Safe Storage Periods for Farm-Stored Rapeseed Based on Mycological and Biochemical Assessment

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Contribution 914, Agriculture Canada, Research Station, 195 Dafoe Road, Winnipeg, Manitoba, Canada, R3T 2M9.

The authors thank M. Barron and L. Henderson for technical assistance, S. Pixton for providing the rapeseed equilibrium relative humidity (ERH) chart, and G. Ayerst and B. Flannigan for critical review of the manuscript.

Accepted for publication 14 November 1979.

ABSTRACT

MILLS, J. T., and R. N. SINHA. 1980. Safe storage periods for farm-stored rapeseed based on mycological and biochemical assessment. Phytopathology 70:541-547.

Deterioration of initially sound rapeseed (*Brassica napus* 'Tower') during storage for 147 days was studied at temperature-moisture levels typical of farm bins in Manitoba. Fat acidity value (FAV) and germination of seed samples, time required for development of odor and visible mold, occurrence of particular fungi and their association with FAV were assessed. In rapeseed stored at 25 C and 12.4% moisture content (MC), *Penicillium* spp. were most frequent after 30 days and *Aspergillus versicolor* after 147 days; whereas at 25 C and 9.7% MC species of the Aspergillus glaucus group were most frequent after 50 days. A guideline for maximum safe storage periods for farm-stored rapeseeds at different temperature and moisture levels was derived from the laboratory data and validated with rapeseed data collected from farm bins in Manitoba. Predictions of poor storability of seeds in six of 15 bins based on a laboratory-tested guideline were validated when the same bins were reinvestigated in the spring of 1979, 85–129 days after binning. The guideline is intended for estimating rapeseed storability, particularly during the first 5 mo after binning, by farmers in northern continental climatic zones typical of western Canada and the northern USA.

Because western Canada includes several climatic zones, harvesting of rapeseed *Brassica napus* L. and *B. campestris* L. is done under a wide range of temperature and moisture conditions with extreme variation between years. Like the cereal crops (5,6), rapeseed is particularly prone to spoilage (8,16) and requires careful storage management. The rate of rapeseed spoilage increases when it is stored in bulk with unevenly distributed high moisture content (MC) and is admixed with green weed seeds. Even when seeds are stored at a relatively low moisture content, (eg, 9.0%), they are not entirely safe and will spoil when binned on hot days (eg, 30 C) (16). The present moisture level recommendations for storage of straight grade, tough, and damp rapeseed by Canadian farmers (4) includes no indication of the different periods of time that rapeseed can be stored safely under various conditions of temperature and moisture.

The purposes of this investigation were: to create a rational basis for selecting storage temperatures to obtain the maximum period of safe storage for rapeseed; to determine the physical limits for the growth of the major seed-borne fungi so that the safe storage periods (as assessed by germination loss, fungal contamination, and fat acidity levels) can be established for rapeseeds stored under a wide range of granary conditions; and to validate the experimentally determined safe storage conditions by observations of farm granaries.

MATERIALS AND METHODS

Seeds for laboratory tests were taken in February 1977 from three 22.5-kg lots of rapeseed (*B. napus* 'Tower') grown in 1976 and stored after harvest in farm granaries in Manitoba (Table 1). Seed lots were passed through a spiral rapeseed separator (Cleland International, Inc., Rogers, MN 55374), thoroughly mixed and air dried to about 5% moisture content on a wet weight basis.

Selection of temperature and moisture regimes. To simulate storage temperature conditions on the Canadian prairies we considered four factors: (i) the rapeseed harvest period in a particular year can be considered to range from 10 days earlier to 15 days later than the official date of the beginning of the wheat harvest published annually in the Manitoba Agricultural Yearbook (7); (ii) maximum and minimum temperatures (at Winnipeg International Airport [3]) for this 25-day harvest period abstracted for the period 1954–1975; (iii) temperatures of freshly binned rapeseed reported by Prasad (14); and (iv) seasonal and annual temperature fluctuation patterns (Fig. 1) for stored rapeseeds established from monthly analyses during 1973–1978 at the center (1 m from the ground, 1.7 m from the upper surface) of a 41-tonne experimental bin of rapeseed (*B. napus* L. 'Zephyr') at Glenlea, Manitoba (techniques described by Sinha and Wallace [16]). By considering factors i–iv, six temperatures were selected to represent particular storage conditions. These were: *44 C* (approximating the maximum temperature [36.7 C] during the harvest periods 1954–1975, plus 7.0 C the difference between air temperature at Winnipeg International Airport and that of freshly binned rapeseed harvested on a sunny day); *31, 25, and 19 C*, actual temperatures of freshly binned rapeseed harvested on a sunny day, on a cloudy day, and in the early evening (19–22 hr), respectively (14); *10 C* (the mean minimum temperature during the harvest periods 1954–1975); and *0 C* (approximating the minimum temperature during the harvest periods 1954–1975 [−4.4 C] plus 4.9 C, the difference between air temperature at Winnipeg International Airport and that of freshly binned rapeseed harvested in the early evening).

Rapeseed moisture contents to be studied were chosen on the basis of our understanding of prairie crop storage conditions since approximation of these conditions was a prime objective. The moisture contents were 7.0 and 9.5, 10.5, and 12.6% (wet weight basis) which represented dry, average, and wet harvest seasons on the prairies. However, any of these moisture levels may occur in some part of the prairie rapeseed-growing area in a particular crop year, depending on the local climate of a farm, the state of seed maturity, and the time of day or night the crop was binned. Because of minor fluctuations during moisture conditioning of the three lots of dry rapeseed (Table 1) the exact moisture contents deviated slightly from the chosen levels. Moisture contents for the four levels in the three lots at the beginning of the experiment were: lot 1—7.1, 9.5, 10.3, and 11.9%; lot 2—7.3, 9.7, 10.7, and 12.3%; lot 3—7.5, 9.8, 10.8, and 13.0%.

Laboratory studies. The three rapeseed lots, although from different sources, were considered to be replicates because all were of good quality and originated from nearby locations in the same province. Each air-dried lot was divided into four 3-kg quantities,

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water was added to each to bring it to the four chosen moisture levels, and each was rotated in a drum for 2 hr to ensure even moisture distribution. Five 400-g quantities at each moisture level were then placed in separate 2,300-ml glass screw-capped air-tight jars. One jar at each moisture level was kept for the duration of the experiment (147 days) at 19 C. The other four were kept for 60 days at 44, 31, 25, 19, or 10 C and then at declining temperatures for the remaining 87 days to simulate normal autumn-winter cooling patterns at the center of a large bin (16). To achieve this, seed samples were transferred after 60 days from one temperature regime to another in three stages at 30-day intervals; for example, from 25 to 22 C at 60 days, 22 to 15 C at 90 days, and 15 to 10 C at 120 days. The other temperature regimes are shown in Table 2. Only rapeseed adjusted to the highest moisture level (11.9%) was maintained constantly at 0 C. One additional jar of air-dried seed of each lot was kept at −15 C for the duration of the experiment and served as a control. Each bottle was sampled eight times, once at the beginning and end of the experiment and on six other occasions depending on the temperature and moisture level of the sample. It was assumed that frequent opening of the jars during sampling minimized anaerobiosis and the accumulation of gaseous seed and fungal metabolites.

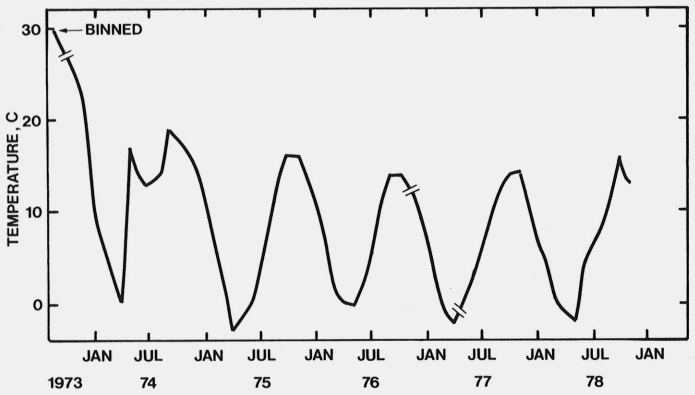

Fig. 1. Seasonal and annual fluctuations of temperature in the center of an experimental 5-m-diameter circular metal bin of Zephyr rapeseed at Glenlea, Manitoba, Canada, during 1973–1978.

Quality. "Quality" was defined as a composite of several attributes of stored rapeseed at particular stages of decay. Criteria included in our concept of a typical sample of high quality rapeseed were: a sweet odor, no visible mold, less than 1% other seeds, greater than 90% germination, more than 97% yellow seeds after crushing, and a conductivity level of less than 75.0 μmho after soaking seeds in 20 ml water at 22 C for 80 min, and a fat acidity value (FAV) of less than 30 mg KOH per 100 g of moisture-free seed. Applicability of these quality criteria was tested earlier (10).

TABLE 1. Agronomic, biochemical, and mycological characteristics of sound Tower rapeseed lots used in the laboratory to determine limits of safe storage

Lot no.	Source	Moisture[a] content (%)	Germination (%)	Crushed seeds (%)			Conductivity μmho	FAV (mg KOH)	Seed microflora components (%)[b]									
				Yellow	Green	Brown			Ac.w.[c]	Al[c]	As. f.[d]	As. g.[d]	As. v.[d]	Ce[d]	Cl[c]	Pa[c]	Pe[d]	Rh[c]
1	Homewood	5.6	98	99	1	0	43.7	16.4	2	6		2	2	2	48		14	6
2	Teulon	4.8	98	100	0	0	40.0	22.7		16	2		2	46	100	4	6	
3	Newdale	5.2	99	100	0	0	32.8	12.8		6		4		86	20		10	4

[a] Wet weight basis on receipt from the farm.
[b] Code: Ac.w. = white actinomycetes; Al = *Alternaria alternata*; As. f. = *Aspergillus flavus*; As. g. = Aspergillus glaucus group species (mainly *A. amstelodami, A. repens* and *A. sejunctus*); As. v. = *Aspergillus versicolor*; Ce = *Cephalosporium acremonium*; Cl = *Cladosporium cladosporioides*; Pa = *Papularia arundinis*; Pe = *Penicillium* spp. (mainly *P. verrucosum* var. *cyclopium*); and Rh = *Rhizopus arrhizus*.
[c] Percentage microfloral components on filter paper moistened with water.
[d] Percentage microfloral components on filter filter moistened with 7.5% NaCl.

TABLE 2. Agronomic, biochemical, and mycological changes in Tower rapeseed lots during 147 days of storage under various temperature-moisture regimes maintained in the laboratory

Moisture[a] content (%)		Temperature regime[c] (C)	Germination[a] (%)	FAV[a]		Conductivity[a] (μmho)	ERH (%)[a]		Spoilage symptom development period (days)		
Initial	Final			Actual reading	Change from zero time (%)		Initial	Final	Visible[a] mold	Moldy[b] odor	<90%[b] germination
5.6	–	Control (−15)	98	16.4	–	43.7					
–	4.9	Control (−15)	93	15.0	−8.5	38.2			–	–	–
7.1	6.4	19 ⟶ 7	88	24.4	+48.7	38.2	57	⟶ 47	–	–	–
11.9	11.3	0	89	24.8	+51.2	32.8	82	⟶ 80	–	–	–
10.3	9.5	10 ⟶ 5	83	25.5	+55.4	43.7	77	⟶ 72	–	–	–
7.1	6.2	25 ⟶ 10	91	29.5	+79.8	49.1	58	⟶ 46	–	–	–
11.9	11.3	10 ⟶ 5	91	30.8	+87.8	38.2	83	⟶ 80	–	–	–
9.5	8.6	19 ⟶ 7	91	34.2	+108.5	43.7	74	⟶ 67	–	–	<147
10.3	9.8	19 ⟶ 7	88	36.4	+121.9	49.1	78	⟶ 74	<77	<77	<105
7.1	6.4	31 ⟶ 13	89	37.1	+126.2	54.6	58	⟶ 48	–	–	<147
9.5	8.6	25 ⟶ 10	90	44.1	+168.9	43.7	75	⟶ 67	<77	<77	<77
11.9	11.3	19 ⟶ 7	90	50.3	+206.7	60.1	83	⟶ 80	<28	<28	<63
10.3	9.6	25 ⟶ 10	86	57.3	+249.3	49.1	78	⟶ 73	<42	<42	<63
9.5	8.7	31 ⟶ 13	84	65.3	+298.1	54.6	75	⟶ 68	<42	<42	<63
7.1	6.0	44 ⟶ 15	0	78.7	+379.8	54.6	63	⟶ 45	–	<91 (yeast)	<28
11.9	11.6	25 ⟶ 10	85	81.2	+395.1	103.7	82	⟶ 81	>28	<28	<63
7.1	5.8	19	89	24.0	+46.3	43.7	67	⟶ 45	–	–	<147
9.5	8.6	19	94	33.0	+101.2	49.1	74	⟶ 68	<147	<147	<147
10.3	9.1	19	91	48.4	+195.1	54.6	78	⟶ 72	<77	<77	<147
11.9	11.4	19	75	73.3	+346.9	49.1	83	⟶ 82	<63	<63	<147

[a] Lot 1 only; first two lines refer to controls examined after 0 and 147 days, respectively, ERH derived from desorption curve for Tower rapeseed based on Pixton and Warburton (13).
[b] Mean of results from individual lots 1, 2, and 3, – = absence of mold and odor and 90% germination or more at 147 days; > = more than, < = less than.
[c] Arrows indicate end points of temperature and ERH% gradients used during the 147-day incubation period, see text for intermediate temperatures.

Abiotic parameters used to assess quality changes in samples collected at 0 and 147 days and in the interim included FAV which was determined by both general (02-01) and rapid (02-02) methods (1) and expressed as mg KOH required to neutralize the free fatty acids in 100 g of moisture-free seeds. The percentage increase in FAV from the original value also was noted (18). Moisture contents (1), internal seed color after crushing (15), and seed conductivities (9) also were determined. The mold odor associated with uncrushed seeds was determined on the eight main samples taken from each bottle and was subjectively assessed on the scale: 0 = no odor, S = slight odor, SS = some odor, and SSS = strong odor.

Biotic parameters used to assess changes in quality of the eight main samples included: Mold visible to the naked eye was subjectively assessed on the scale 0 = no mold, M = little obvious mold, MM = obvious mold, and MMM = profuse mold. Seed germinability was determined by the filter paper method (17). The microflora present on 150 seeds from each sample was determined by placing 100 seeds directly on filter paper moistened with water; ie, the filter paper (FP) technique (17); and 50 seeds on filter paper moistened with 7.5% NaCl; ie, the salt filter paper (SFP) technique (11). The molds occurring on 130,000 seeds were recorded after incubation and examination as described previously (11).

We calculated the moisture content/equilibrium relative humidity (ERH) relationships from our own moisture content and temperature data with the aid of charts for Tower rapeseed derived from the data of Pixton and Warburton (13). The equilibrium relative humidity of the air around the seeds is a governing environmental factor for fungus initiation in the temperature range

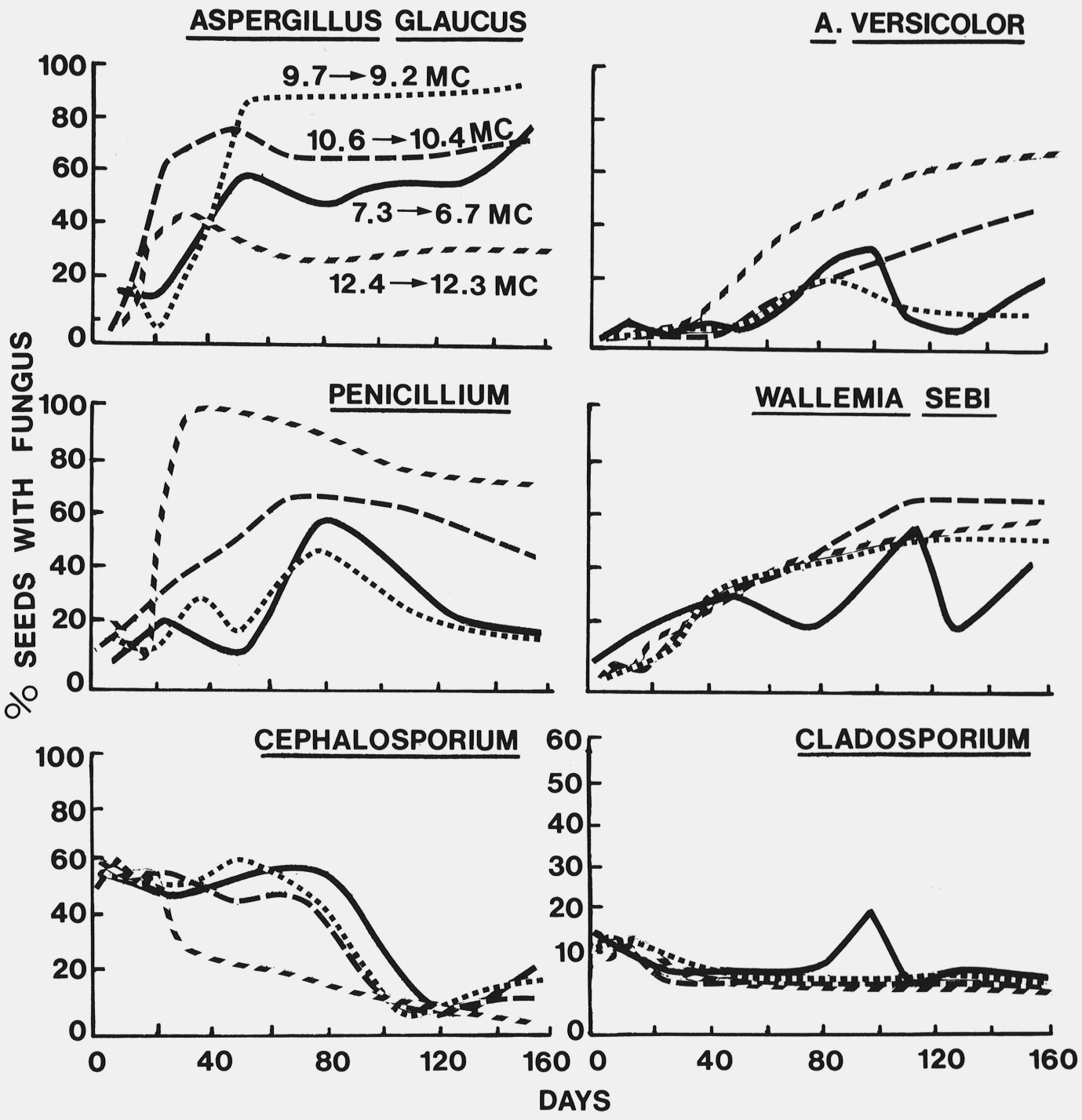

Fig. 2. Mean percentage frequency of occurrence of particular fungi on three lots of Tower rapeseed stored at 12.4, 10.6, 9.7, or 7.3% mean moisture content (MC) levels, and 25 C declining to 10 C over 147 days.

suitable for growth (12). The two figures at either end of an arrow represent the extremes of a particular temperature, moisture content, or ERH regime used in an experiment.

Granary studies. To assess the relevance of our laboratory-based time-temperature-moisture criteria for safe storage of rapeseed, 15 bins of freshly harvested seeds of cultivars Tower, Regent, and Torch (*B. campestris* L.) binned between 1 September and 15 October 1978 were examined between 12 October and 1 November 1978 and again between 9 January and 5 February 1979. Bins were located in the Teulon, Arborg, Plum Coulee, McDonald, and Westbourne areas of Manitoba. Temperatures and moistures were taken 2 m from the upper surface in the center of bins with a flexible thermocouple probe taped to a 150 × 1.5-cm wood rod and wired to a Digimite Thermo-indicator with a range −190 C to 400 C (Thermoelectric, Saddle Brook, NJ 07662). Three 250-g samples were obtained at the same depths with a torpedo probe then pooled and analyzed for FAV and other abiotic and biotic factors as previously described.

RESULTS AND DISCUSSION

Laboratory studies. The seed in lots 1, 2, and 3 (Table 1) initially were sound and of high quality as shown by high levels of germination, low conductivity and FAV, and low levels of *Penicillium* spp. (mainly *P. verrucosum* var. *cyclopium* [Westling] Samson, Stolk and Hadlock) and of the A. glaucus group *Aspergillus* spp. (mainly *A. amstelodami* [Mang.] Thom and Church, *A. repens* [Corda] Sacc., and *A. sejunctus* Bain and Sartory). The qualities of these seed lots were similar to those of high quality rapeseeds previously studied from a wide range of locations in the prairie provinces (10). Seed of the three lots had a shiny appearance and the numbers of chipped or cracked seeds were approximately similar (1–2%) in each lot. Crushed seed of all lots produced the normal sweet odor with no trace of the sour odor associated with spoilage. Characteristics of the seeds in the cold room (−15 C, control) after 147 days were similar to those of control lots at the beginning of the experiment (Table 2).

Patterns of fungal development and their relationship to deterioration of rapeseed quality. The most important postharvest fungi associated with deterioration of stored rapeseed were *Aspergillus* spp. of the A. glaucus group and *Penicillium* spp. (11,16). Their frequency of occurrence on SFP at different moisture contents and 25 C temperature regime are summarized in Fig. 2. Maximum percentage of seed infection by *A. glaucus* occurred after 50 days at 9.7% MC and 25 C, and after 42 days at 9.7% MC and 31 C (not shown in Fig. 2); both regimes were equivalent to 75% ERH. Infection by *Penicillium* spp. was rapid under conditions of 12.4% MC and 25 C (= 84% ERH) and reached maximum

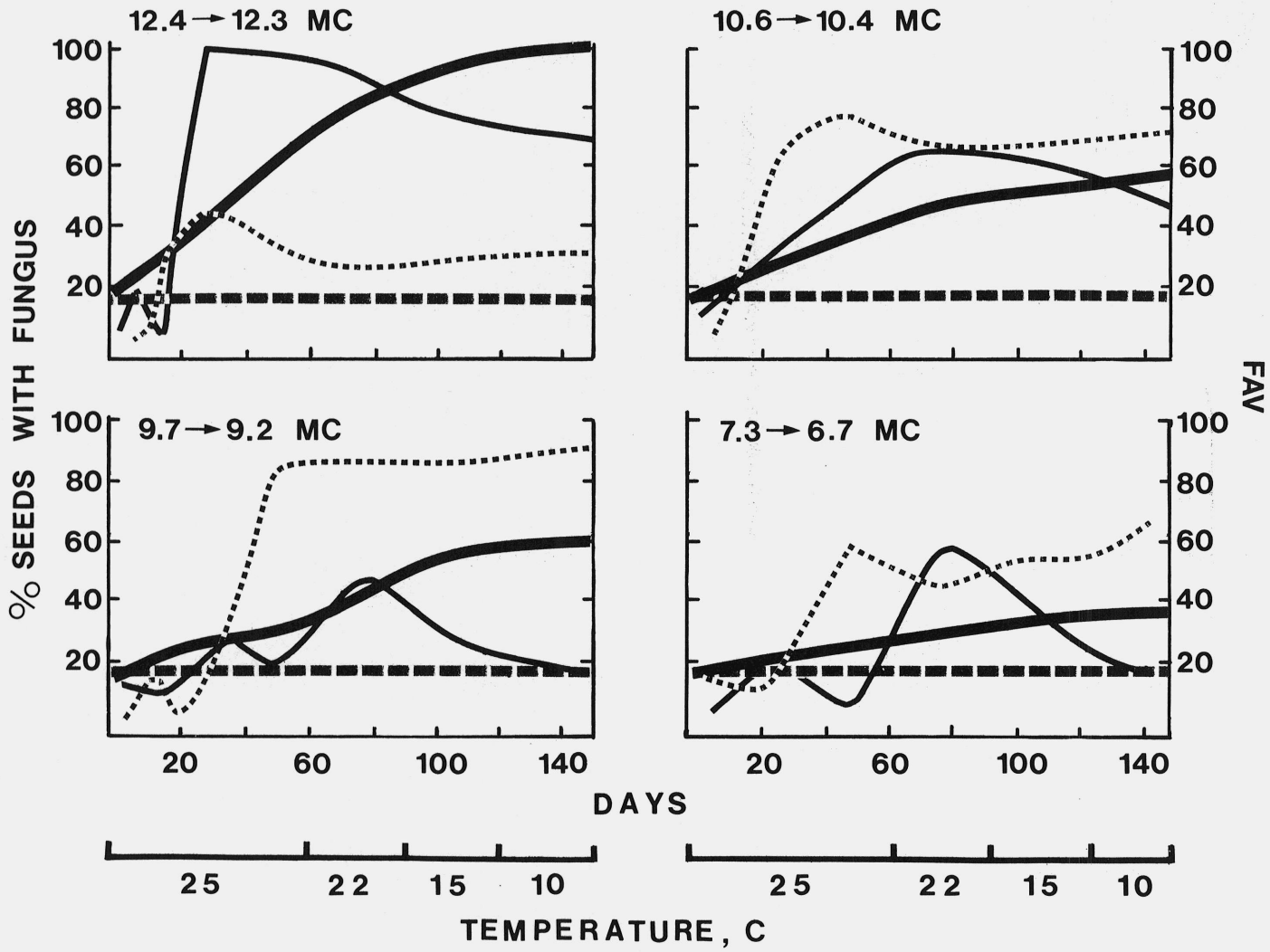

Fig. 3. Mean percentage frequency of occurrence of predominant fungi in relation to fat acidity values (FAV) of three lots of Tower rapeseed stored at 12.4, 10.6, 9.7, or 7.3% moisture content (MC) levels, and 25 C declining to 10 C over 147 days (▪▪▪▪▪ *Aspergillus glaucus* group; ▬▬ *Penicillium*; ▬▬ FAV; and ▬ ▬ ▬ FAV control).

frequency of occurrence by 30 days. Other important postharvest fungi that were isolated included *A. versicolor* (Vuill.) Tiraboschi and *Wallemia sebi* (Fres.) von Arx. The patterns of occurrence of the preharvest fungi *Cephalosporium acremonium* Corda and *Cladosporium cladosporioides* (Fres.) de Vries indicated a gradual decline with storage time (Fig. 2). The occurrence of other microorganisms was irregular and did not form a distinct pattern. For example, the maximum frequency of isolation on SFP for *A. candidus* Link ex Fr. occurred after 80–120 days at 7.3 and 9.7% MC, both regimes at 19 C declining to 7 C. *Alternaria* spp., *Aspergillus fumigatus* Fres., and *A. wentii* Wehmer also were present in low numbers on the rapeseed at certain temperatures.

The deterioration of good quality rapeseed, incubated at four moisture levels under the declining temperature regime 25 C→ 10 C, and the corresponding increase in FAV (plotted as means of lots 1, 2, and 3) is shown in Figs. 3 and 4. Since high FAV appeared to be associated with high moistures and/or initial storage temperatures (Table 2), it was expected that the higher the initial moisture content the higher the FAV (Figs. 3 and 4). The frequencies of occurrence of the predominating fungal species or groups of species are plotted in Figs. 3 and 4 together with corresponding changes in FAV, for particular moisture-temperature combinations. There appeared to be an association between rise in FAV and incidence of certain types of fungal species. Further experiments with individual species would be needed to determine whether there is a cause and effect relationship.

Relationship of ERH to fungus development. Changes in ERH of the intergranular air in the bottles during 147 days of storage at various moisture-temperature regimes, are summarized in Table 2. The minimum ERH for mold growth generally is regarded to be about 70% ERH (2,12,13). The 70% ERH figure was exceeded during storage at several moisture-temperature regimes, but visible mold growth and a moldy odor were not always apparent in the bottles. This was because fungal growth was limited by temperature at 10 C and 83% ERH, and also at 19 C up to some ERH between 67 and 74%. Visible molds and a moldy odor also were associated with other moisture-temperature regimes (Table 2).

Germination of seed-borne spores of postharvest fungi was facilitated by the optimal moisture and temperature plating conditions used in the present experiment. However, the physiological state of the spores probably differed depending on the moisture-temperature storage regime used. Thus, *A. glaucus* in lot 1 was probably merely surviving at a suboptimal ERH of 57→ 47% generated during storage at 7.1% MC and 25 C → 10 C (Table 2) as shown by the low to moderate fluctuating levels in Fig. 2. However, *A. glaucus* was actively proliferating at the optimal ERH

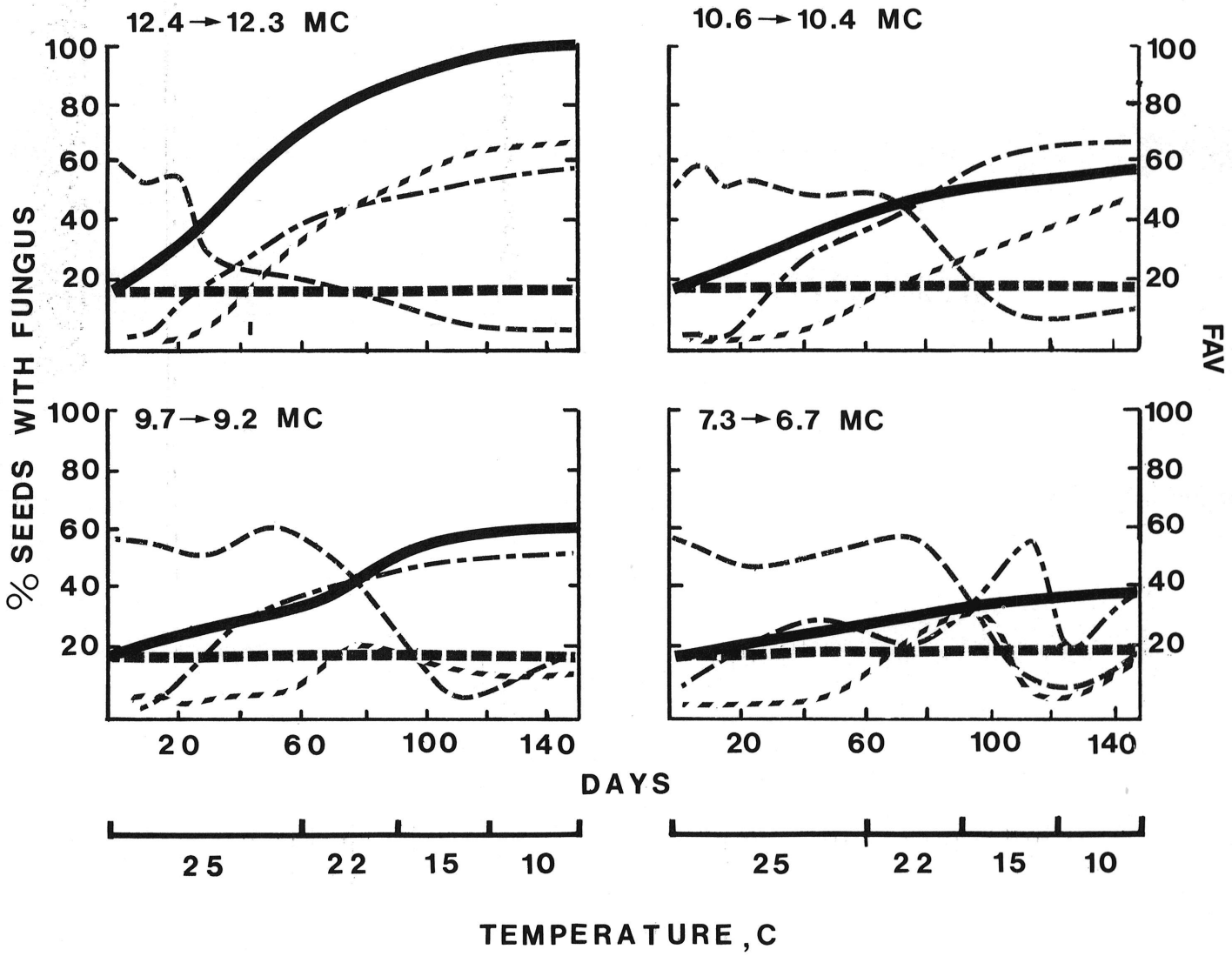

Fig. 4. Mean percentage frequency of occurrence of predominant fungi in relation to fat acidity values (FAV) of three lots of Tower rapeseed stored at 12.4, 10.6, 9.7, and 7.3% mean moisture content (MC) levels, and 25 C declining to 10 C over 147 days (▰ ▰ *Aspergillus versicolor*; ▬ ▪ ▬ ▪ *Wallemia sebi*; ▬ ▬ ▪ *Cephalosporium*; ▬▬ FAV; and ▬ ▪ ▬ FAV control).

of 75→ 67% developed during storage at 9.7% MC and 25 C→ 10 C as shown by the steep curves in Fig. 2.

Granary studies. The objective of the granary studies was to determine to which extent the safe storage limits (based on temperature-moisture-time regimes) for rapeseed established from laboratory experiments apply to the actual conditions of storage on farms in Manitoba. Our prediction model for spoilage of stored rapeseed gives several specific safe storage limits. For example, it indicates that freshly harvested sound rapeseed of 7.1% MC can be stored safely at fluctuating temperatures between 19 and 7 C for at least 147 days; seeds of 9.5% MC, however, stored at temperatures between 25 and 10 C spoil in less than 77 days (Table 2).

Moisture contents at the 2-m level in most bins were below 8.6% and temperatures below 21 C (Table 3) reflecting the low ambient temperatures in September-October at binning. The contents of bins 6, 7, 9, 12, 14, and 15 were predicted to have poor future storability. These conclusions were based on ERH data, whether the temperature or moisture was limiting for development of particular fungi, frequency of occurrence of specific postharvest fungi, FAV levels, seed germination, and length of time binned.

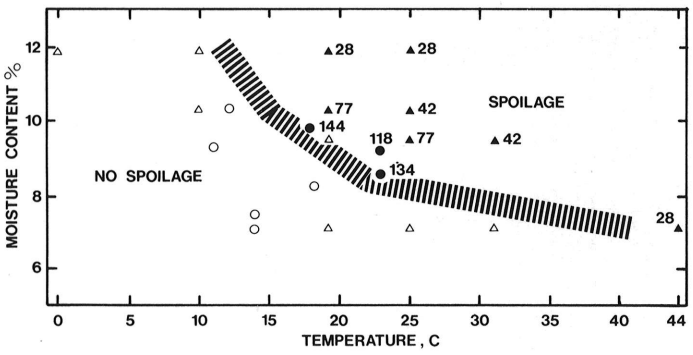

Fig. 5. Maximum periods (up to 147 days) for safe storage of rapeseed binned at various temperatures and moisture contents at a depth of 2 m in the center of a bin 5 m in diameter as determined from laboratory and commercial bin data. Laboratory tests: solid triangle with 77 denotes signs of spoilage within 77 days; open triangle denotes no indication of spoilage within 147 days. Commercial bins: solid circle with 144 denotes spoilage after 144 days; open circle denotes no spoilage detected. /////// denotes limit for safe storage.

The validity of our model was tested as follows. The temperature-moisture combination at the 2-m depth in each granary was compared with those used in the laboratory (Table 2); results from the closest laboratory combination were used as a guide to the future storability of the rapeseed. In bin 10 (during initial storage in the fall) the combination of 10.3% MC and 12 C was similar to that of the laboratory combination of 10.3% MC and 10 C (Table 3). Because laboratory-stored rapeseed under such a combination did not spoil we predicted that granary samples also would not spoil by spring. This was confirmed; spring samples from this bin indicated no marked increase in FAV, postharvest fungi, or germination loss. In bin 12, the combination of 9.2% MC and 23 C (Table 3) was similar to the laboratory combination of 9.5% MC and 25 C (Table 2). The laboratory-stored rapeseed spoiled within 77 days and the rapeseed in the bin also was spoiled in the spring as predicted. Of the six bins predicted to have poor future storability, three had deteriorated rapeseeds by spring (as indicated by increased recovery of *A. glaucus* and *W. sebi* and high FAV), the other three had been emptied during winter. Rapeseed in all other bins had good keeping quality even though some of the FAV's remained high (bins 8 and 10). No trends were evident for either decreased or increased seed moisture content over the storage period. Because many of the selected bins were scheduled to be emptied, this experiment was terminated at this stage.

Guideline for maximum periods of safe storage of rapeseed binned at different temperature-moisture combinations. Seed temperature and moisture at binning and length of storage period are the main factors affecting fungal development in stored rapeseed. The guideline for maximum periods of safe rapeseed storage is presented in terms of temperature and moisture rather than ERH (Fig. 5) because at theoretically suitable ERH levels above 70%, fungal growth was restricted by low temperatures. ERH was, however, a useful indicator of conditions for potential fungal development. The line of demarcation (between the group of points showing spoilage and those showing no spoilage) was arbitrarily drawn and therefore should be regarded as an approximation rather than a concrete boundary. The maximum periods for safe storage were determined in the laboratory using

TABLE 3. Temperature and moisture characteristics at binning and storability of freshly harvested Manitoba-grown rapeseed examined during fall 1978 and spring 1979

Bin no.	Cultivar	Total amount rapeseed (tonnes) / Bin capacity (tonnes) and type[a]	Characteristics at the 2-m level: Fall samples: Days binned	Moisture content (%)	Temperature (C)	ERH(%)	FAV[d]	As. gl[e]	Pe[e]	Wa[e]	Projected storability[f]	Spring samples: Days binned	Moisture content (%)	Temperature (C)	FAV[d]	As. gl.[e]	Pe[e]	Wa[e]	Deterioration
1	Tower	36/38 M	32	7.1	14	56[b]–60[c]	32		2		√	115	8.0	−7	14				no
2	Tower	75/75 M	32	7.3	21	58 – 63	30	8	22		√								bin empty
3	Tower	52/52 W	20	7.5	13	58 – 63	15		2		√								bin empty
4	Tower	45/45 M	20	7.5	14	59 – 63	30		2		√	122	6.3	−8	10	6	2		no
5	Tower	36/36 M	21	7.5	10	58 – 62	16		2		√								bin empty
6	Tower	20/23 W	26	7.7	26	64 – 66	39		8		x								bin empty
7	Tower	36/38 M	32	8.3	25	67 – 70	38	16	2		x								bin empty
8	Tower	45/62 M	32	9.3	11	72 – 74	67		2		√	85	8.6	−3	55				no
9	Tower	15/31 M	56	9.8	18	75 – 76	58		4	4	x	144	9.5	−3	40	98	2	34	yes
10	Tower	19/23 W	12	10.3	12	77 – 78	36				√	128	10.2	−12	33		2	6	no
11	Regent	52/52 W	27	5.4	25	42 – 45	55		14		√	129	5.9	−3	12	6	2		no
12	Regent	40/40 W	30	9.2	23	73 – 75	18	2	4		x	118	9.7	−3	56	30		2	yes
13	Torch	36/37 M	31	8.2	18	66 – 69	16				√	115	7.2	−6	17	14		2	no
14	Torch	27/34 W	35	8.6	23	70 – 72	32	2	12		x	134	8.5	−8	36	50			yes
15	Torch	11/37 M	1	16.2	21	91 – 91	24	4	38	4	x								bin empty

[a] M = metal; W = wood.
[b] ERH % for desorbing seed.
[c] ERH % for absorbing seed; ERH data derived from desorption and absorption curves for Tower rapeseed based on Pixton and Warburton (13).
[d] Expressed as mg of KOH/100 g moisture-free seed.
[e] Percentage microfloral components on filter paper moistened with 7.5% NaCl: As.g. = Aspergillus glaucus group spp.; Pe = *Penicillium* species mainly *P. verrucosum* var. *cyclopium* and Wa. = *Wallemia sebi*.
[f] √ No spoilage in next 5 mo at least; x spoilage likely.

storage temperatures relevant to farms and were confirmed through deterioration-time studies of freshly harvested, farm-binned rapeseed. The guideline is intended for practical use by producers for estimating storability during the first 5 mo and also to determine the potential requirements for drying or cooling by aeration. The guideline is likely to be applicable to rapeseed stored in areas with a northern continental climate similar to western Canada and northern USA as the suggested periods for maximum safe storage are derived from the fall temperatures characteristic of these areas. Because the legal rapeseed safe storage moisture content limit in Canada (10.5% for straight grade) does not ensure freedom from spoilage in storage, our guideline would be especially useful for Canadian producers in formulating their postharvest drying and storage strategies.

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