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Research Programme Objective F2

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

SPONTANEOUS HEATING IN MOIST ESPARTO GRASS

EXPERIMENTAL STUDY

P. C. Bowes and Mrs. P. L. Hinkley

SUMMARY

It has been shown that moist esparto grass can undergo spontaneous heating in the same way as other moist vegetable material.

It is considered that heating to ignition should be regarded as probable; so that if a stack of esparto grass becomes wet and shows signs of heating, it should be dismantled and allowed to cool or should be processed immediately.

February, 1959

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Addendum 1

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ADDENDUM

The following to be added to paragraph on procedure:-

The moisture content of the esparto grass, after wetting for the purpose of the self-heating tests, was 40 per cent of the dry weight for the sample of sound grass and 37 per cent for the mildewed grass.

April, 1959.

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INTRODUCTION

From a review of available information and incidents of fire in stored esparto grass [1] it was concluded that spontaneous ignition was unlikely to occur in dry esparto grass. However, reports following fires indicated that spontaneous heating could occur in the grass when wet with water from fire hoses. It was suggested that if stored esparto became wetted sufficiently for such heating to occur it should be assumed that heating might continue to ignition as in haystacks.

The experiments described in this note have been carried out to confirm whether or not moist esparto can, in fact, self-heat in the same way as hay. The aim has been to cover only the early stages of the heating which is due to the activity of micro-organisms and is common to all moist vegetable material so far studied.

EXPERIMENTAL

Materials

Two samples of North African esparto grass were tested. Both were green-brown in colour, one being sound and the other containing a proportion of, apparently, mildewed grass. The initial moisture contents of the samples were 9.9% of the dry weight for the former and 11.2% for the latter.

Apparatus

The tendency of the grass to self-heat was studied in an "adiabatic" calorimeter based on the design of Norman, Richards and Carlyle[2]. The calorimeter containing the sample was a Dewar flask of 715 ccs capacity immersed in a water bath provided with a heater. A system of automatic control ensured that as the temperature in the calorimeter increased due to self-heating of the contents, the bath was heated so that its temperature followed the temperature in the vessel with an average lag of 0.22°C. Air, saturated at the temperature of the bath as far as possible by bubbling through a vessel of water immersed in the bath, was passed through the calorimeter at a rate of 400 cc at N.T.P. per hour; the variation in air flow was ± 12%.

The temperature of the system and the concentration of carbon dioxide in the effluent gas were recorded continuously; the latter with the aid of an infra-red gas analyser calibrated with mixtures of air and carbon dioxide of known composition.

Procedure

A weighed sample of the grass, chopped into short lengths, was mixed with a small quantity of water for about 10 minutes. Excess water was then drained off and the grass weighed again to determine the amount of water added. After this treatment the grass appeared uniformly wet on the surface and pieces tended to stick together. The interval between the initial wetting of the grass and the beginning of observations of its self-heating in the calorimeter was about $\frac{3}{4}$ hour.

Determination of heat loss

At the end of a test, when it was evident that reaction within the calorimeter vessel had ceased, the rate of heat loss from the calorimeter at different temperatures was determined from the rate of cooling and the estimated water equivalent of the inner shell of the Dewar flask and its contents (94g). The rate of heat loss, q, was found to be

$$q = 6.75 + 0.113\Delta t \quad \text{g.cal hr}^{-1}$$

for Δt in the range 10-40°C, where Δt is the difference in temperature between the calorimeter and the surroundings.

The heat loss may be expected to be greater than zero when $\Delta t = 0$, as in the above equation, since it is unlikely that the air flowing through the calorimeter was ever saturated. But since the equation gives $q = 0$ when $\Delta t = -60°C$, it is concluded that the linear relationship for the heat loss fails as Δt approaches zero.

RESULTS

The temperature record for the run with the sample of sound grass is shown in Figure 1, together with the rate of carbon dioxide evolution calculated simply as the product of instantaneous concentration of carbon dioxide and the mean rate of air flow during the test. The maximum concentration of carbon dioxide attained was 12.4% by volume.

The rate of heat evolution is shown in Figure 1, calculated from the mean rate of temperature change over finite intervals of the temperature record and corrected for heat loss. The calculation has not been made for temperatures below about 25°C, i.e. less than about 5°C above atmospheric, in view of the uncertainty in the rate of heat loss for small values of Δt (above).

In the test on the sample of slightly mildewed grass the temperature alone was recorded. The rise in temperature followed a course similar to that for the sound grass, Figure 1.

The records for the temperature rise and rate of evolution of carbon dioxide in Figure 1 show features commonly observed during heating in moist vegetable material due to the activity of micro-organisms (mould fungi and/or bacteria)[3, 4]. In particular, there are two distinct stages in the heating - the first with a maximum rate at about 50°C and the second, with a lower maximum rate, at about 60°C. The rate of heat evolution follows the same course as the rate of carbon dioxide evolution; the slight time lag between the two records can be explained simply by the presence of a heat loss whose rate increases with temperature.

The temperature maximum of 67°C is less than the maximum possible in heating due to microbiological activity, i.e. about 75°C. This may be due to the heat loss from the calorimeter having been too great, or to conditions not having been suitable for development of the thermophilic organisms capable of continuing the heating to the higher temperature; these organisms may even have been absent.

The rate of carbon dioxide evolution decreased continuously following attainment of the maximum temperature, and showed no sign of recovery as the temperature passed through the optimum for the second, high temperature, group of organisms; thus indicating that self-sterilisation of the material was virtually complete.

At the first stage of maximum activity the heat of reaction was 5.5 g.cal per cc of carbon dioxide at N.T.P. or 124 Kg cal per mol. Within the limits of experimental error this is comparable with the heat of combustion of carbohydrate, i.e. about 111 Kg cal per mol of carbon dioxide produced. This is of the order of magnitude to be expected for the fully aerobic dissimilation of plant material by microflora, at least in the initial stages when readily available carbohydrate is present.

A minor point of incidental interest is that evolution of carbon dioxide attained a rate of about 1 cc per hour within 3 hours of moistening the grass, i.e. long before fungal spores would have germinated. This was probably due to respiration of the grass itself, since it might perhaps be expected that in a plant such as esparto grass, which is adapted to an arid habitat, a proportion, at least, of the tissue would remain viable for very long periods.

CONCLUSIONS

The points of similarity between the heating of the moistened esparto grass in these laboratory tests, and heating that has been observed in hay and other vegetable material, are sufficient for it to be concluded that a stack of baled esparto grass may, if it became wetted in the interior, behave in the same way as a stack of insufficiently dried hay; i.e. it may undergo spontaneous heating to a temperature of about 75°C.

Further heating to ignition may occur but, since the means by which hay heats to ignition is not understood, it is not possible to reach a firm conclusion. It nevertheless appears reasonable to regard ignition as probable. Hence, if ever a stack of esparto grass becomes wet and shows signs of heating, it should be dismantled and cooled or should be processed immediately.

ACKNOWLEDGMENT

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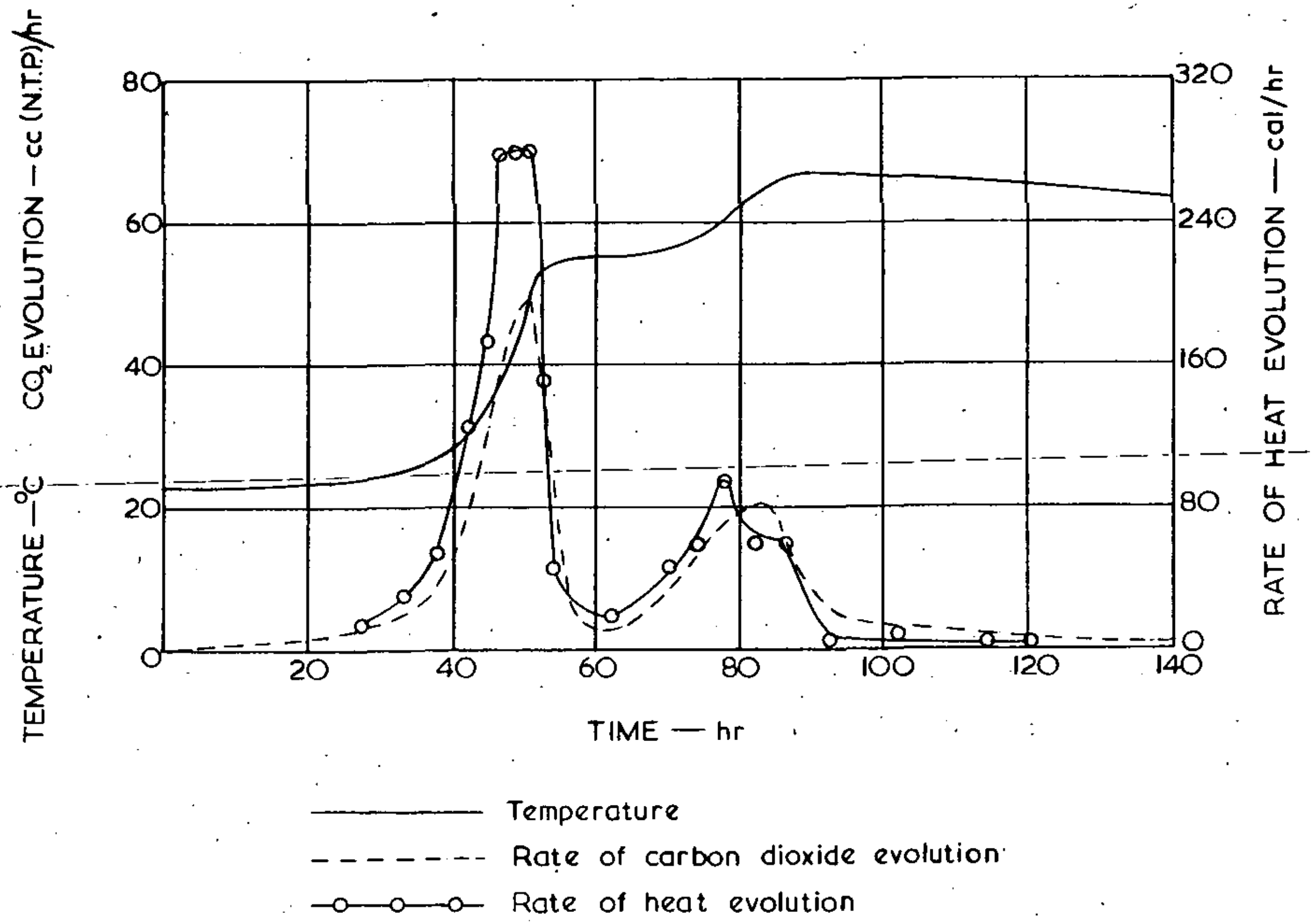

FIG.1. SPONTANEOUS HEATING OF MOIST ESPARTO GRASS