Survival of *Salmonella montevideo* on Wheat Stored at Constant Relative Humidity

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Eleven samples of Ottawa variety hard red winter wheat were inoculated with a standardized suspension of *Salmonella montevideo*. The contaminated wheat samples were placed in constant relative humidity (RH) chambers held at 25 C. Relative humidities were 7, 11, 22, 33, 43, 53, 62, 75, 84, 92, and 98%. Constant RH at 25 C was maintained with different saturated salt solutions in the sealed chambers. Periodic counts of viable *S. montevideo* cells per gram of wheat were made over a 28-week sampling period. Viable counts of *S. montevideo* on wheat held at 7, 11, and 22% RH decreased from an initial 10^6 cells/g of wheat to a final count of 10^4 cells/g in each sample. Samples stored at 33, 43, 53, and 62% RH decreased from 10^6 viable cells/g to 3.6 × 10^3, 10^3, 10^2, and 20 viable cells/g, respectively. No viable *S. montevideo* cells were detected in the samples held at 75, 84, 92, and 98% RH after 22, 16, 26, and 16 weeks, respectively.

The ability of pure cultures of salmonellae to survive at various constant relative humidities (RH) and on various surfaces has been studied, (3, 7), but the relationship of RH to the survival of salmonellae on a surface with its normal flora present has not been studied in detail. *Salmonella* have been isolated from cereal grains and from cereal grain products (1, 8, 9). *Salmonella montevideo* and *S. muenchen* have been isolated from wheat (V. D. Foltz, 1968 unpublished data). The number of *Salmonella* present and the length of time these cells would survive were not reported.

In recent years, *S. montevideo* has been one of the 10 most frequently isolated serotypes from human and nonhuman sources (2). This study was designed to determine the survival of *S. montevideo* on normal wheat stored at various constant RH.

**MATERIALS AND METHODS**

**Test organism.** The culture of *S. montevideo* used in this study was originally isolated from meat and bone meal.

**Wheat.** Ottawa variety hard red winter wheat was used in this study. Wheat selected had not been subjected to fumigants and was harvested under carefully controlled conditions. The wheat was cultured for

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dilutions were surface plated on Brilliant Green Agar plates. The plates were incubated 24 hr at 37 C and then counted. Typical colonies from each plate were picked and transferred to Triple Sugar Iron Agar (TSI; Difco) slants which were incubated 24 hr at 37 C. Slants with typical salmonellae reactions were further identified with *Salmonella* poly H antiserum and *Salmonella* O group C1 (Difco) antiserum. Agglutination in poly H and O group C1 antisera and the TSI slant reaction were used as the criteria for identification of colonies as *S. montevideo*. During this study, there were no colonies chosen as typical colonies that did not react as *S. montevideo*.

Constant RH chambers. One-gallon wide mouth jars (3.8 liters) were used as constant RH chambers. Constant RH was maintained with various saturated salt solutions held at 25 C (5). The lids of the jars were sealed with Brewer's Anaerobic jar sealing clay to insure that moisture could not enter or leave the chambers. Total volume of saturated salt solutions in each jar was 300 ml. Table 1 gives the compound used and corresponding RH at 25 C.

**RESULTS**

During the 28 weeks of storage, viable counts were made. The number of viable cells appeared to be a direct function of the RH of storage. As the RH increased from 7 to 98%, the number of surviving *S. montevideo* cells decreased. Survival patterns fell into three general groups.

Figure 1 includes those samples held at 7, 11, and 22% RH. Cells on wheat stored at these humidities decreased from an initial viable count of $10^4$ cells/g to a final count of $10^0$ cells/g of wheat. Test organisms exhibited first a rapid decrease in numbers, then a slow decrease. The survival patterns for the next group of samples appear in Fig. 2. The initial counts of the samples held at 33, 43, 53, and 62% RH were approximately $10^4$ viable *S. montevideo* cells/g of wheat, and the final counts were $3.6 \times 10^0$, $10^0$, $10^1$, and $20$ cells/g of wheat, respectively. The viable counts of *S. montevideo* on the wheat held at 75, 84, 92,
and 98% RH approached zero before the end of the sampling period (Fig. 3).

The final moisture content was determined for each sample. Moisture content of the wheat samples and the corresponding RH of storage are given in Table 2.

**DISCUSSION**

Survival curves of *S. montevideo* are very similar to those reported for *S. newport* (7). Similar results were reported by McDade and Hall (3) with *S. derby* and by Proom and Hemmons (4) with *S. pullorum*.

Wheat stored below 13% moisture is considered to be at a safe storage moisture level. Few fungi metabolize at this moisture level, and no bacterial multiplication can occur (6). An increase in the number of viable cells is an important consideration, but survival of dangerous organisms must also be considered. In this study, *S. montevideo* survived storage for 28 weeks on seven wheat samples held at a RH that resulted in equilibrium moisture contents of less than 13% (Table 2). Wheat samples held below 75% RH had an equilibrium moisture content of 13% or less. Wheat stored at these moisture levels would remain at high quality for a long period of time. As shown in this study, *S. montevideo* would also survive storage at these moisture levels. Survival of *S. montevideo* was highest on samples held at equilibrium moisture contents of 6.2, 6.3, and 8.1%. Certainly these moisture levels are rarely attained during storage, but a large amount of wheat is stored from 9 to 13% moisture. Figure 2 includes the samples that fall into the 9 to 13% equilibrium moisture range. Survival of the test organism was not as great on these samples as on the samples stored at lower moistures. Viable salmonellae in any food or feed constituent are a potential source of disease. In the samples held at 75, 84, 92, and 98% RH, the number of surviving *S. montevideo* were very low (Fig. 3). Only the sample stored at 75% RH was at a safe storage moisture level, 12.9%. The final moisture contents of the samples held at 84, 92, and 98% RH (Table 2) were above the recommended level for safe storage of wheat. No explanation can be offered at this time for the apparent enhanced survival of the sample held at 92% RH (Fig. 3). Fungal growth was evident on these three samples. *Aspergillus*, *Penicillium*, *Alternaria*, and *Fusarium* species were present. The presence of these metabolizing fungi may have had an effect on the survival of *S. montevideo* by removing water from the environment or producing toxic by-products.

Storage at moisture levels above acceptable conditions results in deterioration of the wheat by fungi and certain autooxidative processes. The test organism did not survive as well at these higher moisture levels, but storage of wheat at these levels would be impractical.

Silverstople and co-workers (8) felt that *Salmonella*-contaminated barley was a source of an epidemic of salmonellosis in Sweden. Other outbreaks of salmonellosis caused by contaminated grain may be attributed to feed in animal cases and to other ingredients in human cases. Con-
taminated grain probably plays a small role in the complex *Salmonella* cycle, but it should not be disregarded, since viable *Salmonella* organisms represent a potential health hazard to man and domestic animals.

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**LITERATURE CITED**


