Ash Content: Its Effect on Combustion of Corn Plants

Abstract. *Two corn plant samples, one cut in the fall while green, the other after weathering over the winter, exhibited strikingly different combustion properties. The increased susceptibility to flaming combustion of the spring-harvested sample is attributable to its decreased ash content, and not directly to its moisture content.*

The combustion properties of cellulose and other carbohydrates can be drastically altered by the presence of small quantities of inorganic impurities (*1*). For pure cellulose, the effect of adding inorganic "ash" constituents is to minimize or eliminate the reactions leading to a flaming combustion process. This effect is attributable to the lowering of the temperature range of significance for the reactions which manifest themselves as glowing combustion. These observations suggest that a similar result may also be found in cellulosic fuels in their crudest form—namely vegetation, both living and dead.

The inorganic composition of vegetation is a function of many variables (*2*). It depends on the species of vegetation, on the soil, on the weather, on the stage of plant development, and on the part of the plant which is being considered. Changes in the proportions of inorganic components can be brought about by various natural and artificial means (for example, unseasonable weather, fertilizers, growth regulators). Thus, in some plants a decrease in the inorganic components of that part which is above ground can be accomplished by introducing a stress which causes a withdrawal of nutrients to the basal portion of the stem and to the roots. Even after a plant dies it is exposed to weathering, and leaching of the inorganic substances may occur. For the thin parts of a plant, the variable amounts of external contamination can represent a significant fraction of the "ash." The possibility that all such variations can have a marked effect on the fire vulnerability of an individual plant and of the complex in which it grows has by and large been overlooked.

Recently, Edwin N. York, an amateur farmer from Kent, Washington, provided us with an opportunity to investigate the effect of natural changes in ash content on the combustion of corn plants. On 30 October 1963, as York was harvesting some stalks of Golden Market Yellow sweet corn for Halloween decorations, he remembered some earlier discussions concerning the problem of fire vulnerability. Consequently, he cut several still-green stalks at ground level and placed them in an open barn, while leaving several identical stalks intact and exposed to the elements. On 5 March 1964 the exposed stalks were also harvested and placed for 1 month in the open barn near the other sample. Since 5 March both samples have received identical treatment. In the subsequent discussion the sample harvested in the fall of 1963 will be referred to as sample F, that harvested in spring of 1964 as sample S.

Sample F is a pale dirty green color, while sample S is straw-colored. If a match is held to a leaf or section of the stalk of sample F, the sample flames fairly readily, but when the match is withdrawn the flames die out. The charred section of the sample continues to glow and forms a powdery white ash, and there is little spread of combustion beyond the region initially ignited. If a match is held to a leaf or stalk segment of sample S, the sample flames readily and the flames spread throughout its entirety. When the flames die out, a black char residue with a considerable amount of structural stability remains and no glowing is observed. If a red hot wire is placed in contact with the leaf of sample F, glowing combustion proceeds to burn a hole of somewhat larger dimensions than that of the wire, but no flaming is observed. If the wire is brought into momentary contact with the leaf of sample S, a sharp, clearly defined hole of dimensions essentially that of the wire is burned through the sample with no glowing observed and essentially no spread beyond the point of contact; if the wire remains in contact with the leaf for a somewhat longer period, the leaf ignites and continues to burn in flaming combustion.

As shown in Table 1 (*3*), the two samples were essentially identical in moisture content, but sample S had roughly one-third as much ash as sample F (*4*). The spectrographic analyses, as well as the colorimetric analysis for phosphorus, indicated a general reduction of all ash constituents in sample S, rather than a complete elimination of select inorganic components. There was a gross difference in the fraction of water-soluble material in the two samples; roughly one-third of sam-

Table 1. Analysis of leaf samples from Golden Market Yellow corn.

Item	Sample F		Sample S	
Date of cutting	30 October 1963		5 March 1964	
Color	Green		Straw	
Match test	Nonsustained flame; glow		Sustained flame	
Hot wire test	Enlarged hole; glow		Sharp hole or sustained flame	
Residue	White ash		Black char	
Weight as percent of dry weight				
Original sample (16 March 1964)		108.0		108.0
Loss, vacuum drying 40°C	8.0		8.0	
Ash	11.4		3.7	
Leached in distilled H_2O, 24 hr				
Total leached	31.2		3.2	
Less ash	1.3		0.2	
Net soluble organic		29.9		3.0
Insoluble organics		58.7		93.3
Unleached sample		68.8		96.8
Insoluble after hydrolysis*		46.3		65.6
Ratio: hydrolyzed/unhydrolyzed		(.49)		(.48)
Spectrochemical analysis of ash				
>50 μg/mg ash	Ca, Mg, Si, Al		Ca, Mg, **Si, Al**	
5–50 μg/mg ash	Na, Fe, P		Na, Fe, P	
0.5–5 μg/mg ash	Cu, B		**Cu, B**	
0.05–0.5 μg/mg ash	Sr, Mn, Ti		**Sr, Mn, Ti**	
Phosphorus by colorimetry				
% of dry weight		0.53		0.17
μg/mg ash		46		46

* With 72 percent H_2SO_4.

ple F dissolved when soaked for 24 hours in distilled water. It is interesting that little of the inorganic component of sample F leached out with the soluble fraction. The insoluble residues of both samples were hydrolyzed with sulfuric acid. In both cases roughly one-third of the hydrolyzed samples dissolved in water; the other two-thirds remained insoluble. By the method of Mendel *et al.* (*5*), the fraction soluble after hydrolysis was shown to be almost all carbohydrate.

Although there are some obvious differences in the organic composition of the two samples, especially in the water-soluble fractions, these differences cannot account for all of the differences in combustion properties. In particular, the enhanced glowing combustion of sample F with decreased flaming vulnerability is attributable to the differences in ash content of the two samples.

The direct effect of water in influencing the combustion of vegetation has been recognized for many years. However, live green grass and grass freshly moistened after being allowed to die *in situ* exhibit strikingly different combustion behavior. When exposed to an open flame, a green blade of grass will shrivel, char, and ablate away without igniting; moistened dead grass will burn readily after a brief interval, during which the moisture is driven off. Thus, the difference in combustion properties must be due to something in addition to the difference in moisture content between the living and dead vegetation. Studies of range management have shown that prolonged drought, which so greatly increases the hazards of wildland fires, also influences the composition of forage by decreasing the inorganic constituents of the vegetation, particularly the phosphorous content (*2*). If it can be established that the prevalence of wildland fires during droughts is significantly influenced by the inorganic content as well as the moisture content of the vegetation, methods that would increase the ash content of vegetation could greatly expand the alternatives available to those charged with the responsibilities of fire control.

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References and Notes

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2. A. Gordon and A. W. Sampson, *Univ. of California Agricultural Experiment Station, Berkeley, Bull. No. 627* (Univ. of California, Berkeley, 1939).
3. We thank George V. Shalimoff of the Lawrence Radiation Laboratory and Anne E. Lipska of the U.S. Naval Radiological Defense Laboratory for assistance with the analyses.
4. The variations found in different portions of the two samples are not large enough to change any of the present conclusions.
5. B. Mendel, A. Kemp, D. K. Meyers, *Biochem. J.* **56**, 639 (1954).

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DNA Synthesis in Alveolar Cells of the Mammary Gland: Acceleration by Ovarian Hormones

Abstract. *In normal alveolar cells of the mammary gland of C3H/HeJ female mice, DNA synthesis lasts an average of 20.7 hours with a coefficient of variation of 26.6 percent. Treatment of the mice with 1 microgram of 17-β-estradiol and 1 milligram of progesterone per day for 3 to 4 days decreases the average duration to 10.7 hours and the coefficient of variation to 13.8 percent.*

Using a P^{32}-labeled precursor of DNA and radioautography at cellular level, Howard and Pelc (*1*) showed that DNA is synthesized during a discrete part of interphase, the period between two cell divisions. The portion of interphase during which a cell doubles its DNA is called the S phase and is equated to the phase during which cells take up the labeled phosphorus into DNA. The process of DNA synthesis is preceded by a period referred to as G_1 and followed by a G_2 phase. Mitosis (M) follows G_2. These four successive phases form the typical generative or proliferative cycle of cells (*2*).

Progress in the analysis of DNA synthesis in recent years has been based largely on the discovery that thymidine is a highly specific precursor of DNA (*3*) and on the introduction of labeled thymidine in radioautographic studies (*4*). The duration of the process of DNA synthesis can be measured with reasonable ease and accuracy by at least two methods (*5, 6*). This has been done with a number of mammalian cells, and tabulation of data from different sources is available in the literature (*7*). Thus far, duration of DNA synthesis in most of the cell systems investigated appears to vary between 5 and 10 hours, with most of the values clustered around 7 to 8 hours. In contrast, generation time —that is, the duration of the entire generative cycle—can vary widely, from 12 hours to several days (*8*). This suggests that the duration of DNA synthesis in different cell types of a given animal species is fairly constant. As the length of the G_2 phase and of mitosis appear also to be rather constant, it has been further suggested that the whole sequence, DNA synthesis-G_2-mitosis, which is often referred to as the "doubling sequence," is approximately of constant duration and that differences in generation time and thus proliferation rate, both within and between cell populations, depends upon variation of the G_1 phase (*8, 9*).

The above concept is debated by Bullough (*10*), especially on the basis of results which demonstrate that there are noticeable variations in the duration of mitosis in the epidermis of the mouse. The range of variation so far discovered by Bullough and Laurence (*11*) is from 1.5 to 5.3 hours in the epidermis in vitro and in vivo. We found that the duration of mitosis showed diurnal fluctuations and depended upon the adrenalin concentration in the cells. The test of the "constancy" hypothesis of duration of DNA synthesis and in general of the "doubling sequence" was also the subject of a paper by Sherman *et al.* (*12*) on the cell population kinetics of the ear epidermis of the mouse; the cells of this tissue are known to have an extremely long generation time—about 24 days. In these cells the length of DNA synthesis averages about 30 hours, and this appears to disprove the tested hypothesis. As the same authors point out, however, the ear epidermis is under conditions of abnormally low temperature in comparison to most of the tissues of the body. Therefore, the long duration of DNA synthesis can reasonably be interpreted as an aspecific temperature effect on chemical reactions. Reported herein are the results of a more stringent test carried out with an internal