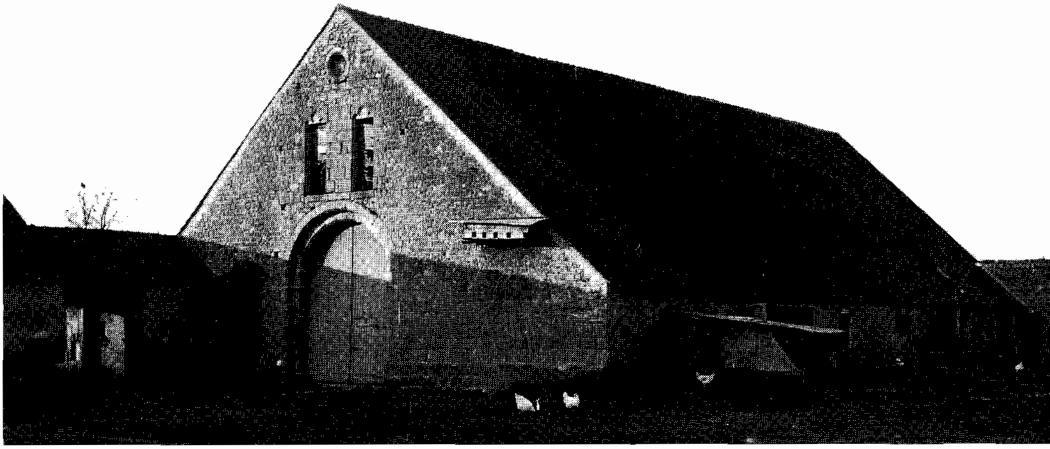

Fig. 8. Barn with a monumental gable, Griselles, Loiret, France. Photo: Grandjean, 1942, Musée National des Arts et Traditions Populaires.

Scheune mit einem mächtigen Giebel, Griselles, Loiret, Frankreich. (Fot. Grandjean, 1942, Musée National des Arts et Traditions Populaires, n° 43.15.101).

century, this entailed manpower resources that were certainly not available everywhere.[28].

The following double-entry table presents a tentative summary of the grain storage techniques identified above. One entry corresponds to the stored item (bulk grain, grain with chaff, etc.), the other to the physical method used to ensure its conservation. This table is not intended to be more than a mne-

IDENTIFICATION TABLE OF GRAIN STORAGE TECHNIQUES					
WHAT IS STORED?	HOW IS IT PRESERVED DURING STORAGE?				
	By some control of the atmosphere			Not by atmosphere control	
	Ventilation		Airtightness	Within permanent buildings	Without permanent buildings
	Natural (free access of air)	Artificial (shovelings)			
Grain in bulk	(rare)	[1]Floor storage (Europe)	[2]Underground silos	[3]Closed storage (e.g. South Asia)	[4]Heaps (as in Egypt), bykes, etc.
Grain in bulk with chaff			?	[5]Garde-piles	[6]Bykes
Ears	[7]Cribs, elevated post-granaries	(rare)	(rare)	[8]Closed storage (e.g. Africa)	
Sheaves	(rare)			[9]Barns	[10]Ricks

Fig. 9. The last sheaves being put onto the stack, Nouan-le-Fuzelier, Loir-et Cher, France. Photo: Maget, 1938, Musée National des Arts et Traditions Populaires.

Die letzten Garben werden auf den Diemen (Schober) gepackt, Nouan-le-Fuzelier, Loir-et-Cher, Frankreich.

monic device. However, if found useful, and after all the necessary corrections and additions have been made, it is hoped that it can serve as a basis for an international system of nomenclature for grain storage techniques.

Ancient European harvest-and-storage systems: A working hypothesis

As the above survey has hopefully shown, the form under which grain is stored (in bulk, in the ear, in sheaves, etc.) is one of the most central points in the structuring of any agriculture. The social level at which storage takes place (household, farmer, landlord, commerce, military, township, etc.), climate and crop species, harvesting and processing techniques, building and transport technology, food habits are all, with other factors, in more or less direct relationship with the mode of grain storage, so that the form of the item stored is at the crux of one of the most extensive networks of interactions in any agricultural economy. Now the question is, how can we put this reasoning to practical use? I shall attempt to show that it is quite helpful for a better understanding of our European agricultural past.

Harvest and storage of grain in the ear: primitive system?

From earlier surveys of harvest techniques, it is assumed here that reaping with the sickle is *not* primitive. Indeed, at least six other modes of cereal harvesting could be identified and shown to be older or technically less evolved than sickle-reaping: three of them consist in harvesting the ears only, either by plucking, or by stripping (with e.g. the two sticks called *mesorias* in Northwest Spain), or by cutting (e.g. with the small rice-knife of Australasia).[29] Although admittedly a rather slow process, the harvesting of ears has many advantages. Ears can be collected at full maturity, with little or no admixture of weed seeds. Subsequent work in carrying home and threshing the crop is minimal. And lastly, storage is easier than either with bulk grain (spoiling quickly) or with sheaves (requiring much larger buildings). It is not surprising, therefore, to find harvest-and-storage of ears one of the most prevalent systems in primitive economies. It dominated almost exclusively in Precolumbian America, it still does so in tropical Africa, and it probably did so in tropical Asia too in former times. It is especially well adapted for maize, rice, and millets, but nothing prevents its being used for other cereals as well. Two apparent characteristics of this system deserve to be noticed:

1. The harvest is usually done by women, or by women and men working together; it is rarely considered a masculine task.
2. The threshing is nearly always a feminine task, being done in small quantities at a time as a part of the daily kitchen work.

By and large, this harvest-and-storage-of-ears system still exists in the Spanish province of Asturias, where the main cereal grown is spelt, the crops being harvested with *mesorias,* carried home in baskets or bags, and stored in the superbly built post-granaries that are so emblematic of the province. The hypothesis that I propose here is that this system did prevail in large parts of non Mediterranean Europe, especially in millet-growing and spelt-growing areas, much later than expected, that is until at least the early Middle Ages.[30] I have no hard evidence to support this hypothesis, but there are nevertheless quite a few points in its favour, especially the following:

– the numerous vestiges of elevated post-granaries on Iron Age sites of northern Europe,[31]
– the words *Speicher* and *espigueiro,* from early medieval Latin *spicarium,* probably coined by clerics to designate something that was absent from classical Latin, a granary especially designed to store ears or spikes,
– perhaps the fact that many Germanic and Slavic speaking areas stuck until recently to the custom of reaping being done by women, whereas in the Mediterranean, reaping was done by men (the contrast seems to be rather sharp, and to date back to at least classical times),[32]
– and finally, the well-known harvesting-machine of the Gauls, the so-called *vallus.*

On the vallus, only the briefest summary can be given here. Basically, it was a big comb, set horizontally between two wheels, and pushed through the standing crop by an ox or a donkey harnessed behind it. The teeth of the comb did not cut the stalks: a number of experiments have shown that the machine could not possibly work that way. What the comb did was to strip off the ears, exactly like

Fig. 10. Finished wheat stacks, Saint-Viâtre, Loir-et-Cher, France. Photo: by Maget, 1938, Musée National des Arts et Traditions Populaires.

Fertige Weizen-Diemen (Schober), Saint Viâtre, Loir-et-Cher, Frankreich.

the mesorias of Asturias: technically, the vallus was nothing else than a number of mesorias fixed side by side to form a comb. Geographically, the vallus is known by five epigraphic representations, all situated along a 300 km straight line going from Reims (France) through Arlon (Belgium) to Koblenz (Germany), that is within what was plausibly a spelt-growing area in Roman times. Chronologically, the vallus is mentioned twice in the ancient literature, the first time by Pliny toward 50 A.D., the last time by Palladius between 450 and 500 A.D. No historical or ethnographic parallel has ever been found.[33]

My point is that all those facts are not to be understood if we stick to the usual (and usually implicit) supposition that the reaping sickle was already commonly used in the area where the vallus was invented. If however we suppose that the reaping sickle was *not yet* used there at the time (although it was already farther south), explanations become much easier to come by. The invention itself is no longer an isolated stroke of genius, since it can be seen as the "mechanization" of a traditional technique, that of stripping off the grain. And the paradox of its complete disappearance four centuries later can perhaps be solved too, if we revise the other assumption that being a "machine", the vallus was necessarily more efficient than the reaping sickle. The vallus was certainly more efficient than the rather slow mesorias. Was it also more efficient than the sickle? We simply do not know. And if it was not, the fact that it was made obsolete by the reaping sickle as it progressed northward conforms to our most logical expectations.

*

Sickle reaping, immediate threshing, storage in bulk: the Mediterranean system

Since this system is pretty well known, its main features can be summarized very briefly; they are as follows:

- harvesting is done with sickles, frequently serrated, and used with a shearing motion; it results in handfuls of stalks with the ears attached;
- the harvested handfuls are bound into sheaves for transport; no bags or baskets are needed as in harvesting ears; animals are frequently used for transport;
- reaping is done by men; women are usually helpers or gleaners only; in some cases, they are even prohibited from entering a field being harvested;
- threshing is done in the open, as soon as the harvest is finished, and the whole crop is threshed at a time; threshing is done with animals, either by making them trot over the stalks (trampling), or by harnessing them to threshing sledges (*tribula, plaustella*), threshing rollers, etc.;
- winnowing immediately follows threshing; it is usually done by shoveling the mixture of grain and chaff left after threshing and after the straw has been carried away with forks;
- grain has therefore to be stored in bulk; it is quite often stored in underground silos, although other modes of bulk grain storage are used as well.

Many of these features are in direct opposition to those of the preceding system (harvest-and-storage of ears), especially the division of labour between men and women, and the fact that the whole crop is threshed at once instead of being threshed in small quantities daily. An important point is the role of working animals. It is quite clear that the Mediterranean system requires much more power for transport and threshing, owing to the fact that a large volume of straw is added to the ears by the reaping process. It can be said that animals are doubly necessary for a smooth functioning of the system: they make the straw more valuable as litter or fodder, and they make it less costly to transport and produce. By and large, a world ethnographic map of the reaping sickle and of working animals would show a fair degree of correspondence.[34]

The chronology of the Mediterranean system is as much of a problem as the chronology of the harvest-and-storage-of-ears system, although the questions are different. Some readers have been possibly upset by the idea that the reaping sickle could have been absent from central Europe as late as the Roman period, since sickles are attested by very numerous finds throughout Europe from Neolithic times on. But most of the trouble comes from the equation *"sickle = reaping sickle"*, one of those implicit assumptions that so urgently need revision. There are quite a few ethnographic examples of people possessing sickles, but never using them for harvesting grain. Archaeologically, neither the form of the blade (if metallic), nor its silica gloss (if of stone) are a proof that the tool was used for reaping grain. Incontrovertible evidence only becomes available with written texts and iconography, that is in the third millenium B.C. in Mesopotamia and Egypt, and in Homeric times in Greece. But even in neighbouring Italy, evidence is not straightforward. The Latin word *falx*, usually translated as "sickle", is in fact of little use because it meant any implement with a concave cutting blade, like a billhook, a pruning knife, etc. Reaping with a sickle is unambiguously described by Varro c. 50 B.C., but there is not a word of it in the book of Cato one century earlier. And since other methods are mentioned by Varro, Columella and Pliny, it does not seem unreasonable to assume that as far as harvesting techniques are concerned, Italy was still in a transitional stage toward the beginning of the Christian era: what I have called the Mediterranean system was not yet fully established there. If we add to this the absence of any evidence in non Mediterranean Europe before the early Middle Ages, the case for a slow progression of the reaping sickle northward, reaching some areas of central Europe as late as the fifth century A.D., does not seem to be quite improbable.[35]

Another chronological problem is that of the *tribulum*. Its recent distribution is more or less well known, but its chronology is an almost total mystery. This is rather surprising since the tribulum is equipped with hundreds of flint teeth that fall out rather easily, are almost indestructible and easy to identify; but nevertheless they seem to be completely ignored in the archaeological literature. As for the ancient textual evidence, I do not know if it has been properly assembled and studied.[36]

Finally, there should be some evidence from storage facilities, granaries and underground silos, but it is still too scarce or vague to be very helpful. Some archaeological studies of granaries are available, but they mostly concern urban granaries, and therefore they can tell us little about farming practices proper. Underground silos hardly provide more meaningful information as yet. They have been found in very large numbers in Iron Age sites in Britain southeast of the so-called "Jurassic ridge", a line going from Bristol to Hull. In France, the situation is roughly the same, although no precise cartography is available; there, silos seem to have all but disappeared during the Roman occupation, to reappear in large numbers after the fall of the empire in the west. This probably means that silos were used by peasants, while the Roman landlords preferred some other kind of granary. During the Middle Ages, the number of silos seems to have decreased continuously, although precise data are still lacking; their area of use seems to have shrunk slowly, till it was restricted to a small part of southwest France (Gascony, Haut-Languedoc) in the 18th century, when they were last used in that country.[37]

It would be very rash to speculate that the presence of silos in Britain and northern France in the Iron Age means an early diffusion there of what I have called the Mediterranean system. However, silos do indicate storage of bulk grain on a rather large scale, which is not easily compatible with the harvest-and-storage-of-ears system. The problem is that we know nothing about the threshing techniques of the time. Evidence for threshing by horse treading in connection with silos would be highly meaningful: I know of none, and I do not even know if it has been looked for.

Delayed threshing, storage of sheaves, barns: the North European system

For most European scholars, this system belongs to their childhood or family memories, since it prevailed until the 1950s, when it was finally made obsolete by the general spread of the combine-harvester. Of course, important changes had occurred since medieval times: the reaping sickle had been replaced by mowing tools in region after region from the 15th century on, and in the 19th century, threshing, mowing and even the binding of sheaves were successively mechanized. But important as they were, these innovations did not modify very much the hallmarks of the system: the making of *sheaves*, their storage in *barns*, and their *delayed threshing* in the course of the winter and spring following the harvest. Only the combine, because it was designed to deliver bulk grain, could put an end to it. Before mechanization, the biggest change had probably been in the division of labour at harvest. With the reaping sickle, it seems that the reaping was frequently done by women and the binding of sheaves by men – at least in central, northern, and eastern Europe, because in France and Britain the state of things is not clear. But with mowing tools, the situation was reversed: men did the mowing, women the binding. The first assertion is difficult to substantiate, though, because the primary sources are often rather vague on harvesting techniques. Especially when the harvest is reported to be done with "sickles" without any further details, there is no way of telling which technique – reaping or mowing – was used. As a result, men have certainly been reported as reaping many times by mistake, while they were possibly mowing with a sickle-like tool.[38]

The problem with barns is not very different. The claim is made here that the presence or absence of barns is highly significant in identifying past agricultural systems: this claim would be obvious nonsense if any kind of large building could be called a barn. That is the reason why the term "barn" is given here a technical, a functional definition. Barns are buildings especially designed for the storage of sheaves, with a threshing and winnowing floor inside. Of course, barns can always be put to other uses, and conversely, any convenient building can be occasionally used to store a part of the harvest. But it is the intended design that counts. Usually, barns are rather large, rectangular buildings; sheaves are stacked on both sides, leaving in the middle a free area with a big door (or two doors facing each other) for the movements of carts or waggons; this area is also the threshing and winnowing floor. Of course, this is only a very general scheme. Actual patterns differed from country to country, and changed with time, and good studies are available in many cases. My only aim here is to give non European readers an idea of what a barn can be. The early history of barns is obscure. We have reasonably good evidence of barns from the 16th or 15th century on, but their origin and development remains a matter for conjecture. A few barns of medieval times have survived to this day, and are now protected as part of the historical heritage. However, they did not belong to farms, but to abbeys, bishoprics, or other authorities entitled to collect tithes. They are often of immense size, witnessing perhaps how awkward the collection of tithes in kind could be, in regions where they were delivered in sheaves (instead of bulk grain, as was usually done in the Mediterranean countries); but whatever it may have been, tithe-barns tell us little about the practices of the farmers. Recently, a few finds of the Roman period in France have been tentatively reconstructed as barns. But this hypothesis needs to be supported by comparable data elsewhere.[39]

Winter threshing in barns was usually done with flails, although we shall see presently that the use of the flail was by no means limited to winter threshing in barns. The flail is possibly one of the implements best studied by ethnographers in Europe (not in France, however), but as with barns, its earlier history is rather obscure. The first mention of flail-threshing is traditionally ascribed to a Roman writer, Saint Jerome (Hieronymus), who died in 420 A.D. The flail seems to have reached Scandinavia in the 10th or 11th century only.[40]

If we bring together what has been said above on the chronology of the reaping sickle, of the barn and of the flail, it is tempting to speculate that what I have called the North European system may have originated in northern France and southern Germany in late Roman times, that is between the third and the fifth centuries A.D. But of course, evidence is too scarce as yet to make it more than a very tentative speculation.

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Immediate threshing with the flail: the Atlantic Coast system

I have named this system after the region where it is best known to me, the western coast of France from Brittany to the Pyrenees, but it did certainly exist elsewhere as well. In a way, it is but a variant of the Mediterranean system, with which it has much in common: threshing of the whole crop at one time immediately after the harvest, in the open, absence of barns, storage of grain in bulk. The main difference is in the technique used for threshing; it is done, not with animals treading the grain, but by men using flails. Of course, threshing having to be done at once, it must be done in a much more expeditious way than when several weeks or months are allowed for it. In the latter case, men work either singly or two to four together, rarely more for want of elbow-room. In the former, there are gangs of ten or twelve men or more, with in addition some women and children to help in heaving or turning the straw, etc. With that number of men handling flails elbow-to-elbow, following a rhythm common to all is not only a matter of stimulation or convenience: it is an absolute requisite if the workers are not to knock each other out instead of threshing the grain. As observed by some writers, threshing in such conditions becomes of necessity a kind of ballet. But it is nevertheless very hard work, for if the flails are of less weight than for threshing indoors, they are wielded more quickly and with a wider movement. In delayed, indoor threshing, the emphasis would be on the length, the continuity of the effort; in immediate, open-air threshing, it would be on the violence of the effort.[41]

From the late 18th century on, the flail was progressively displaced by new animal-drawn threshing implements, chiefly wood or stone rollers of different kinds. For want of detailed local studies, the chronology of this change is not known. But fortunately, stone rollers are virtually indestructible, so they still can be seen in hundreds lying in odd corners everywhere in the vast stretch of country from the Pyrenees to the Loire. North of the Loire valley, stone rollers become much less numerous, suggesting that they only reached the area shortly before threshing machines came into general use.[42]

On the origin of the Atlantic Coast system, nothing is known with any certainty. However, there is good evidence that horses were used to tread out the grain on two points of southern Brittany in the early 19th century, that is very probably without any direct connection with the progression of the threshing roller going on farther south.[43] If those occurrences (preferably with some others) could be shown to be survivals from earlier times, the case for a Mediterranean origin of the Atlantic Coast system would be stronger. And it would add to the existing evidence for underground silos in Britain and northern France in support of the hypothesis of an early extension of Mediterranean techniques into Northwest Europe.

Conclusion

In a way, technology is a study of alternatives. For any given end in social life, there is always a plurality of ways and means. One primary task of technological history is to record for each time and place what exactly people do for a living, a task that necessarily entails having some preliminary idea of the range of possible alternatives. Usually, facts are seen only inasmuch as there is a place for them in the observer's mind – it is for this very simple reason that experienced observers see more things more quickly and more precisely than untrained ones! What I have tried in the first part of this paper is to compile the best data recorded by past observers of grain storage, and to arrange them as conveniently as I could, in the hope that the result can eventually prove useful for future studies.

A point that must perhaps be stressed once more is that my aim was not to propose a classification of grain storage techniques, but only a way to identify them. To many readers, the difference can look too subtle to be true, and I must confess that the epistemological discussion that would be required to justify it is beyond my grasp. What I can say from experience, however, is that it works to make this difference. We all share the everyday experience of being able to identify the hundreds of items present in our daily surroundings, while we would be at a complete loss to classify them (in so far as classifying them would make any sense indeed). As a matter of fact, telling magpies from blackbirds does not require an up-to-date knowledge of the classification of birds; an example that shows, I believe, that identification comes first, and classification second. Identification is indispensable to avoid helpless confusion, whereas classification is only a convenient way of arranging items after they have been identified. The possibility of classification depends on prior identification, not the other way round. It is for this reason, I feel, that attempts at classifying technical items, especially agricultural implements, have so far produced mixed results at best, as is well known to readers of *Tools and Tillage*.

Just pausing for a moment to think about what a classification of granaries would look like, can help us to better understand why it is so. For granaries require the use of a bewildering number of traits to be accurately described. They can be round or square, wide or narrow, tall or low, elevated or ground-level; they can be built of wood, stone, mud, wickerwork, or of several of those materials combined in different proportions and ways; they can have apertures at different levels, or a removable roof; they can have balconies and other appendages; they can be permanent or temporary, fixed or movable, etc., There are serious reasons to doubt that classifying granaries on the basis of such criteria would be either feasible or relevant.

But the problem is different if we think in terms of identification, in my opinion at least. For the aim is not to work out one grand system encompassing all descriptive criteria. The aim is to understand what people do, that is, speaking of granaries, what exactly such or such contrivance has been designed for. For example, a narrow shape may be relevant if it is designed to ensure a better ventilation, otherwise it is not. In Southeast Asia, elevated granaries are usually built with a frame of posts slightly inclined inward, a device too easily overlooked, but important because it has been contrived as a compensation for the outward pressure exerted on the walls by the grain stored there in bulk. Many other examples have already been mentioned in this paper. My point is that in man-made objects, human design is what makes those objects what they are. So the question of design must never be lost from view if we do not want to run into endless and meaningless minutiae.

Finally, a last remark must be made concerning the second part of this paper. I have described four "systems" characterized by specific combinations of harvest, threshing and storage techniques in Europe. Perhaps the use of this term was unfortunate, in so far as it could appear to support the idea that technical "systems" are integrated wholes, having an existence of their own, like living organisms as it were. My opinion is quite the opposite. I view such "systems" basically as configurations of techniques among many others, that for some reasons happen to have been especially important historically. But other configurations do exist, and quite a few of them are to be found in Europe itself. I did not describe them because they were of local or secondary importance only, but without them, a picture of past agricultural Europe would be quite incomplete.

Eine Methode zur Bestimmung von Techniken der Getreidespeicherung und ihre Anwendung für die Geschichte des europäischen Ackerbaus.

Bis vor wenigen Jahren war das Speichern von Getreide ein ziemlich vernachlässigtes Thema in Geschichte und Anthropologie. Ein Grund dafür war die Vorstellung, daß die Aufbewahrung von Getreide "ein leichtes" sei: und in der Tat ist es das in den industrialisierten Ländern geworden, aber in früheren Zeiten war es im allgemeinen schwierig und teuer, und so ist es auch heute noch in den meisten Ländern der Dritten Welt. Getreide-Konservierung ist – historisch gesehen- keine Selbstverständlichkeit, ihre Methoden und ökologischen Voraussetzungen müssen gründlich verstanden und beschrieben werden.

Diese Untersuchung unterbreitet eine Methode zur Bestimmung von Getreide-Konservierungstechniken ausgehend von den beiden folgenden Fragen: *Was* genau wird eingelagert? Und *wie* wird es in der Einlagerung konserviert?

Die Beantwortung der Frage *Was* setzt voraus, daß jedes Getreideerzeugnis, angefangen bei den frischgeernteten Garben bis hin zùm Endprodukt, Brot oder Brei, zu prüfen ist um festzustellen, ob und wie lange es lagerfähig ist. Dieser Überblick ist für aufbereitete Erzeugnisse (nach dem Mahlen) nur kursorisch erfolgt, weil diese als Lagerprodukte entweder keine große Rolle spielen oder keine besonderen Konservierungstechniken benötigen. Der Hauptteil der Untersuchung befaßt sich dagegen mit unbearbeitetem Getreide (vor dem Mahlen), einmal wegen seiner allgemeinen Bedeutung als Nahrungsmittelvorrat und zum anderen, weil es besondere Konservierungstechniken erfordert. Unbearbeitetes Getreide kann eingelagert werden als: 1. gedroschenes und gereinigtes Korn; 2. Korn mit Kaff (gedroschen aber nicht geworfelt); 3. Ähren (von den Halmen getrennt); 4. Halme mit Ähren, ungebunden; und 5. Garben (Halme mit Ähren, gebunden). Jede dieser fünf Arten der Einlagerung ist mit bestimmten Erfordernissen und Einschränkungen verbunden.

Hinsichtlich der Frage *Wie* werden die verschiedenen Mittel und Möglichkeiten aufgezählt, um das Getreide vor Schaden zu bewahren, sowohl vor als auch während der Einlagerung. Vor der Einlagerung ist Trocknen die üblichste Methode, was entweder auf natürlichem Wege (Sonne und Wind) oder mit Hilfe künstlich erzeugter Wärme (Darren etc.) erfolgen kann. Während der Einlagerung ist der einzige Weg das Getreide vor Schaden zu bewahren, daß man versucht, die Luftverhältnisse unter Kontrolle zu halten. Am gebräuchlichsten sind dabei drei Methoden: 1. Belüftung (Zuführung von Außenluft, um das Korn zu kühlen); 2. Luftabschluß (Luftzutritt wird verhindert, um die Atmung von Insekten und anderen potentiell schädlichen Organismen zu unterbinden) und 3. unkontrollierte Einlagerung (Belüftung wird vermieden, aber echter Luftabschluß ist nicht beabsichtigt).

Aus der ersten Frage resultiert die Bestimmung eingelagerter Materialien, aus der zweiten die Bestimmung der Speichermethoden. Um diese Speichertechniken im einzelnen zu identifizieren, bleibt zu bestimmen, welche Methoden bei welchen Materialien angewandt werden. Am einfachsten läßt sich das mit Hilfe einer Tabelle verwirklichen, in der die Materialien nebeneinander und die Methoden untereinander angeordnet sind, so daß jedes Kästchen eine bestimmte Technik darstellt. Auf diese Weise lassen sich zehn gebräuchliche Techniken unterscheiden.

Der zweite Teil der Untersuchung baut auf den Resultaten des ersten auf in der Absicht, Zeugen früherer Ernte-, Dresch- und Speicher-Praktiken in Europa einer Neueinschätzung zu unterziehen. Versuchsweise werden vier Systeme von Ernte-bis-Lagertechniken, die in sich jeweils bestimmte Muster aufweisen, unterschieden: 1. Ernte und Speichern der Ähren; 2. Sichelernte, sofortiger Drusch durch Tiere und Speichern des gedroschenen Korns; 3. Sichelernte, später Flegeldrusch, Einlagerung der Garben; 4. Sichelernte und sofortiger Flegeldrusch. Das System 1 ist wahrscheinlich das älteste, es existiert noch in Asturien (Spanien). System 2 hat sich in den Mittelmeerländern seit der Antike erhalten, System 3 im nördlichen und mittleren Europa seit dem Mittelalter und System 4 an der Atlantikküste Frankreichs (und wahrscheinlich auch andernorts). Aber die relative Chronologie und die regionale Verbreitung der vier System ist bisher noch nicht genau bekannt. Erhöhte Pfostenspeicher sind wahrscheinlich charakteristisch für das System 1, unterirdische Silos für das System 2 und vielleicht auch für System 4, Scheunen für System 3. Aber diese Relationen sind bei weitem nicht einstimmig und unser Wissen ist noch viel zu lückenhaft, als daß diese Schlußfolgerungen vorläufig viel mehr als theoretische Erörterungen sein könnten.

Notes

1. As an introduction to the technical literature of the 1970s, see e.g. Araullo *et al.* 1976, National Academy of Sciences 1978, 1978a, and AUPELF 1980.
2. The paper by Ida Hahn (1919) is a good example of the few in-depth discussions to be found in the older literature (I am grateful to Dr. Hans Medick for having drawn my attention to this reference). Usually, storage is only mentioned *en passant,* if at all (e.g. Maurizio 1927, Childe 1951, etc.). On the other hand, ethnographic studies of peasant granaries are numerous, but their emphasis is usually more on architectural features than on storage proper.
3. The last general famine in Europe was that of 1816-1818, probably as a consequence of the Tambora eruption (Post 1977, Stothers 1984). But local dearths continued afterward: in France, the last ones occurred in 1845-1847 and in 1854-1856 (Fourastié *et al.*1969: 163-164). From the end of the 17th century, people later known as *economists* proposed free commerce as an infallible remedy against the recurrence of dearths; but when commerce was officially freed by the French government in the 1760s, things did not improve, and the experiment ended in failure: for a number of reasons, including of course the lack of adequate transport, commerce was not the solution for inland countries. So the debate increasingly focused on an alternative: long-term storage as a means to average out good years and bad years. The problems were many, and the debate produced countless books, pamphlets, and papers all over continental Europe from about 1750 to about 1850; after that date, the fear of dearths all but disappeared, owing to the glut of grain imports from overseas. This literature does not seem to have been studied by historians.

   But old fears can be surprisingly quick to reappear. Ida Hahn's paper was written in 1919, hungry times in Germany. And the sudden depletion of world grain stocks in 1972 as a result of massive Soviet purchases (Pickstock 1974, Trezise 1976) was probably not foreign to the renewal of scholarly interest in the topic of grain storage in the 1970s mentioned above.
4. Childe 1951: 19.
5. Gast & Sigaut (eds.) 1979, 1981, 1985.
6. The themes not dealt with here can be summarily arranged under two main headings: "Storage and environment", and "storage and society". Food storage is self-evidently one of the points where social and environmental processes are most tightly interconnected, for both the need for food reserves and the possibility to conserve them are dependent on environmental factors. However, I do not know of any geographical study of these, and similarly, grain storage seems to be absent from the vast literature on the economic incidences of climatic variability (e.g. Prior and Jones 1985). On "storage and society", the situation is different, since the socio-political importance of food-storage is so conspicuous that scholars could hardly miss it. About 30 of the 76 papers in Gast & Sigaut 1979, 1981, 1985 (henceforth quoted as GS 1979, etc.) explicitly deal with it, and there are also works like Halstead & O'Shea 1982 or Testart 1982.

   On grain storage in general, bibliographies of respectively 508 and 347 items have been compiled by Sigaut 1978, 1979, and each paper in GS 1979-1985 has one, so that the field is pretty well covered. There is no such thing as an exhaustive bibiliography, however, and many important works are not to be found there, for example Audette & Grolleaud 1983, Berg 1949, Clément 1985, 1987, Corbier 1985, Fenton 1983, Füzes 1984, Grolleaud & Raison 1987, Jones *et al.* 1986, Multon (ed.) 1982, Rickman 1980, Ripp (ed.) 1984, Rystedt 1949, Selmeczi Kovács 1976, Shejbal 1980, etc. I am grateful to the many colleagues that kindly supplied me with otherwise inaccessible informations and copies of rare documents; I cannot name them all, but Boris Andrianov, Gösta Berg, Alexander Fenton, Endre Füzes, Grith Lerche, Axel Steensberg and Gene C. Wilken have been especially helpful.

7. Former accounts of this identification method: Sigaut 1979, and in GS 1981. For another point of view: Bromberger in GS 1979.
8. Flour packing for export overseas: Bucquet 1783: 34. Late survival of mortar-and pestle in western France: Auriault 1976.
9. Parboiling of rice: Gariboldi 1974. *Bulgur*, *Talgnn*, and *Haberkern*: Avitsur 1975, , Ferchiou in GS 1979, Gamerith 1975, Haley & Pence 1960, Hubert 1984, Kläy 1971, Seringe 1818: 216.
10. Ahvenainen 1963: 14-16, Fenton 1976: 94-95, Grolleaud & Raison 1987, Richmond 1963: 126-127, Vilppula 1955.
11. *Moyettes* or *dizeaux* (small drying stacks in the fields): e.g. Heuzé 1873: 256-265. *Grünkern*: Künzig 1964. Asturias (Spain): Krüger 1927, Neira Martinez 1955, Ortiz & Sigaut 1980.
12. The fact that shoveling is so much taken for granted has probably prevented scholars from asking questions about its history; however, see Beutler in GS 1981. Shovelling is attested in Denmark since 1585: C. R. Hansen 1968 (ref. provided by Ax. Steensberg). Shovelling of maize ears in France: Sigaut 1979: 48.
13. Aeration devices in Chinese granaries: Bray in GS 1981; for ricks and barns in Scotland: Heuzé 1873: 270-271, and Fenton (pers. comm.).
15. Cribs in France: Sigaut 1979: 48. Elevated granaries of N. Portugal and NW. Spain: Gomez Tabanera in GS 1981 (gives the main relevant literature); of the Alps: Huber 1944, Raulin 1974, Davico in GS 1985.
16. At least four different explanations can be imagined for the absence of rat-guards under elevated post-granaries. 1) Rodents are normally eaten, so traps for catching them are preferred to rat-guards. 2) Snakes, weasels, mongooses, cats, dogs, etc., are allowed to live near or under the granaries. 3) Triangular trusses are not used in timber building, so the granary frame would not be rigid enough if the posts were interrupted at the rat-guards level. And 4) the wooden posts are so hard and well-polished that rodents cannot climb them. There is some substance in explanations 3 (Clément 1985: 18, 35-36) and 4 (Ryukyu Islands, Japan).
17. Information on traditional underground silos has been compiled by Sigaut (1978) and Fenton (1983). There is perhaps no better proof of the unbelievability of silos than the number of experiments made on them by archaeologists (Bowen & Wood 1967); the undisputed leader in this field is Peter J. Reynolds (1974, and in GS 1979).
18. On modern methods of grain storage in controlled atmosphere: Shejbal 1980, Ripp 1984.
19. Sigaut 1978, and in GS 1979; Lomüller 1978: 351.
20. Doyère 1862, partially reprinted in Sigaut 1978.
21. North Africa: Holtz in Sigaut 1978. India: Ramiah 1937: 61, 101.
22. Sigaut in GS 1979: 16-17.
23. India: Bainbrigge-Fletcher & Ghosh 1921, partially reprinted in Sigaut 1978. Southeast Asia: Clément 1985, 1987. Rome: Rickman 1971.
24. France: Reneaume 1707: 68, Tessier 1793: 455, etc. Britain: Marshall 1787, I: 193. On *garde-piles*: Saint-Félix Mauremont 1820: 256, Deffontaines 1932: 56-57.
25. *Bykes* of Scotland and Ireland: Fenton 1976. *Morai* and *puri* of India: see n. 23. China: Bray 1984: 403, Wagner 1926: 279. Fuerteventura: Tessier 1793: 458. Poland: Lasteyrie 1819: 31. Senegal (Serer): Garine in GS 1981.
26. Audette & Grolleaud 1983, Grolleaud & Raison 1987.
27. Harvest, transport and storage of "loose corn" (as against "sheaf corn") is described by Marshall (1787, I: 188, and 1790, I: 218-221) for the counties of Norfolk, Kent, Surrey, and the Midlands.

28. There is something to be found on barns in every work on rural buildings, For more specific data, see e.g. Baumgarten 1965, Brunet 1982, Selmeczi Kovàcs 1976. On ricks in France, see e.g. Heuzé 1902, II: 158-165; on ricks as recent innovations in Norfolk in the late 18th century, see Marshall 1787, I: 230. On weevils: Buckland 1981.
29. Sigaut 1978a, 1985.
30. Harvesting ears with mesorias is attested in Asturias (Spain), in West Georgia (USSR) and in the Himalayas (Nepal, Bhutan): Čitaja 1969, Krüger 1927, Neira Martinez 1955, Ortiz & Sigaut 1980, Toffin 1983. As already noticed by Krüger, the *mergae* or *mergites* of the Roman writers were probably mesorias. Data found in Maurizio (1927: 140) hint that a similar tool may have been used by the ancient Slavs.
31. Buchsenschutz in GS 1985, and Villes *ibid.*
32. See n. 38.
33. Renard 1959, Kolendo 1960, 1980: 155-177.
34. References in harvesting and threshing in the Mediterranean are too numerous to be listed here, but see Lerche 1968, Rasmussen 1969, etc.
35. For a recent reinterpretation of silica-gloss: Anderson-Gerfaut 1983. On sickles in Ancient Egypt: Vandier 1978. On *falx* and its meaning: Le Gall 1959.
36. On animal-drawn threshing devices: Luquet & Rivet 1933, Vakarelski 1973, Steensberg 1971, Aubin & Eches in GS 1985, etc.
37. Available maps of underground silos have been compiled in Sigaut 1978. On silos in France in medieval and early modern times: Garcia 1987, Lassure in GS 1981, Mauny in GS 1985, Polge in GS 1979.
38. The division of labour between men and women in sickle-reaping seems to have a pretty clear-cut geography. A tentative map, not including East and Southeast Asia where the problems are different, would show two large areas where reaping was done by women, (1) non-Mediterranean Europe and (2) India, separated by a third area, (3) from Spain and Morocco to Afghanistan, where sickle-reaping was or is done by men. This third area probably included a large part of France and most of South Britain, whereas North Britain (Scotland to Yorkshire) belonged to the first. Accustomed as he is to see the reaping done by men, Marshall (1788, I: 387) expresses a real surprise at seing it done by women in Yorkshire.
39. Ferdière in GS 1985.
40. Parain 1979: 92, Kłodnicki 1982. Scandinavia: Steensberg 1983: 68-69.
41. Open-air flail-threshing developed independently in late 18th century Yorkshire for rape and oats: Marshall 1788, II: 21-24 & 36-41. For western France: Parain 1979: 21. Heuzé (1873: 275-289,1875:345-355) gives detailed parallel accounts of barn and open-air threshing. In barn threshing, a worker could thresh 1.5 hl of wheat per day; in open-air threshing, the rate was between 2 and 2.5 hl. The difference is due to at least four factors. (1) People work faster in a team than alone. (2) Work days are longer in open-air threshing. (3) There is usually less straw in open-air threshing, because in western France, the crop is cut higher. And (4) the threshed straw is bound into bunches in barn threshing, whereas it is simply put into a heap in open-air threshing.
42. Parain 1979: 24-25, Heuzé 1873: 289-295 and 1875: 356-361, Aubin & Eches in GS 1985.
43. The two points in question are Belle-Ile-en-Mer, Morbihan (Trochu 1821: 158) and Penmarc'h, Finistère (Lalaisse in Juilliard 1976: 132). There is also evidence of open-air threshing in the early medieval village of Borup in Denmark (Steensberg 1983: 66-68, and pers. comm.).

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