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# OPTIMIZATION OF THE CYCLE OF A CONTROLLED ATMOSPHERE PACKAGING MACHINE FOR RED MEATS

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Please refer to Folio 68.
[Ed. note: Folio 68 incorrectly labelled S8P10.WP]

## INTRODUCTION

The storage life of chilled meat can be greatly extended by packaging the product under an $O_2$-depleted atmosphere of $CO_2$ (Gill, 1990). For such a packaging system to be successful the residual $O_2$ content of the atmosphere established in pouches must be <500ppm. With higher $O_2$ concentrations metmyoglobin formed at the meat surface will permanently discolour the product (Gill, 1989).

Low residual $O_2$ concentrations can be attained by evacuation of the pouch using a vacuum pump, or by a sequence of steps involving both pouch evacuation and flushing of the pouch interior with a gas of very low $O_2$ concentration. Flushing alone is unsatisfactory in practice, because pockets of air not displaced by the flushing action will remain to contaminate the atmosphere of the sealed pouch.

The operating speed of a packaging system can be critically important for its commercial success. A number of operating factors associated with a CAP system were believed to have an influence on both the final $O_2$ content inside the pouch and upon the duration of the packaging cycle. Factors thought to be important from a machine-control viewpoint include pouch and chamber evacuation times, the number of evacuation-flush cycles applied prior to sealing, the volume of $CO_2$ that is included in the sealed pouch, and the pouch size. Therefore, the functioning of a CAP machine was examined, to determine the extent to which these factors affect both the duration of the packaging cycle and the residual $O_2$ content of pouch atmospheres.

## MATERIALS AND METHODS

A modified Captron III machine (RMF Inc., Grandview, MO, USA) was used for this study. The machine evacuates air from a flexible pouch through a snorkel while simultaneously evacuating air from within a hood that encloses the pouch. The pouch is then flushed, or filled with a gas (e.g., $CO_2$), while the hood is vented to the ambient atmosphere. When the gas filling stage is completed, the pouch is automatically sealed. The machine uses a vacuum pump (Type RAO 400-B033-1002, Busch Vacuum Technics Inc., Montreal, PQ, Canada) which has a rated displacement of 151 $L\ s^{-1}$, and which is capable of drawing a vacuum of 0.5 torr in the vacuum manifold. The original control system of the Captron III was replaced by a custom-built system that allowed independent settings of the evacuation, flushing and gassing (filling) times, and wholly manual, partially automatic, or fully automatic operation of the machine, to permit the most flexible control over the packaging cycle. During pouch gassing the hood inlet valve was automatically controlled to maintain a positive pressure of between 50 and 80 torr between the pouch and the hood atmospheres. A mass flow meter (model 558A, MKS Instruments Inc., Andover, MA, USA) inserted into the gas line allowed monitoring of pouch filling. The required pressure adjustments were accomplished by intermittently venting the hood according to hood and pouch vacuum pressure feedback signals emanating from pressure gauges (MICRO SWITCH 241PC15G, Honeywell Ltd., Freeport IL, USA). Histories of the pouch and hood pressures, and the $CO_2$ snorkel flow rate for one complete packaging process are shown in Figure 1 .

When a flush cycle was selected, the processes of evacuation and gassing were repeated. Evacuation of the machine was monitored using pressure gauges (model PG3, Pirani Leybold Inficon Inc., East Syracuse, NY, USA) located in the vacuum manifold, the snorkel and the floor plate enclosed by the hood. The functional modes of the switches controlling hood closure, pouch sealing, evacuation, gas filling, hood evacuation and the hood closing and opening events were monitored.

Pouches constructed of a gas-impermeable aluminum foil and plastic laminate (Securefresh, Auckland, NZ) were filled with $CO_2$ to either 1/6th or 1/2 of their maximum capacities. The maximum capacities of the four pouches tested were 6, 18, 36, and 72 litres respectively. To eliminate any confounding effects of enclosed product, all experiments were conducted using empty pouches. Evacuation times up to 40 seconds were used, as total evacuation times of more than 40 seconds produced little or no change in the amount of oxygen remaining in the pouch. The applied flush volume was set to be identical to the final gas fill volume. The oxygen concentrations of the pouch atmospheres were determined using an oxygen analyzer (model MS-750, Mocon Controls Inc., Minneapolis, MN, USA). Samples for analysis were withdrawn into a gas-tight syringe that was inserted into the pouch through a stick-on septa. As a precaution against spurious readings, all final reported $O_2$ measurements were calculated as an average of three measurements taken from separate pouch atmosphere samples. The concentration of $O_2$ in the gas used for flushing and filling was determined using samples drawn from a line through which the gas was flowing.

The total process time ($q_p$) for a packaging cycle was defined as the time interval between full lowering of the vacuum hood and the initial rising of the hood at the end the cycle, as signalled by a proximity switch indicating the hood's position. The total pump evacuation time ($q_e$) was defined as the total time that the hood and snorkel vacuum valves were open, and the total gassing time ($q_f$) was defined as the duration that the gassing valve was open. The time to seal the pouch and allow the seal to cool ($q_s$) was maintained at 12.5 seconds. All timing measurements were made and recorded in software to an accuracy of ±0.1 second. To verify that all times were recorded correctly, the total process time ($q_p$) was calculated as the sum:

$$\theta_p = n(\theta q_e + \theta_f) + \theta_s + \theta_m \qquad (1)$$

where: $n$ = number of cycles
$\theta_m$ = time required for other machine functions (s)

For comparison purposes, data were analyzed to determine the total process time required to achieve an $O_2$ concentration in the pouch atmosphere of 400ppm. For each set of packaging conditions, experimental parameters for a non-linear mathematical model of the relationship between experimental process time and residual $O_2$ concentration was obtained using a non-linear curve fitting procedure (NLIN procedure, SAS Institute Inc., Cary, North Carolina, USA). The appropriate equation was then used to solve for the "minimum process time". From this information, the corresponding optimum pump evacuation time was calculated using equation 1.

## RESULTS AND DISCUSSION

The oxygen concentration in the final pouch atmosphere was found to vary with total process time in an asymptotically declining, inverse exponential fashion, as shown in Fig. 2. The following general model was found to fit the data very well:

$$[O_2]_f = [O_2]_i - ([O_2]_i - [O_2]_m)\exp(-\alpha a/(\theta_p - \varsigma)^{\gamma}) \qquad (2)$$

where: $[O_2]_f$ = Oxygen concentration of the final pouch atmosphere (ppm)
$[O_2]_i$ = Oxygen concentration in the pouch for a process time = t (ppm)
$[O_2]_m$ = Minimum possible $O_2$ concentration in the pouch (ppm)
$q_p$ = Total process time (s)

$\theta$ = Minimum possible process time (s)
a = Experimental time constant ($s^g$)
$\gamma$ = Experimental parameter.

The experimental parameters ($\alpha$, $\gamma$) obtained by regression analysis were used to determine the necessary process times, $\theta_p$, for each pouch configuration (i.e., pouch size, fill volume, flushing sequence) to achieve the pouch atmosphere $O_2$ concentration of 400ppm. In all pouch system configurations, the minimum possible oxygen concentration, $[O_2]_m$, in equation 2 was arbitrarily calculated to be 90% of the average of the lowest three $O_2$ concentration measurements. This ensured a good fit of equation 2 to the experimental data, and analytical consistency.

The results of the analysis for total process times to achieve a concentration of 400ppm are shown in Figures 3 and 4 for pouches gassed to 1/6th and 1/2 their capacity, respectively. For pouches gassed to the 1/6th level, it was found that $\theta_p$ tended to decrease with pouch size when a single evacuation and gassing cycle was used, whereas $\theta_p$ increased with pouch size when two cycles were applied. Moreover, a reduction in $\theta_p$ resulted from the addition of a flush (i.e., 2nd cycle) to the packaging process for the two smallest pouches tested. Because the larger pouches demand more time for gassing, it had been expected that the total process time would increase with pouch size, and the result for a single cycle, 1/6 gas fill is not readily explained. Differences in total processing time between pouches of differing size cannot be explained by differences in evacuation time, since the total internal volume of the hood and pouch must remain constant. However, pouch size and fill volume were factors that influenced the time required to vent the hood following pouch sealing, such that increasing the pouch size or the fill volume led to a reduction in the hood venting time. This is easily explained by the fact that the larger or more fully-filled pouches displace volume within the vacuum chamber, thereby reducing the required venting time at the end of the process. However, this effect alone could not explain the longer $q_p$ values for the two smallest pouches that were filled to 1/6th capacity and subjected to a single cycle. The only obvious factor contributing to this unexpected trend (see Figure 3, 1 cycle) was the apparent inability of the CAP machine, using a single cycle, to reduce the oxygen concentration in the smaller pouches to the same extent as in the larger pouches, regardless of the evacuation time (one evacuation) taken to achieve this. That is, $[O_2]_m$, which varied overall between about 350ppm and 30ppm, tended to decrease with increasing pouch size. This was particularly evident in the 1/6-gas-fill, single-cycle case. The importance of $[O_2]_m$ in the calculation of the total processing time, $q_p$, is evident in equation 2.

For the pouches that were gassed to 1/2 their maximum volume, it was found that $\theta q_p$ increased with pouch size when either a single (no flush) or a double (one flush) cycle was applied (Figure 4). For the smallest pouch, no significant advantage was achieved by adding or deleting a flush, and a flush did not improve the total process time for any of the pouches tested. With the exception of the smaller of the two pouches and the single-cycle condition, the total process time increased as a result of filling the pouches to 1/2, instead of 1/6th, their maximum capacities. The fact that the two smaller zero-flush, 1/6-fill-volume pouches required more total process time than their zero-flush, 1/2 fill-volume counterparts likely reflects the unexpectedly high $[O_2]_m$ values found for the former condition, as mentioned above. For the 1/2-filled pouches of sizes 1 and 2, the fact that no significant change in the required total processing time resulted from the application of a gas flush, taken together with the results for the 1/6-filled pouches, indicates that for the smaller 2 pouches a reduction in the total process time should be possible by adding a flushing step when the gas fill-volume is *below* half the maximum pouch capacity.

Because the flushing and final gassing steps involved identical gas volumes, a further reduction in $\theta_p$ might have been achieved by reducing the gas volume used for flushing. With the exception outlined above, it would otherwise appear that the minimum required $CO_2$ gas volume should be added to the pouch to minimize the total process time.

## CONCLUSION

The performance of a particular CAP machine for packaging red meats has been characterized by modifying its controls. In general, the pouch size, the gas fill-volume, and the number of machine cycles used are critical factors that influence the total process time. The results obtained in this study tend to support the choice of the smallest possible pouch, a small relative gas fill-volume, and a small evacuation chamber (i.e., hood). When using a Captron III machine for pouch sizes of 38cm x 41cm and 41cm x 61cm, the use of a flush step would appear to be justified for reducing the process time.

Further research to investigate the cause of the higher observed minimum oxygen concentration values (i.e., $[O_2]_m$) for the smaller pouch sizes subjected to a single cycle is needed. If these minimum values can be reduced, any justification for a flushing step based on process time may be eliminated. On the other hand, reducing the volume of gas used in each flushing step, and increasing the number of flushing steps might prove to be worthwhile towards reducing the total required packaging process time.

## REFERENCES

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