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The Use Of Predictive Modeling In Shelf Life Determination Of Paints

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Abstract: The spoilage of six water-based paints was monitored during storage at room temperature (30 ± 2^0C) for 10 months at two weeks intervals. The bacterial population ranged from $1.0 \times 10^1 - 4.7 \times 10^5$ cfu/ml, while the fungal population ranged from $1.0 \times 10^1 - 5.5 \times 10^3$ cfu/ml over the study period. The spoilt paint sample served as the control with bacterial population count of 3.4×10^{10} cfu/ml and fungal population count of 3.2×10^5 cfu/ml. The bacterial strains isolated from the fresh paint samples were identified as *Bacillus polymyxa*, *Bacillus brevis*, *Bacillus laterosporus*, *Proteus mirabilis*, *Escherichia coli*, *Lactobacillus gasseri* and *Lactobacillus brevis* based on standard cultural and biochemical techniques and isolates' phenotypic profiles using the analytical profile index (API 20 E and ID 32 E test systems. The fungal isolates were identified as *Aspergillus niger*, *A. flavus* and *Penicillium citrinum*. The microbial growth data from the fresh paint samples and the spoilt sample were fitted into a predictive model to estimate the shelf life of paints as 27, 22, 30, 36, 22 and 23 months respectively. [Academia Arena, 2009;1(4):58-63]. ISSN 1553-992X.

Keywords: Predictive modeling, paints, shelf life

INTRODUCTION

Paints are uniformly dispersed mixtures having a viscosity ranging from a thin liquid to a semi-solid paste, consisting of a pigment (the substance that provide colour) suspended in a liquid vehicle such as oil or water. They solidify when exposed to air (Briggs, 1980). The effects of microbiological spoilage of paints such as viscosity loss, gassing, malodour, discolouration and visible surface growth can lead to a reduction in shelf life and significant economic loss to the paint industry (Gillatt, 1992; Adeleye and Adeleye, 1999). The contamination occurs during production and poses greater problems when they are not detected until the paint reaches the end user, since there is no shelf life indication on the paints. This occurs because the shelf life is not known. Therefore, the estimation and indication of shelf life is a major challenge facing the paint industry. The paucity of information on shelf life has also led to the indiscriminate use of lead to improve durability and shelf life. A common practice of manufacturers in industries is to utilize various short cuts, e.g. bracket tables (Porterfield and Capone, 1984) and the Q-Rule (Connors *et al.*, 1973) to estimate and project shelf life. These techniques share the advantage that decisions may be made by analyzing only a few stressed samples. However, they also have some limitations since they are based on assumptions about the product components and are valid only in so far as these assumptions are accurate. Any method adopted for determination of the validity of paint stability and shelf life should be based on analytical precision, the use of appropriate controls within the experimental design, the assumptions embodied in a mathematical model, and the measured characteristics of product components. Over the past few decades, other methods such as microbial stability techniques (Anderson and Scott, 1991) and sensory evaluation (Trees *et al.*, 2000) have been used to determine the shelf lives of other products, however, these also have their limitations. Microbial stability testing assessment techniques require that the test period should be long enough to allow significant product degradation under recommended storage conditions. Secondly, the testing protocol does not permit one to distinguish percent degradation from inter assay variation. Although, data collected at an appropriate frequency is such that a trend analysis may discern instability from day-to-day imprecision. The reliability of data interpretation needs to be improved by including in each assay, a single lot of reference materials with established stability characteristics. This may help to minimize the impact of systemic drift and inter assay imprecision. Sensory techniques involve the use of trained laboratory panel of judges to evaluate the appearance of degradation typical of the

product by use of a 5-point structured category scale. Each evaluation contains a marked reference sample that is obtained from a fresh production batch. A score of 2 on the category scale indicates 'just detectable' deterioration in sensory qualities compared to that of the marked reference which is a fresh product. A score of 3 indicates 'clearly detectable but not acceptable' deterioration, and a score of 5 indicates that the judge considers the sample unacceptable. Samples are usually evaluated twice, and means of scores are calculated over replicates for each sample (Trees *et al.,* 2000). This method is subjective and less accurate and not suitable for paints and paint products as they are not foods for human consumption.

An alternative to direct product testing is predictive microbiology, the modeling of microbial populations, which has become an active area of research. Unfortunately, there has been no record to date where predictive modeling has been applied to determine the shelf life of paints. Predictive models are mathematical equations which can use the information from a large microbiological database to predict inactivation or growth of microorganisms under defined conditions (Trees *et al.*, 2000). Predictive models offer considerable prospects for use in shelf life determination of microbiological based products. Predictive microbiology has proven its value for a useful model-based description of microbial growth ever since its development (McDonald and Sun, 1999; McMkeen and Ross, 2002). Data used in building a model are usually acquired from laboratory experiments. The problem of unrestricted use of lead in paint production to improve the shelf life has been traced to the fact that the shelf life of paints has been ignored by manufacturers. The importance of adhering to this strict manufacturing ethics cannot be over emphasized, especially in a warm and humid environment where deterioration is facilitated. Furthermore, the ingestion or inhalation of lead-based paints has been implicated in plumbism and learning disabilities (Rabin, 1989; Banks *et al*., 1997; Landrigan, 2000; Lanphear *et al*., 2000; Dietrich *et al*., 2001; Lewendon *et al*., 2001; Mathee *et al*., 2007). Thus, the use of predictive modeling in estimating the shelf life of paints, which is a critical step in evaluating new formulations is the aim of the present study.

MATERIALS AND METHODS

Isolation Techniques

Freshly made paint samples (DK1 – DK6) in 4 liter plastic containers were monitored for microbial growth for a period of 10 months at 2 weeks intervals. Aliquots (0.1ml) from both low (10^{-2}, 10^{-4}) and high (10^{-6}, 10^{-8}) ten -fold serial dilutions of paint samples were plated by pour plate technique on Nutrient agar, Mac Conkey agar and Potato dextrose agar plates in three replicates and incubated aerobically at room temperature (33 ± 3^0C) for 2 -5 days. Spoilt paint samples were also analyzed as described for the fresh paints. The developed colonies were counted, purified by subculturing and identified by the API 20E and ID 32E test systems.

Model Development

The growth data obtained were fitted into a suitable model (Dawes, 1969) to predict the time when the paint samples would reach absolute spoilage level (3.4×10^{10} cfu/ml). The time it took to reach this microbial population level (i.e N_t) was taken as the shelf life of the fresh samples. To estimate the shelf life time of freshly produced paint samples, the model was used as given below:

$$\frac{\text{Log}_{10} N_t - \text{Log}_{10} N_o}{\text{Log}_{10} 2} = \frac{t}{T}$$

Where N_t = highest cell count as colony forming units (i.e. total heterotrophic microorganisms) at the end of log. Phase; N_o = Initial cell count as colony forming units (total heterotrophic microorganisms) immediately after production; T = mean generation time of (total heterotrophic microorganisms) during log. phase; t = duration (months) taken for the population to increase exponentially from N_o to N_t..

RESULTS AND DISCUSSION

The microbial population count of the fresh paint samples immediately after production were observed to be approximately 1.0 x 10^1 cfu/ml for both the total bacterial count and total fungal count. In contrast, the spoilt paint samples (PSA- PSE) had total bacterial count of 3.4 x 10^{10}, total coliform count of 2.9 x 10^7 and total fungal count of 3.2 x 10^5 cfu/ml (Table 1). A summary of the mean changes in the microbial population density of fresh paint samples monitored at 2 weeks intervals is given in Fig. 1. Microbial population counts have been used by many investigators to establish deterioration of paints (Gillatt, 1992; Adeleye and Adeleye, 1999; Da Silva, 2003). In this study, the results show that there was a time interval which elapsed before the initial population density N_o began to increase in number. This time interval known as the lag phase (L) varied from 4 – 5 months in the paint samples tested. This probably may be the effect of biocides incorporated during production. The predominant bacteria isolated from the fresh paint samples included *Bacillus polymyxa* (OB-1), *Bacillus brevis* (OB-2), *Bacillus laterosporus* (OB-3), *Proteus mirabilis* (OB-4), *Escherichia coli* (OB-5), *Lactobacillus gasseri* (OB-7) and *Lactobacillus brevis* (OB-8). The fungal isolates included *Aspergillus niger* (OB-9), *A. flavus* (OB-10) and *Penicillium citrinum* (OB-11). Other workers have also reported the occurrence of *Bacillus*, *Pseudomonas*, *Enterobacter*, *Proteus*, *Aerobacter, Escherichia*, *Micrococcus* etc. in paints and painted walls (Jakabowski et al., 19883; Ogbulie, 2004; Saad, 1992). In addition, *Pseudomonas aeruginosa* (OB-6) was regularly isolated only in the spoilt paint samples. This is most likely possible because the Pseudomonads can degrade an exceptionally wide variety of organic molecules. Thus, they are very important in the mineralization process. This finding also reflects the observation of Dey (2004) who reported that Pseudomonads are the most commonly encountered group, comprising at least 75% of isolates from spoilt paint samples. Three different fungal species were isolated from both fresh and spoilt paint samples. Two of the three fungal species isolated belonged to the genus *Aspergillus* while the third fungus was *Penicillium citrinum. Aspergillus* species have been observed in fresh paints (Adeleye and Adeleye, 1999). *Aspergillus* has been reported as one of the most abundant fungi isolated from biodeteriorated paint films in Egypt (Saad, 1992) and Japan (Inoue and Koyano, 1991). When the data obtained from the microbial population count were fitted into the model (Dawes, 1969), the estimated average shelf life was 26 months. Despite active research on predictive modeling over the last few decades, several studies that have been published (Fu *et al*., 1991; Fu and Labuza, 1993; Ross, 1996; Koutsoumanis, 2001; Koutsoumanis and Nychas, 2001; Ross and McMkeen, 2003) show that the emphasis of predictive microbiology has been on perishable and processed foods. It is noteworthy therefore, that predictive models have been used in the present study to determine and predict the shelf life of paints based on microbial growth kinetics.

Table 1. Microbial population densities in spoilt paint samples

Paint sample	Total bacterial counts (x 10^{10} cfu/ml)	Total coliform counts (x 10^7 cfu/ml)	Total fungal counts (x 10^5 cfu/ml)	Fungal isolates	Bacterial isolates
PSA	2.9	1.1	2.5	OB-9	OB-2, OB-3, OB-4, OB-6, OB-7
PSB	3.4	1.1	3.2	OB-9, OB-11	OB-1 OB-6, OB-7, OB-8
PSC	3.0	1.0	2.8	OB-10, OB-11	OB-3, OB-4, OB-6, OB-7
PSD	2.5	2.9	2.5	OB-10 OB-6	OB-2, OB-4,
PSE	3.1	1.1	2.2	OB-11 OB-6	OB-1, OB-5,

Values presented are means of triplicate samples.

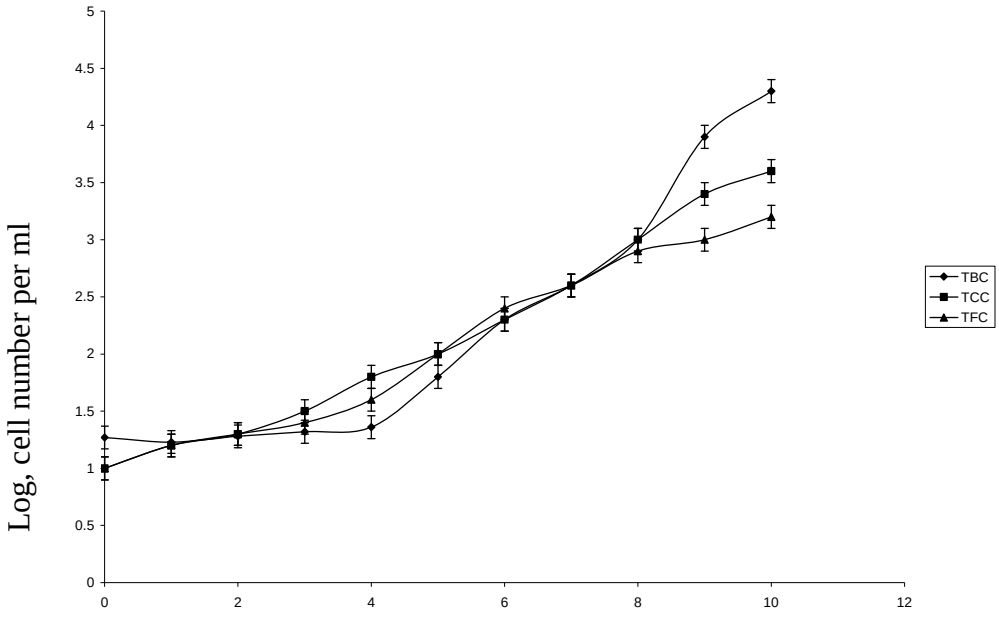

Fig. 1. Mean changes in microbial population density in fresh paint samples DK1-DK6. TBC, total bacterial count; TCC, total coliform count; TFC, total fungal Data represent the averages of triplicate determinations.

CONCLUSION

The results of the extensive analysis of freshly made paint samples monitored over a period of 10 months, showed the characterization and documentation of the microorganisms associated with spoilage of water based paints made in Nigeria. Based on the results obtained in this work, it is clear that the increasing levels of deterioration which resulted from contaminated raw materials, factory processing units and packaging materials all have significant impact on the microbial population count and hence aesthetic qualities of water-based paints. These have also contributed to the gradual reduction of the shelf life of paint to 2 years.

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