Feasibility of in-store drying in China

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Abstract

Grain aeration, as a physical method of insect control in grain, is a well-established technique in many parts of China However, in-store drying, designed to reduce the moisture content from 18% down to 14% wb at higher air flowrates, has not been studied before Weather data analysis and computer simulation of in-store drying was conducted for two important grain growing provinces in China, Heilongjiang (maize) and Sichuan (paddy) This was used to estimate the total available time for in-store drying both with and without additional heat, as well as to find the most suitable periods of the year for drying. Important information related to the equipment required and strategies to be used was used to optimise the drying process.

Background

The People's Republic of China (PRC) is one of the major world producers of grain (see Table One) In spite of ranking among the world's top producers of paddy and wheat (number one) and maize (number two), China's huge population of over 1.2 billion and dependence on rice and wheat as staple foods make sustained and expanding grain production an important issue. Since land resources are limited (only about 10% of the area of the country being arable land), a significant expansion of the area under cereal crops is not conceivable. Therefore, efforts are being undertaken to address the problem of postharvest losses of grain, especially those related to grain drying and storage.

Table 1. Production of major grain crops in China in 1997 Source: FAO (1998).

	Production (MT)	% World production	% Asian production
Paddy	202.7	35.0	38.2
Wheat	123.3	20.1	46.4
Maize	104.7	17.8	73.3

Traditionally, grain handlers have made considerable effort towards reduction of postharvest losses. One improvement in production has been multiple cropping, although this has led to a further handling problem. Since more grain is being handled by the same facilities, increasing amounts of high moisture grain are being harvested, procured and stored by the depots of the government Grain Handling Bureaux The latter procure about 30% of the total quantity of grain produced in China for human and animal consumption, and the amount of high moisture grain has been estimated at about 30Mt (Ren Yonglin & van Graver, 1996)

Current Drying Practise

Sun-drying is still the predominant form of grain drying at farmers level and still plays in important role in government owned depots (Ren Yonglin & van Graver, 1996, Li Huojin, 1996, Ju Jin Feng et al., 1996 and Genzhang Zhuge et al, 1993) Given the fact that the depots are still dependent on sun drying for about 50% of their drying capacity, they often cannot cope with the increasing amount of incoming wet grain. This is due to factors such as (Ren Yonglin & van Graver, 1996):

- Introduction of high yielding but late maturing varieties.
- Occasional bumper crops.
- The requirement for farmers to deliver grain to depots as soon as possible after harvest.

It has been established (Genzhang Zhuge et al, 1993) that delayed drying was responsible for qualitative losses, especially in maize (moulds) and in paddy (yellowing, decreased germination and increased proportion of brokens). Mechanical drying is available in a number of grain depots and can be categorised as:

- Hot air drying
- Aeration drying (where the term 'aeration' refers to near ambient air drying)

Mechanical drying was introduced into China in the 1940's (Ju Jin Feng et al., 1996), initially in Northeast China. Up to now, about 40 types of grain dryers (Cao Chongwen, 1997), including flat bed dryers, continuous flow dryers (mixed flow, cross flow, concurrent flow), fluidised bed dryers and vibrating fluidised bed dryers have been used. The heat source is generally coal, and direct as well as indirect heating is practiced. Older designs of column dryers are often criticised for their excessive energy consumption

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as well as environmental pollution.

Among the designs used in aeration drying are round silos with radial flow distribution from a central ducting, and round silos with in-floor ducting. There are also horizontal warehouses with on-floor or in-floor ducting with a capacity of over 1000 tonnes. There exist a large number of designs of small round aerated mud or mat silos, many of them also fitted with air distribution ducting, used for temperature control in grain

Geography and Climate

Grain is grown in most of Eastern China, predominantly maize in the northern part, wheat in the central part and paddy in the southern part of the country (Ren Yonglin & van Graver, 1996). Given the vast expanse of the country (from latitude 20 – 50° North), grain is grown under a range of soil and climatic conditions using a range of agronomic practices.

China has three major grain crops in its northeastern provinces, namely rice, wheat, and maize. With growing pressures on reducing losses (currently estimated as 10% of material production), reduced land availability and increased harvest yields, the grain industry is looking to modern dehydration systems and mechanical aeration to reduce sun-floor requirements, increase handling rates and improve grain storage stability

The northeastern provinces of Heilongjiang and Jilin are among the major producers of grain in China The major grain crops are, in order of importance: maize (60% of the total grain production in both provinces), rice, wheat and soybeans. The maize production in the two provinces of northeastern China accounts for 20 – 25% of the total national production

The two provinces are located in a climatic zone characterised by a frost-free period of about 150 days and a short growing period. There is a very short transition period between autumn and a severe winter with temperatures in the range of −20 to −30 for several months Any delay in planting or growth of the crops, especially maize, may result in a late harvest Grain will not be able to attain full maturity and the moisture content at harvest may be as high as 30% wet basis.

Grain Procurement

In the Heilongjiang province, maize is harvested manually in late September-early October, in some years up to November It is initially stored on cob after removal of sheaths. Shelling is usually performed on wet maize with moisture contents ranging from 25 – 35% The procurement by the state owned grain handling authority starts on 15 November and lasts till the end of December. This refers to the compulsory quota that every farmer is supposed to supply at a fixed price as payment of land rent and tax Grain in excess of the quota can be sold at the market price There are two sorts of market price: the negotiated price for surplus grain and the ceiling buffer stock price Farmers will store a certain quantity of grain on farm in order to obtain a higher market price

Grain procured by the grain handling authority goes initially into 'first line' grain collection depots, which are distributed within 30 km from each other. First line collection depots perform quality tests: measure moisture content, impurities (foreign matter and brokens), and thousand kernel weight. These depots usually do not have mechanical dryers and only limited sun-drying floors Grain would be either directly sent to intermediate or central depots, or stored temporarily in brick, mud or mat silos before being sun-dried and dispatched to these higher level depots The latter, particularly the central depots, generally have coal-fired column dryers of a standard design (Zhengzhou Grain Science and Research Institute, 15 t/h) as well as sunning floors and often warehouses and small brick silos with aeration facilities This applies to maize, but also to paddy, soybeans and wheat.

In the northeastern provinces, paddy is generally procured in August-September, followed by soybeans and sorghum and finally by maize Early maize is sun-dried or goes into the column dryers. Late maize often arrives at high moisture content (25 – 30%). However, being already in a frozen state it is often stored frozen until February-March

Logistics of In-store Drying

Most of the stored maize is sun-dried during spring and early summer Aeration equipment is used for ventilation in autumn and to a limited extent for drying in spring and early summer Since very little drying, except with high temperature column dryers, occurs in winter, there is usually a huge stockpile of wet maize and some wet paddy, that has to be dried within a very short period of time as the weather warms Given the availability of storage space, some of which has been fitted with air distribution systems, the concept of in-store drying may provide an adequate solution for increasing the drying capacity of the existing system.

Since the climate and infrastructure appear to be appropriate, a project researching their applicability is currently in progress In-store dryers are best suited to low to medium moisture products, and so would have to rely on the existence of hot air dryers, such as those already mentioned. However, the drying capacity of the latter would be artificially increased, since they would be involved in drying grain in the moisture range where they are most

efficient, i e to a moisture content of 18%.

In addition, in-store dryers could be used during the cold winter months By doing so, grain at 14% could be dispatched to its final destination, freeing up space in the store for grain presently kept outside In-store drying could be practiced using additional heat or ambient air if the relative humidity is low In-store drying technology could also be applied to other grains stored wet throughout winter, especially paddy, as well as to grain crops harvested earlier in the season such as wheat and soybeans This may help give the dryers a high utilisation factor.

The situation for paddy in the southern temperate or subtropical provinces of China is similar to that in most places in Southeast Asia, where paddy is being harvested during the wet season Throughout the region, this results in a high demand for mechanical dryers, caused by:

- the inadequacy of sun drying to cope with the amounts of grain being produced,
- a steady increase in the amount being produced, due to advances in agronomy and farm mechanisation,
- harvesting under conditions of high relative humidity and temperature, so that this grain has a higher average moisture content than the dry season crop

The main area targeted by the study is the province of Sichuan, which produces considerable amounts of paddy, as well as some wheat and corn

Weather Data

Weather data for two years (given as hourly records of temperature and relative humidity) have been obtained for the city of Zhaodong in Heilongjiang province. Weather data for seven years (given as six-hourly records of temperature and relative humidity) have been obtained for the city of Yibin in the province of Sichuan This weather data was used in conjunction with a one dimensional in-store drying model (Driscoll, 1996) to design a suitable drying solution for maize and paddy in these two regions of China.

In the simulation, air outside a window of allowed conditions is rejected, resulting in the dryer fan being switched off until the ambient conditions satisfy the window limits again These limits are typically expressed in terms of two dry bulb temperatures and two relative humidity limits If burner heat is provided, the burner is switched on if the ambient air is above a critical relative humidity, and then the resulting air is tested in terms of the window limits.

Results: Northeastern China

Weather data for Zhaodong City, Heilongjiang province for 1984 and 1994 (see Figures 1 & 2), were analysed using a strategy-testing module of the dryer simulation.

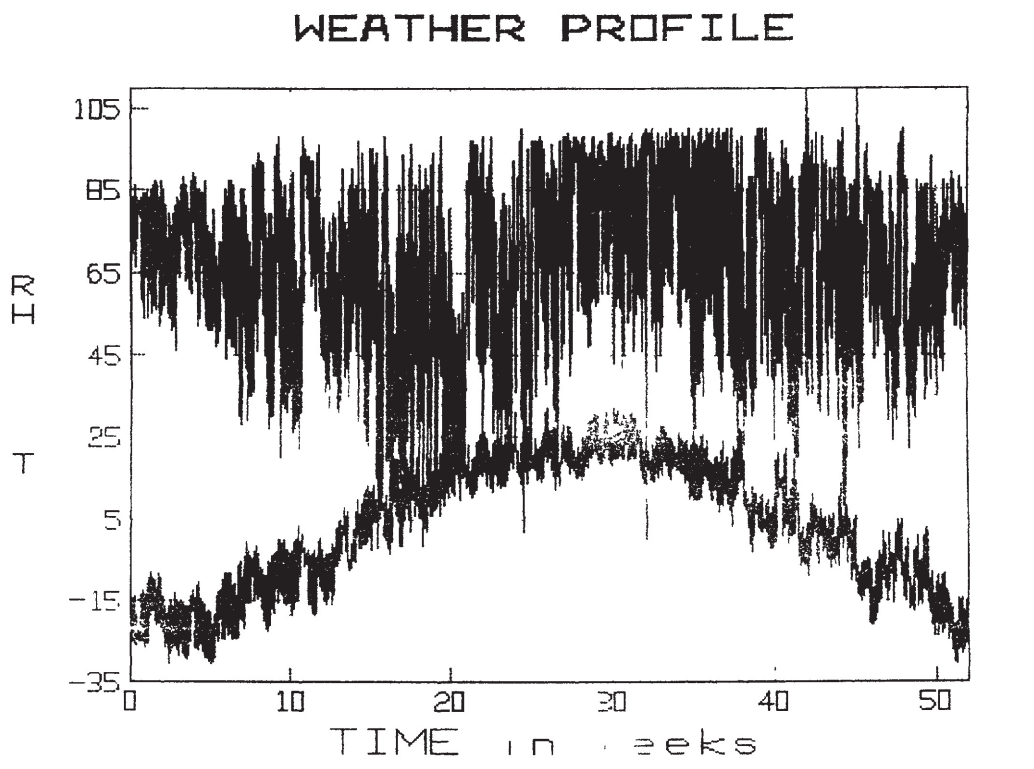

Fig. 1. Weather profile for Zhaodong (Heilongjiang province) on an hourly basis in 1984

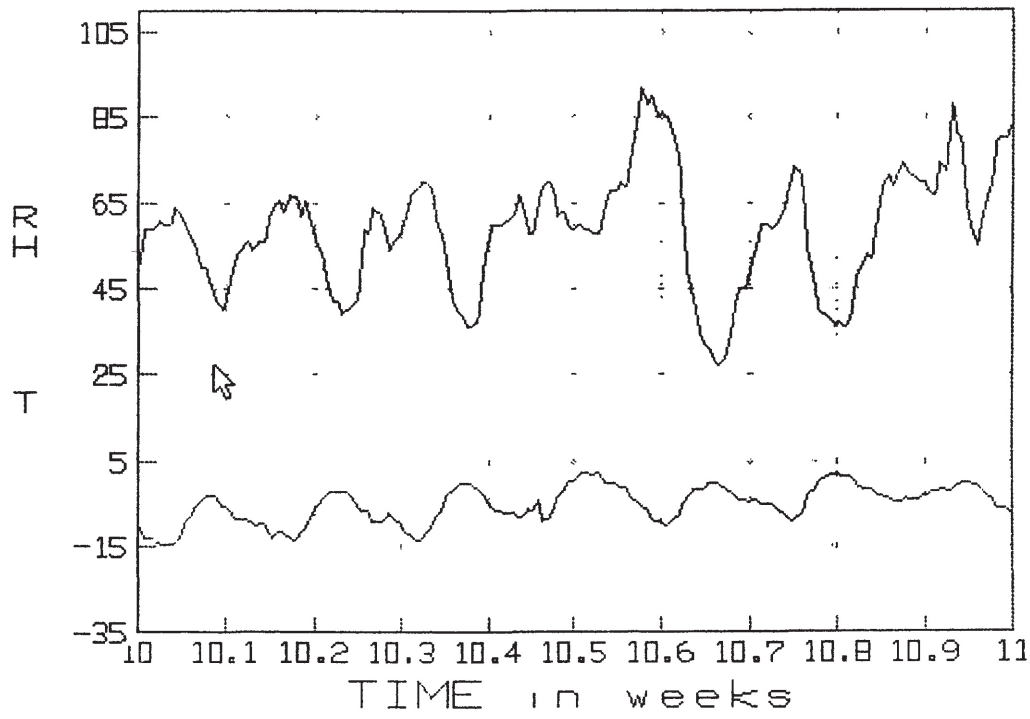

Fig. 2. Weather profile for Zhaodong (Heilongjiang province) in the month of February on an hourly basis in 1984

The aeration module was used to test the ambient air with (case one) and without (case two) additional heat. In this analysis, a window of permitted air for the dryer was chosen by setting temperature limits of 0 – 20℃ and relative humidity limits of 50 – 75% rh. For the case of heated air, a burner capable of heating the air by 5℃ was simulated, and the window limits chosen were 0 – 20℃ and 50 – 90% rh.

Limiting the relative humidity to 75% is necessary for grain stored under low temperature since the equilibrium moisture (EMC) content at 10℃ is as high as 15 for maize and 14 for paddy

However, these values of EMC have been established for varieties grown in Southeast Asia or Australia and the determination of these properties for the varieties grown in Northeast China is currently in progress. The results of the analysis for the two options are shown in Figures 3 – 6. Each plot shows the average relative humidity of the acceptable air (yellow), average temperature of the acceptable air (purple) and the percentage of acceptable air (dark blue)

Since the most critical period for drying of maize in Northeastern China is in early spring (March-April), the percentage of suitable drying hours using ambient air with and without additional heating has been summarised in Table 2 for these weeks only.

Table 2. Suitable drying weather for in-store drying in Zhaodong in the years 1984 & 1994 during weeks 11 – 18.

PERCENTAGES OF ACCEPTABLE AIR

Year	Ambient air	Ambient air + additional heat
1984	16.3	24.3
1994	14.8	19.1

The variation between years is small compared with the variation due to the burner The results suggest that a burner is necessary for this period of the year in Heilongjiang

Results: Southern China

A similar analysis was carried out for Yibin in the Sichuan province for the years 1987 & 1991. However, given significant differences in the weather pattern (especially higher ambient temperatures in winter, see Figures 7 & 8) the temperature limits for in-store drying have been changed to between 5 – 25℃.

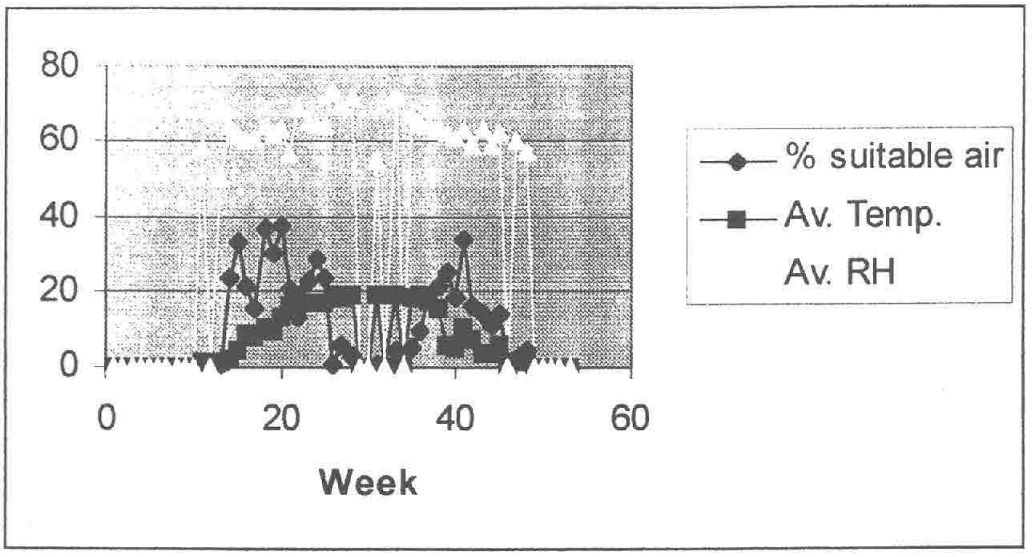

Fig. 3. Weather data analysis for Zhaodong 1984. Suitability of using ambient air without additional heating.

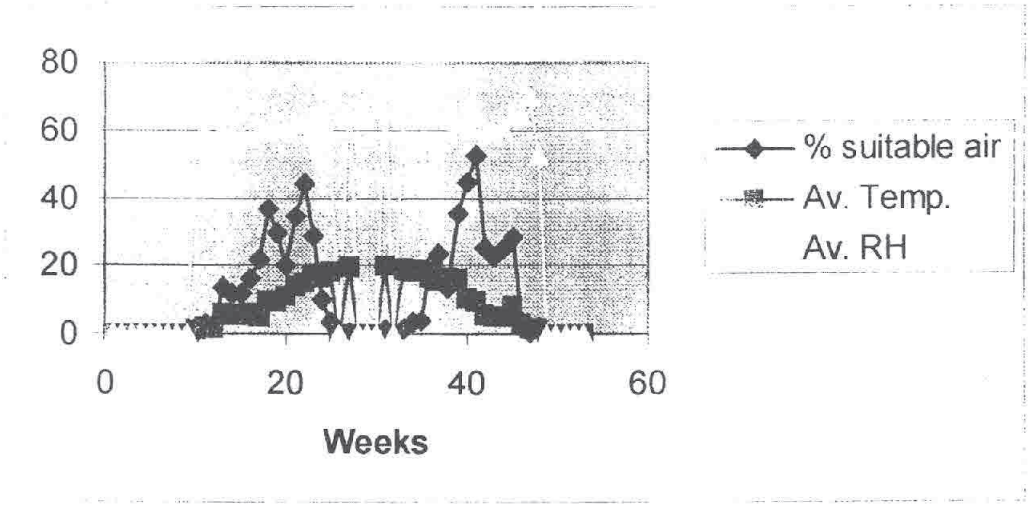

Fig. 4. Weather data analysis for Zhaodong 1984. Suitability of using ambient air with max. 5℃ temperature increase.

October to November are the months when the second crop of paddy is to be put into storage. Since the harvest is to be completed before winter, there are usually backlogs in drying of grain procured by the grain handling authority and hence there is a significant demand for dryers.

Table 3. Suitable drying weather for in-store drying in Yibin in the years 1987 & 1991, during weeks 40 – 47.

PERCENTAGES OF ACCEPTABLE AIR

Year	Ambient air	Ambient air + additional heat
1981	36.7	44.6
1991	44.6	47.3

The results of the analysis of weather data are shown in Figures 9 – 12.

The results of the analysis of the amount of air suitable for in-store drying during the crucial months of October to November are shown in Table 3.

Recommended Strategies

By selecting ambient air in the range 50 to 90% relative humidity, in conjunction with a burner supplying 5℃ for Heilongjiang, the simulation predicts that sufficient air was available for the two representative years chosen to dry the product using in-store drying. This conclusion applies to both regions studied.

Based on the curves of acceptable air, it appears that delaying the drying in Northeast China (figures 3 – 6) and advancing the time of drying in Sichuan (figures 9 – 12) would result in higher percentages of suitable air.

The direction of air distribution should be upwards through the grain in order to recover waste fan heat and so further increase the natural air drying potential. This factor was not taken into account in the aeration module, and provides a small safety margin for the recommendations contained here. (Foster G.H. & Tuite J. 1992).

A thorough analysis of several years of weather data collected on an hourly basis could result in a better estimate of the amount of air required in an average year. This was possible for Heilongjiang, but the fact that there were only six-hourly data for Yibin available results in a lesser degree of accuracy in the estimate of the amount of air available for in-store drying.

Acknowledgements

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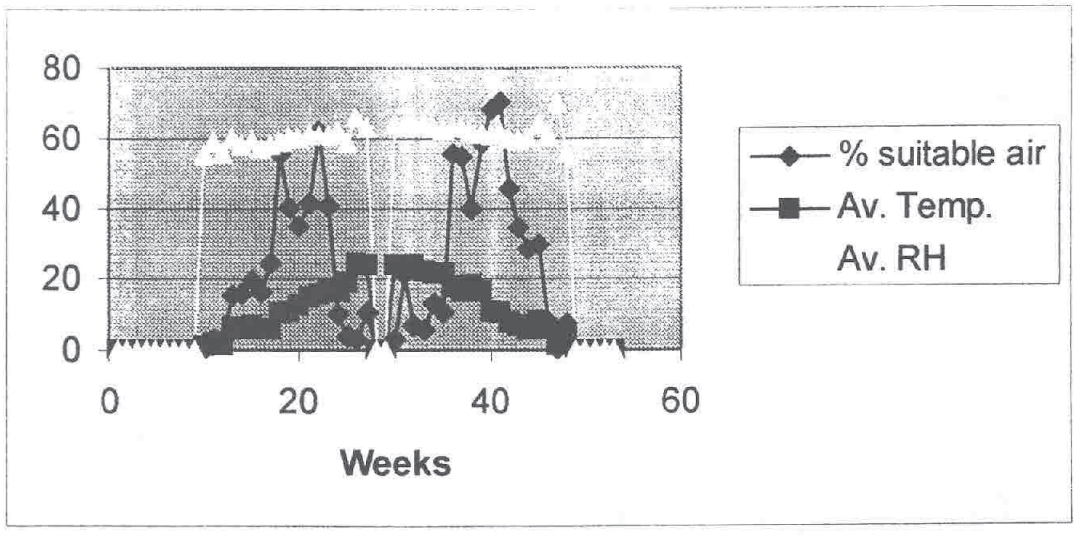

Fig. 5. Weather data analysis for Zhaodong 1994. Suitability of using ambient air without additional heating.

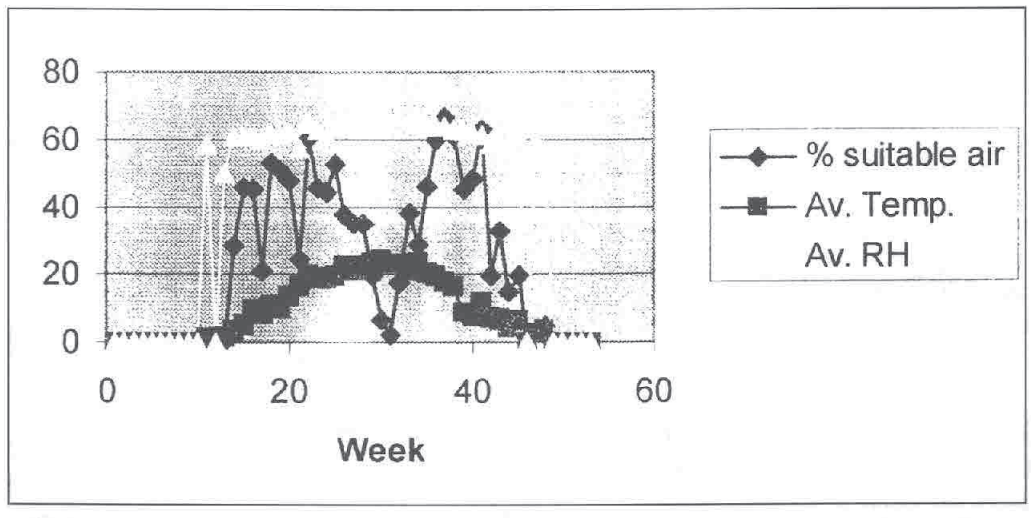

Fig. 6. Weather data analysis for Zhaodong 1994. Suitability of using ambient air with max. 5℃ temperature increase.

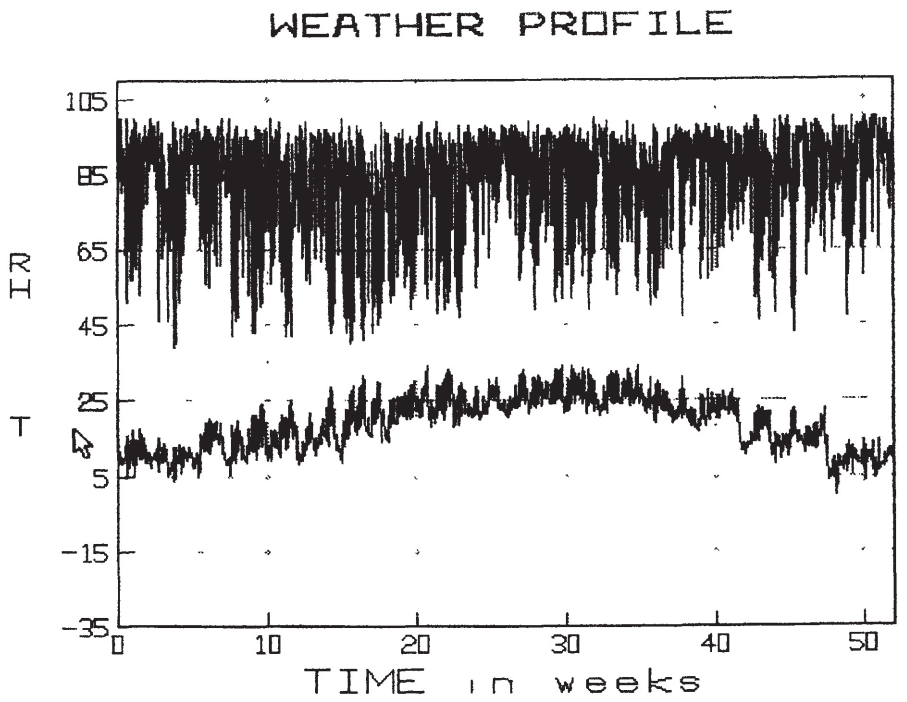

Fig. 7. Hourly weather data for Yibin, Sichuan province, 1987

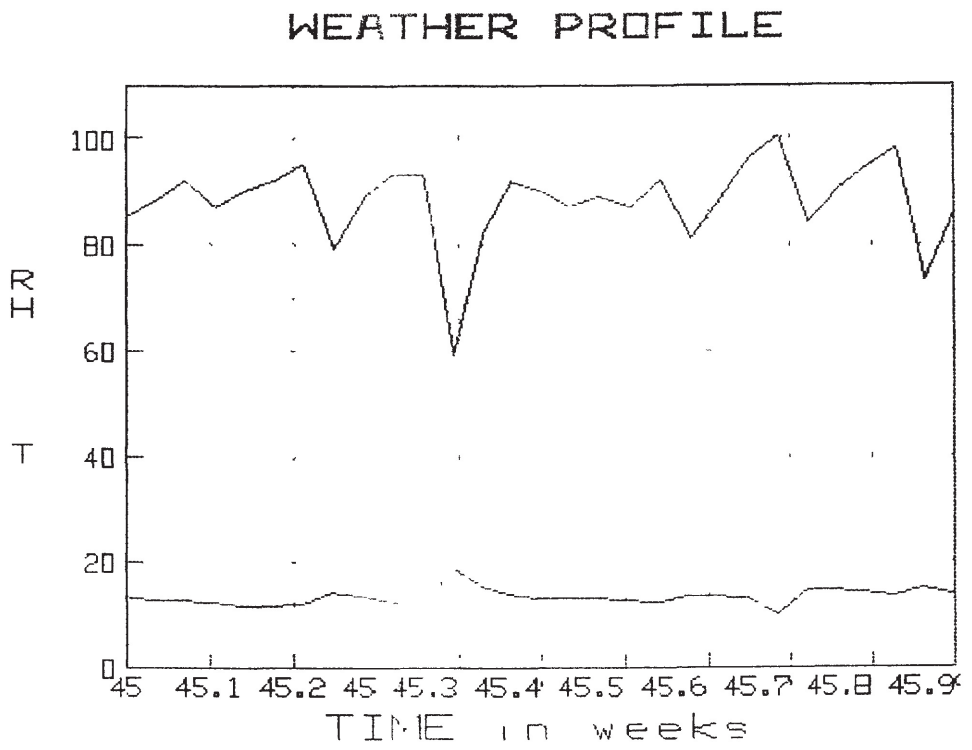

Fig. 8. Hourly weather profile for Yibin, Sichuan province, November 1987

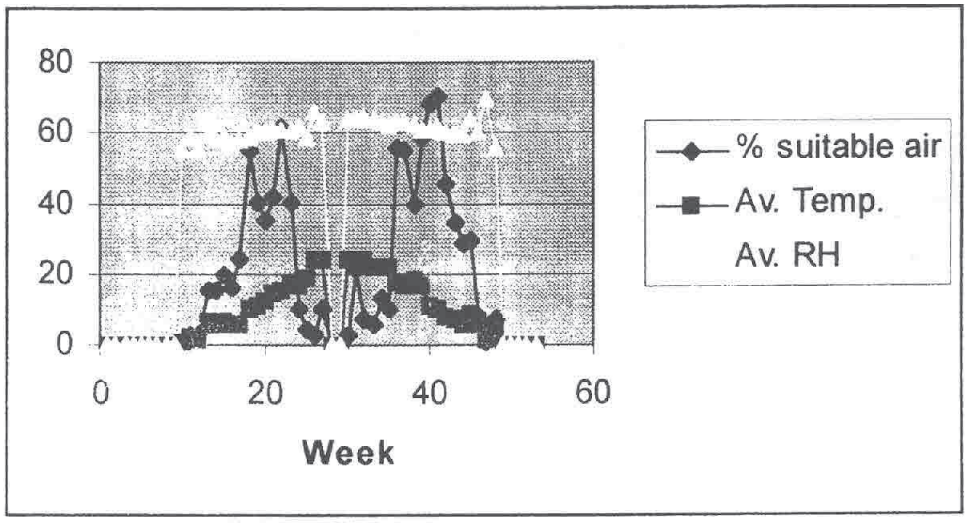

Fig. 9. Weather data analysis for Yibin 1987. Suitability of using ambient air without additional heating.

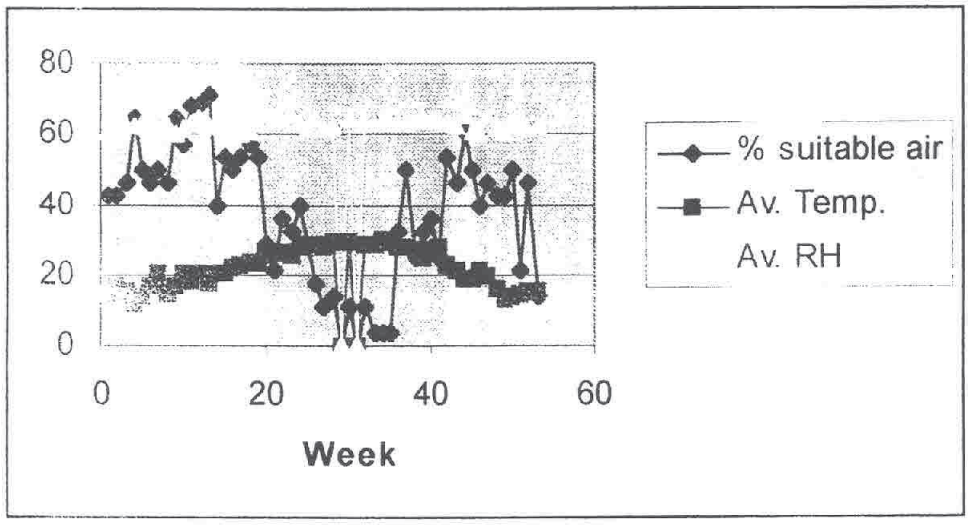

Fig. 10. Weather data analysis for Yibin 1987. Suitability of using ambient air with max. 5℃ temperature increase.

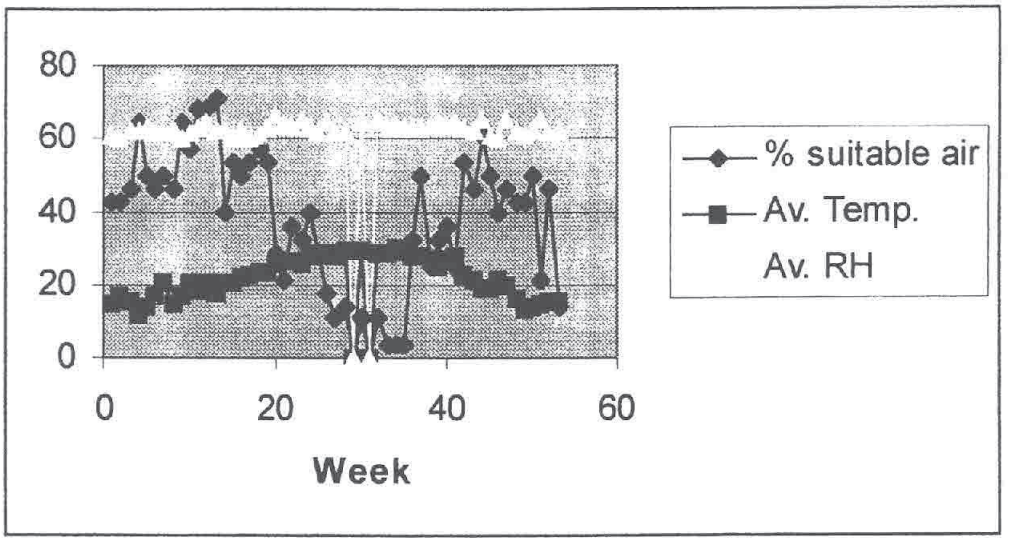

Fig. 11. Weather data analysis for Yibin 1991. Suitability of using ambient air without additional heating.

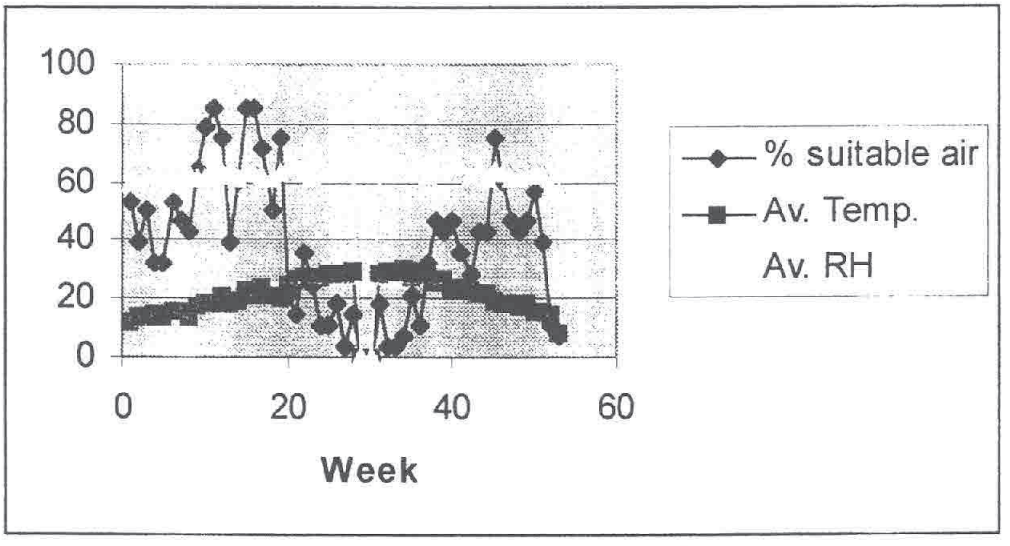

Fig. 12. Weather data analysis for Yibin 1991. Suitability of using ambient air with max. 5℃ temperature increase.

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