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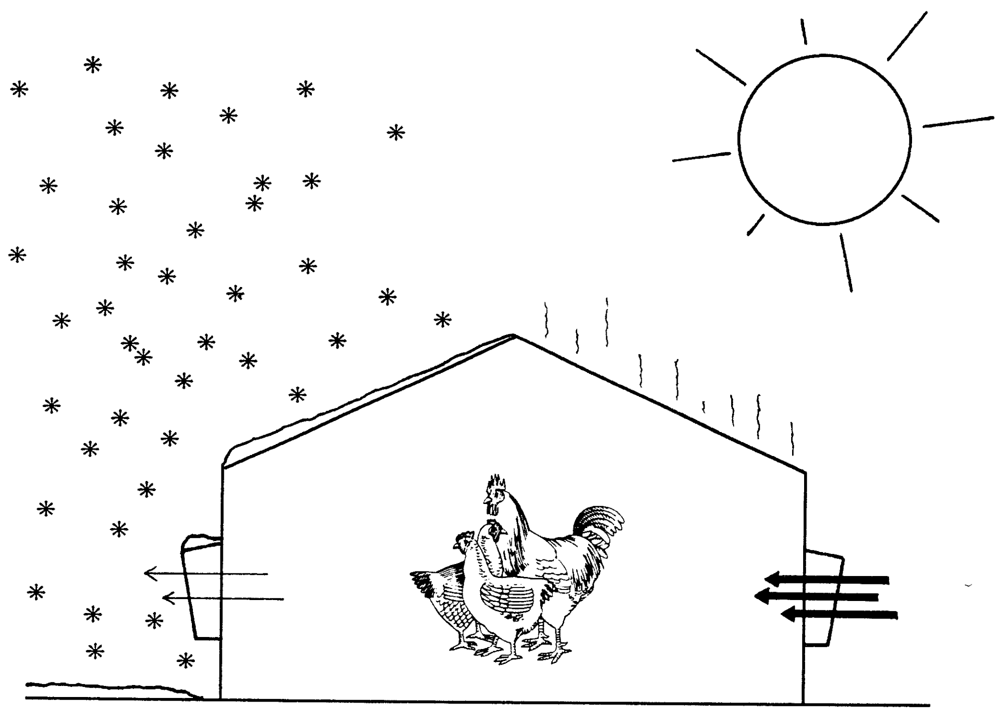
Implications for New York



R.B. Murray-Prior
W. Lesser

Department of Agricultural Economics
Cornell University Agricultural Experiment Station
New York State College of Agriculture and Life Sciences
A Statutory College of the State University
Cornell University, Ithaca, New York 14853-7801

COMPUTERIZED ENVIRONMENTAL CONTROL OF EGG-LAYING OPERATIONS: IMPLICATIONS FOR NEW YORK[1]

by

R. B. Murray-Prior and W. H. Lesser [2]

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[2]Roy Murray-Prior is Graduate Research Assistant and William Lesser is Associate Professor in the Department of Agricultural Economics at Cornell University. The authors wish to acknowledge the suggestions made on earlier drafts by Professors Kalter, Milligan and Tauer of the Agricultural Economics Department. Professor Dan Cunningham of the Poultry Avian Department and Professor Mike Timmons of the Agricultural Engineering Department provided valuable information on the intricacies of computer control of environmental systems. We would also like to thank those members of the poultry industry involved in the survey and the manufacturers of the control equipment for providing information about their systems.

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I. SUMMARY

The declining cost and increasing power of microcomputers has encouraged the development of computerized systems which control the environment of poultry houses. This study assesses the impact of this innovation on the egg industry in New York state. It discusses the return on investment, economies of scale implications, impact on competitive position compared to major producing areas, and effects on electricity demand.

The main functions of computerized environmental control systems are to maintain temperature at near optimal levels for production and keep ammonia below harmful levels. This they do more efficiently than conventional controls. A survey of four egg producers in New York who have installed the systems shows the main benefit to be a 6-8 percent reduction in feed consumption. Egg production, mortality and egg size may also be improved. The benefits appear to arise from improved control which allows the temperature to be maintained at close to optimum for production, resulting in a reduction in the effects of heat stress during summer and temperature variability in winter.

Investment in the system studied ranged from 42 cents per bird for a 60,000 bird unit to 24 cents per bird for a million bird unit. Return on investment is high for both small and large operations. Some size economies occur because of lower per unit costs, and larger operations may also achieve further gains through improved management control.

Although initial adoption may be slow because it is difficult to observe the benefits of the system and to try it out on a small scale, it is expected that most producers will adopt computerized, controlled environment housing within the next 10 to 15 years. The innovation should help maintain the competitive position of New York State and may provide some benefits over southern states. Electricity consumption by poultry producers is unlikely to be significantly affected but peak loads may be reduced.

II. INTRODUCTION

Egg production has declined in New York in recent years in both absolute and relative terms. The number of layers has declined from 7.99 million in 1976 to 6.71 million in 1985. Egg production has declined from 1,903 million to 1710 million over the same time (NY Crop Reporting Service, 1986).

Tauer and Lesser (1984) give a number of reasons for this decline. Production in New York has traditionally been a small scale family operation, but changes in technology have encouraged the expansion of large scale operations which have shifted to be closer to the sources of cheaper labor and feed in the South and Mid-West. Vertical integration of all stages of production has occurred at the same time leading to further pressure on small producers. In New York over 75 percent of laying birds are found on farms with more than 50,000 birds. Table 1 shows the numbers of laying birds on various sizes of farms in the state.

TABLE 1. Hens and pullets of laying age on New York farms in 1982

Farm Size # birds	Number Farms	Number Laying Birds
> 100,000	18	3,641,286
50-99,999	19	1,225,800
20-49,999	36	1,082,411
10-19,999	33	458,756
Total birds (farms with > 10,000 birds)		6,408,253

Source: 1982 Census of Agriculture.

Production in the warmer areas of the country has also been favored because housing costs were cheaper. Open sided houses were used versus the totally insulated and environmentally controlled houses required in New York. Maintaining heat in winter is also easier and cheaper.

Currently an important innovation, the use of microcomputers to control the environment of poultry houses, has the potential to contribute substantially to productivity in the poultry industry. The rapidly increasing power and decreasing cost of microcomputers, plus the development of associated expert systems, means that computers can now be used by the ordinary poultry producer to monitor and control the environment of poultry houses to an extent not possible previously. Computers are also being used to monitor and control feed and water use, egg collection flows, mixing of feed and to provide a wealth of information to the manager. Systems combining a number of these tasks are now being sold and used commercially, both in New York and other states.

This new technology raises a number of questions about its likely impact on the poultry industry in New York. What is the technologies profitability? Is the technology likely to be widely adopted? What effects will it have on the size of the egg industry in New York? Will the technology encourage or discourage the trend to larger operations?

<u>Objectives of Study</u>

The objective of this study is to assess the broad impact of computer control of environment in the egg industry, with particular attention to New York production. In particular:

1. To investigate the likely returns from installing a computer controlled environmental system.

2. To assess economies of size and management requirements of the system

and their implications for the widespread adoption of computer control by New York egg producers.

3. To evaluate the expected impact of the technology on the relative competitive position of the New York industry.

4. To appraise the electrical demand ramifications of any change in the structure of the sector in the state.

III. RELATIONSHIPS BETWEEN ENVIRONMENT AND EGG PRODUCTION

Important Environmental Factors for Layer Houses : A Review of Literature

The important factors to be monitored and controlled in a layer house are the air quality factors (temperature, humidity and ammonia levels) along with water, light and feed. Typically these are presently being monitored and controlled manually, or with simple sensors and time switches, but lend themselves to computer control. The ease of controlling these factors simultaneously depends on the design of the shed and the ambient climate. Another factor which interacts with them is bird density. These factors are discussed in turn below.

Temperature - Energy obtained from feed is used by the laying hen for body maintenance, body growth, feather production and egg production. Energy requirements for maintenance decrease as the surrounding temperature increases. During the winter the task of a ventilation system is to conserve shed heat while controlling humidity and ammonia levels (North, 1984). For hot periods heat generated by the birds must be removed to avert production-reducing stress.

Deaton (1983a) suggests that at 60^{o}F more feed is required to produce a dozen eggs than at any temperature up to 90^{o}F. However, above 75^{o}F egg size begins to decline, while egg numbers are not greatly affected by temperatures up to 90^{o}F. As shown in Table 2, egg production and egg size remain approximately the same at 75^{o}F as at 60^{o}F, while feed consumed per dozen eggs declines by 12 percent. At 80^{o}F a slight reduction in egg production occurs while egg size begins to decline.

North states that high temperatures reduce egg size in two ways: (a) Pullets which are grown during hot weather will be up to 20 percent lighter and hence will have lighter eggs at the start of production and will generally weigh less and produce lighter eggs throughout their productive life, (b) Temperatures above 80^{o}F depress egg production, egg size and shell quality. The longer the hot period the greater the effect. Moreng and Avens (1985) also suggest temperatures above 80 - 85^{o}F decrease size and production of eggs and increase thin shelled and poor internal quality eggs.

TABLE 2. Temperature effect on commercial egg layers

Average Temperature (^{o}F)	Relative Production (%)	Relative Egg Size (%)	Relative Feed/Doz (%)
60	100	100	100
65	100	100	95
70	100	100	91
75	100	99	88
80	99-100	96	86
85	97-100	93	85
90	94-100	86	84

Source: Deaton (1983a).

A number of authors have suggested either that some temperature fluctuation is desirable, or at a minimum, does not have a significant effect on feed consumption, egg production and egg shell strength (Moreng and Avens,1985 and Puri et.al.,1985). However, this was for fluctuations in the range 68^{o}F to 86^{o}F. Deaton et. al. (1986) compared a constant temperature of 70^{o}F (21^{o}C) with a 24 hour linear temperature cycle that ranged from 75^{o}F to 95^{o}F to 75^{o}F. Although hen-day production and eggshell breaking strength did not differ significantly between the two regimes, the birds on the constant temperature gained significantly more weight, consumed significantly more feed, and laid significantly heavier eggs. They indicate the reduction in egg weight is due to decreased feed consumption under high temperatures, while decreases in eggshell strength appear to be due to heat stress.

Temperature also interacts with the caloric, protein and calcium content of the diet. Because in hot weather the birds require less energy from feed and eat less, they should be fed lower energy feeds, with a higher protein percentage and higher calcium percentage (North).

<u>Humidity</u> - A bird loses heat in two main ways. Sensible heat loss is heat lost to the surroundings via radiation, conduction and convection and this raises the surrounding temperature. Insensible (or latent) heat loss occurs through the loss of moisture by respiration. This does not increase the surrounding temperature. At temperatures below 70^{o}F, a bird loses about 75 percent of its body temperature through sensible heat (North). As temperature rises insensible heat loss becomes more important. Therefore as the temperature of the surrounding air rises, humidity becomes an important factor as this governs the ability of the bird to lose moisture and heat via respiration. The lower the humidity the greater the amount of moisture which can be evaporated. However, work by Puri et al. indicate that latent heat production may not be very sensitive to humidities between 65 percent to 85 percent.

Humidity sensors (humidistats) are sometimes used to control fans which ventilate and modify interior humidity (Carson, 1986). A problem arises with attempts to lower humidity by ventilation when outside humidity is high (Worley and Allison, 1985). For example a system which tries to maintain relative humidity below say 70 percent would be operating continually when outside humidity was above 70 percent. A computer system can be programmed to allow for this by monitoring both outside and inside humidity. When outside humidity is above 70 percent inside humidity will only be adjusted so the ratio of outside to inside humidity is less than a certain level (e.g. 0.9).

<u>Ammonia</u> - During the winter ventilation is reduced in layer houses to avoid heat loss. This can lead to build-up of ammonia levels. A review by Carlile (1984) discusses in detail the effects of ammonia on poultry. Exposure of poultry for long periods to levels of ammonia as low as 20 ppm has been shown to cause a number of diseases. Ammonia is a major cause of keratoconjunctivitis which can cause considerable financial loss, although mortality is generally low. The respiratory tract can also be affected. This reduces resistance to respiratory infection leading to increased susceptibility to Newcastle disease and air sacculitis. Exposure for extended periods to levels from 20 to 60 ppm have been implicated.

Respiration rate may also be reduced at ammonia levels from 75-100 ppm. Deaton et al. (1984) noted that point of lay pullets exposed to 200 ppm atmospheric nitrogen for 17 days had reduced feed intake and reduced growth rate. This led to lower subsequent per cent egg production and a mortality of 25 percent during the 28 day period immediately after exposure. Even at low concentrations, ammonia is absorbed by the egg, increasing pH and increasing the rate of deterioration of the albumen (Carlile, 1984).

Although higher levels can be tolerated for short periods, most research shows that ammonia levels should be maintained at less than 20-25 ppm if the above-mentioned problems are to be avoided (North).

<u>Water and Light</u> - With the low moisture content of commercial feeds, chickens require a constant supply of clean, cool water for optimum growth, production and efficiency of feed utilization (Scott et.al., 1982). Water deprivation for a day can result in the cessation of egg production. Consumption increases as the temperature rises, especially above the thermo-neutral zone, as evaporation from the lungs via panting is used to maintain body temperature.

With growing pullets the length of the light day should not be allowed to increase as this leads to a decreases in the number and size of eggs produced during the early stages of production (North). However, for laying hens, the length of the light day should not be decreased. Maximum egg production occurs between about 14-17 hours of light per day. Despite this, other work has shown intermittent lighting programmes with fewer total hours can achieve results equivalent to continuous lighting programmes. These programmes should not be started until the pullets have been laying for at least 8 weeks (North).

Bird Density - A large number of experiments have been conducted on this factor; however, the results are generally inconclusive. In general, increasing the bird density decreases egg production per bird, increases feed consumption per dozen eggs, but increases egg weight (North). Mortality also increases. These factors vary with the particular management conditions of the grower, hence so does the optimum density. Although optimum bird density is likely to be influenced by environmental conditions, no experimental evidence of the benefits of computer controlled environments has been found.

Facility Design

North suggests that housing adequate to meet the optimum requirements for good egg yields and economy of production should: "Provide warmth to the birds during cold weather; Cool the birds during hot weather; Reduce the humidity in the house; Reduce the ammonia in the building; Provide adequate air movement through the enclosure." (p.154).

Typically poultry houses are from 30 to 40 feet wide (North, 1984; Timmons, 1986) this being the normally recommended width in order to achieve adequate ventilation. Larger houses are achieved by increasing the length of the house.

Two main types of houses exist, open-sided and controlled environment houses. Houses in the warmer climates tend to be of the former type and rely on natural ventilation, while in climates similar to New York state the totally enclosed controlled environment houses are used (Timmons, 1986). Ventilation in controlled environment houses is provided by exhaust fans and artificial light is provided. They are well insulated and generally achieve improved feed conversion when compared to open-sided houses with curtain walls (Timmons 1983).

In southern areas of the U.S. where open-sided houses are common, the most important climatic problem is hot weather, (Deaton, 1983b) although cold conditions during the winter can also lead to losses in production. However, advantages gained by using enclosed houses are partially or completely lost by the cost of the mechanical ventilation during favorable weather conditions (Timmons, 1983).

Even in environmentally controlled housing, large temperature variations exist due to the problem of temperature stratification (Timmons, 1986). Average temperature differences of up to 10^{o}F during cold and moderate temperature conditions have been noted between different sections of a house.

Electrical Energy Use

Electrical equipment is used in environmentally controlled poultry houses for lighting, ventilation, feeders, manure scrapers, egg collection and water supply. A study by Stetson and Farrell (1981) in Nebraska showed power consumption tends to be predictable and nearly constant. A peak of consumption occurred during the summer as more fans were operated to control the temperature. Consumption per bird during summer was approximately twice that during the winter.

The proportion of consumption used by the various electrical equipment as reported by three studies is shown in Table 3. The results of the studies using different methodologies suggest electrical usage to be approximately 5 Kwhr per bird per year (Driggers, 1971; Turner, 1975).

TABLE 3. Proportion of electrical demand of equipment in layer sheds

Equipment	A	B	C
Ventilation	37%	46%	45%
Lighting	8%	26%	35%
Feeders & Egg Collection	45%	10%	11%
Other	10%	18%	9%
Total	100%	100%	100%

Source: A: Stetson et.al., 1981.
B: Driggers, 1971.
C: Turner, 1965.

Although these studies are based on very small samples and two are dated, they suggest ventilation accounts for a large part of electricity demand.

The 1987 Farm Management and Energy survey of 24 poultry farms in New York state gave an average annual consumption of about 2.5 Kwhr per bird (assuming electricity cost of 10 c/Kwhr) (Kelleher).

IV. FUNCTIONS OF COMPUTERIZED CONTROL SYSTEMS

Potential for Computer Control

A number of systems have been developed and tested by researchers to control temperature, relative humidity and ammonia levels in broiler houses (Daley & Ross, 1986; Lamade, 1984; Reece et.al., 1985; Worley and Allison, 1985). Commercial systems are also available[1] which to varying degrees monitor and control temperature and ammonia levels in layer houses, and as well may act as warning devices and/or monitor and control other equipment associated with the poultry house.

[1]Companies marketing this equipment include Aerovent Fan & Equipment, Inc, Automated Environments Inc., Poultry Management Systems, Inc. and Sci Agra Inc.

Currently, most environmentally controlled poultry houses use thermostats, timers and pressure sensors to operate the fans and baffles which control ventilation and hence temperature, relative humidity and ammonia levels (Lamade, 1984). When the temperature rises above a certain level, one or more fans are turned on to remove warm air. Fans may also be activated by timers whose purpose is to maintain a minimum of air circulation to control relative humidity and/or ammonia levels. Pressure sensors control inlet baffles which maintain the negative pressure status of the houses. The grower sets the thermostats and sensors to achieve a desired level of control based on present and expected weather conditions. Personal visits are required to monitor conditions and to reset thermostats and timers when conditions change.

Computer controlled systems generally use a larger number of sensors to monitor conditions. These are connected to a microcomputer which controls the fans, baffles and other devices to maintain the desired conditions (Daley & Ross, 1986; Lamade, 1984; Reece et.al., 1985; Worley and Allison, 1985). Alarm systems are also included which alert the manager when conditions can not be maintained.

Timmons and Gates have carried the control process one step further by developing a program which simulates the operation of broiler houses, monitors the inside temperature, and optimizes economic return as a function of: bird market value; feed, fuel, and electrical costs; house thermal characteristics; outside air temperature; and current bird weight. They have attempted to select the optimum inside environmental temperature to maximize economic return - that is value of meat grown during the control interval less costs of production in terms of feed, fuel and electricity. This compares with previous systems which aimed to maintain conditions within predetermined limits. These limits are normally those which give optimum feed efficiency or rate of gain but not necessarily optimum economic return. No published information has been found on similar systems for layer houses.

Means of Control

Temperature - Temperature is controlled in most systems via sensors linked through a computer to fans and baffle control motors.

Ammonia - Many of the computer controlled systems use ammonia sensors to measure ammonia levels in the houses with variable results. Both Daley and Ross (1986), and Worley and Allison (1985) have noted problems with variability in readings received from ammonia sensors. In field use it is often necessary to recalibrate the ammonia sensors periodically.

Water, Light and Feed - Another benefit of computer controlled systems is their ability to monitor and control water, light and feed. The commercially available systems can monitor water pressure and control the lighting and feeding cycles. Daley and Ross, who monitored water and feed consumption, did so in order to detect abrupt changes which indicate onset of disease in broiler flocks.

Other Factors - Computer systems can also be programmed to sound alarms or alert the grower when problems arise which can not be controlled by the normal operations of the system. Alarms may sound on the computer, or through the use of a modem and telephone so that key personnel may be called to respond to the problem.

Muir and Graves (1985) suggest computer controlled systems only require standby generators one third the size, hence reducing cost. Normally, when power is interrupted the generator has to have the ability to start all fans at once. Starting a fan requires four times as much power as running. The computer controlled system can start the fans in sequence thereby reducing the load on the generator. The savings depend on the timing of the purchase or replacement of a generator and the relative purchase prices of the sizes required.

Description of Available Systems

A number of commercial systems are available using various forms of programmable computerized control to provide varying degrees of environmental control in layer houses. Information was obtained on the systems sold by four companies: Aerovent Fan & Equipment, Inc. of Lansing, MI;Automated Environments of Ithaca, NY; Poultry Management Systems, Inc. of Saranac, MI; and Sci Agra, Inc. of Fort Wayne, IN. No attempt has been made to compare the efficiency of the equipment produced by these companies. The following is a summary of the factors claimed to be controlled.

Aerovent Fan & Equipment, Inc.

Stage Manager Control System
* Monitors temperature.
* Remote digital display of temperature.
* Controls ventilation, heating, cooling and air inlet equipment.
* Alarm system for high/low temperature and power failure.

Automated Environments

PMS 2000
* Monitors environmental temperature, ammonia, water pressure on each row, A.C. power, refrigeration unit cooling, generator operation, grain storage temperature, building security and fire.
* Controls fans, heating, evaporative cooling, inlet baffles, refrigeration units, generator testing, grain storage ventilation and side curtains.
* Time scheduled controls of temperature, feeder operation, lighting, boiler operation and other ON/OFF switches.
* On-site and call-out alarm system for temperature, water pressure, ammonia, power failure, refrigeration and system integrity.
* Daily 24 hour report on inside and outside temperature averages and ranges, ammonia levels and system efficiency.
* System can be monitored and operated from a remote terminal.

Poultry Management Systems, Inc.

NOAH II (Natural On-Line Animal Housing)
* Monitors feed consumption, water consumption, temperature, ammonia, fan operation, feed bin levels, water pressure and light function.
* Controls and verifies lights, feeders, ventilation schedules, baffles and baffles positions.
* Gathers feed and water consumption data and analyzes to give feed conversion and efficiency and water usage.
* Reports include: egg size charts, egg production and mortality graphs, costs per dozen and a Lotus-compatible data base system.

Sci Agra, Inc.

Environmental Control System
* Monitors temperature, ammonia, light and fan operation, water and feed consumption.
* Controls lights, ventilation, fan and baffle systems, feeder operation.
* Reports available daily on temperature, lights, water and feed consumption, and fan operation.
* System can be monitored on a remote terminal.
* Serve as a security watchdog.

Poultry Management Systems and Sci Agra also produce egg counting and egg flow systems which can be integrated with the environmental control systems.

V. ECONOMIC EVALUATION OF COMPUTER CONTROL SYSTEMS

Benefits of Computer Control

Little documented evidence is available on the benefits of computer control of environmental systems in poultry houses. Timmons and Gates (1985) suggest that to make realistic decisions about environmental control systems, estimates need to be made of benefits occurring over a sustained length of time. Automated Environments Inc. (1987) claim improved feed efficiency, increased egg production and size, lower mortality rates and more efficient use of power. None of their claims are in the form of a statistically valid trial, consisting rather of comparisons between controlled and uncontrolled houses and comparisons on the same house before and after installation of the system. In addition a 10% increase in bird density is claimed. They claim approximately a $1.00 per bird saving per year in variable costs as a result of increased value of egg sales and decreased feed consumption.

Timmons and Gates (1986) simulate a broiler house using a procedure to select the optimal temperature to maximize economic return. They predict savings of 0.5 cents to more than 2.5 cents/kg of liveweight.

Selection of Research Approach

A search of the literature failed to reveal any studies which had documented the benefits of computer controlled systems in layer houses. Ideally, a controlled study over a number of years would be utilized to account for the seasonal effects and the normal annual fluctuations and improvements in productivity. This was ruled out because of the difficulty involved in comparing controlled with uncontrolled houses and the time and cost of such an experiment. It was decided to survey producers who had installed the system and to attempt to obtain before and after information where possible.

Data Collection Procedures

All four New York producers who have installed a computer controlled environmental control system were interviewed personally. All of these were using the system sold by Automated Environments Inc. Information was obtained where possible on: Layout of layer houses; Location of computer equipment; Cost of computer equipment; Effects of system on production; Changes in costs; Opinions about the system and; Reasons for the changes which occurred. The manufacturer provided data on system component costs.

The four operations surveyed ranged in size from 30,000 birds to 480,000 birds. Management ranged from owner operated to company owned and managed. Houses ranged in size from 30,000 birds to 70,000 birds and include deep and shallow pit designs. The "pit" refers to the manure collection system.

Benefits Found for Computer Controlled Layer Houses

Discussions with four egg producers using a computer controlled system indicate the following gains are possible:

Decreased Feed Consumption - All producers indicated feed consumption decreased after installation of the system. The extent of this change was influenced by the time of year and other changes which occurred simultaneously. The three producers who were able to estimate changes which occurred with the same flock or similar flocks indicated decreases in feed consumption over a year of 1.2, 1.8 and 2.0 lbs of feed per 100 birds per day i.e. 5.1%, 7.8% and 8.3% respectively. Another factor noted by one producer was feed consumption was consistent from week to week with his computer controlled flocks, while consumption in his non-controlled flocks showed much larger fluctuations. Decreases in feed consumption were the most common benefit noted.

Lower Body Weights - Two producers indicated the reduction in quantity of feed consumed which occurred as a result of installing the computerized system led to lower body weights of the hens. This was difficult to quantify but appeared to be about 0.2 lbs. per bird less at 60 weeks. There was also some suggestion of decreased variability in body weights.

Egg Production Increases - Egg production was not measured accurately by most producers, however, Adam Baum Egg Farms[2] claim to have gained at least 8 extra eggs per bird per year (approximately 3.5 percent).

Mortality Decreases - Once again the results here are sketchy and ranged from no noticeable difference to a decrease of 3 percent per year.

Egg Size - This was difficult to quantify. Because of improved ability to control feeding and hence weight of birds, greater control over egg size should be possible although this was not documented. No decreases in egg size were noted.

Density - Most producers were using a density of 60 sq.ins. per bird with and without the system. Adam Baum Egg Farms had experimented with densities of 54 sq.ins. and 48 sq.ins. per bird. It appears that higher densities may be possible with computer controlled sheds, however, there is a tradeoff between reduced shed costs, changes in feed consumption and decreased egg production per bird. Higher densities require a higher level of management.

Other Benefits - Computer systems can also be used to control brooder house environments. Producers indicated that this improved the evenness of birds, reduced feed costs and brought them into production earlier.

Egg quality may also be improved although this was not quantified.

Alarm System - The ability of computers to monitor continually conditions in the poultry houses is an important advantage in itself. Emergencies resulting from power or water failures, lightning strikes etc. are reported immediately. This has the potential to avert major losses which sometimes occur because of such occurrences. Although no system is fool-proof, the risk of these losses is substantially reduced and all producers indicated the system had advantages over their existing alarm systems.

The ability to monitor electric motors and water pressure also means that many potential problems are averted before they occur, resulting in savings in labor and expense.

Operating Costs

Labor - No savings in labor costs for poultry house monitoring and maintenance were noted, although the general comment was that labor was used more efficiently because of the ability to track down and fix problems more efficiently. The main labor saving comes about due to the reduction in feed required which means that less labor is needed for mixing feed.

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[2] Adam Baum Egg Farms is the company which developed the PMS 2000 system which is marketed by Automated Environments Inc.

Utilities - Although no accurate figures on power usage were obtained, those interviewed indicated total consumption over the year was about the same or slightly higher. The computer system appeared to use less during the winter because of reduced heat losses and more during the summer because of increased fan use. However, it may be possible to reduce peak usage significantly by using the computers potential to stagger start-up and running time of all electrical equipment. This could reduce costs for large operations.

Management - Discussion with users indicated the need for good management to take advantage of the benefits of computer control. The computer system itself is easy to use, but the grower needs a good understanding of shed ventilation, and poultry management.

Reasons for Benefits

The benefits claimed for computer controlled environments appear to occur for two main reasons; temperature/feed interactions and improved management control.

Temperature/Feed Interaction - Monitoring of temperature in poultry sheds has indicated wide average temperature fluctuations throughout the day. As well, separate locations within a building will have very different temperatures.

Figure 1a shows a graph of temperature variation (for one day in April) of a layer house monitored and controlled by the PMS 2000 system. Figure 1b shows the temperature variation on the same day, at the same site, for a similar house, which was being monitored, but not computer controlled.

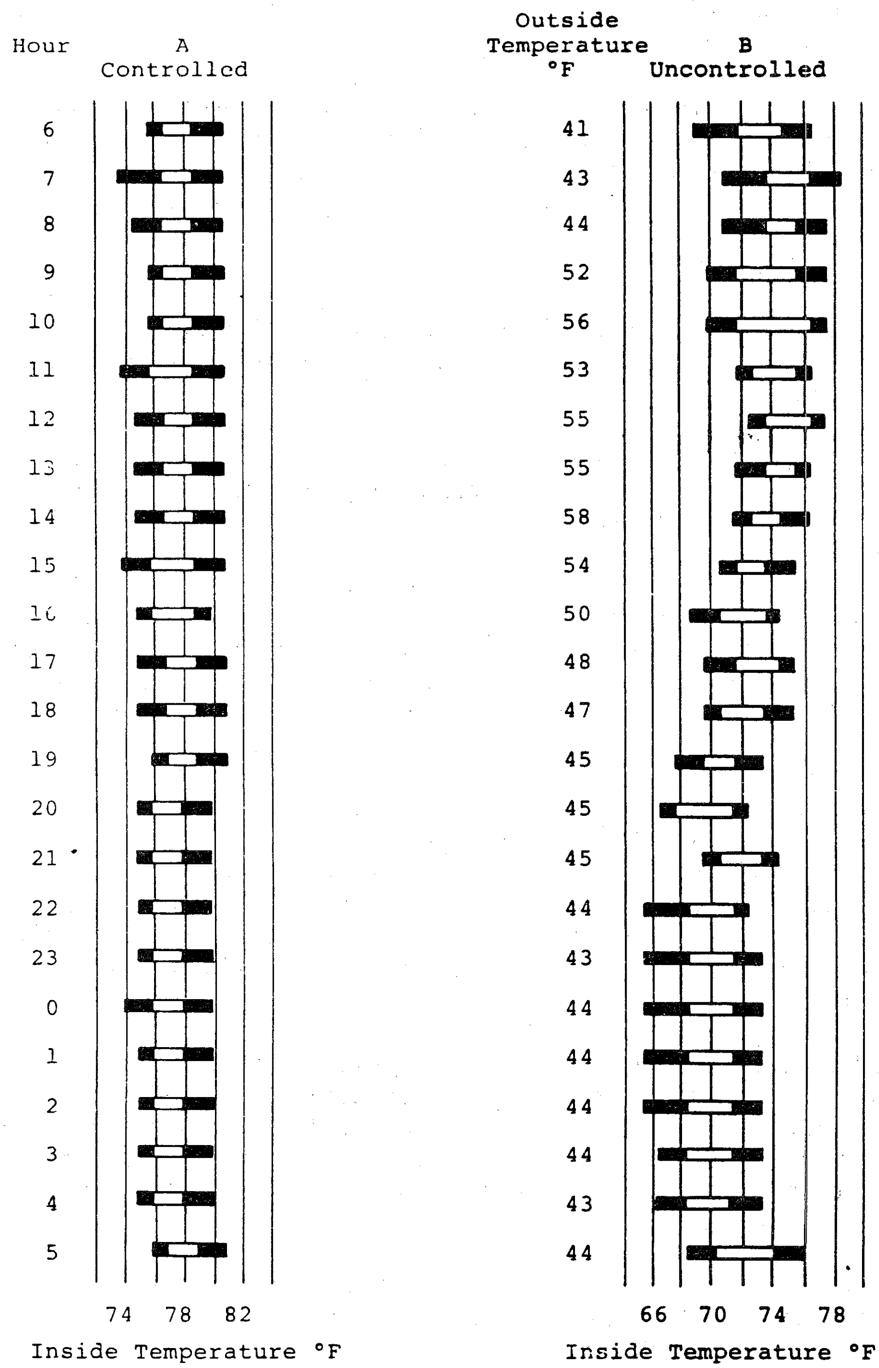
The average temperature inside the computer controlled house for the 24 hours was 77^{o}F with a range from 76 - 78^{o}F while for the conventionally controlled house the average was 72^{o}F with a range of 68 - 76^{o}F. This occurred despite the fact that the manager was able to use the monitoring of this house to improve the efficiency of his manual control system above that which would have occurred without the monitoring. These graphs are indicative of the improved control over temperature which can be achieved with computer controlled systems.

As noted in the literature review, the optimum content of feed for birds will vary with temperature. If birds are kept at a consistent temperature, then the feed they receive can be mixed precisely for that temperature. However, when temperature varies, especially from one part of the shed to another, then some birds will be eating feed which is not optimum for their environment.

Feed intake can be more precisely controlled and birds will use the feed more efficiently. This could explain the lower body weight of birds raised in the controlled environment.

Improved Management - Monitoring of temperatures in the sheds makes management more aware of the variations which occur and the possibilities

Figure 1A and B: TEMPERATURE VARIATION IN COMPUTER CONTROLLED LAYER HOUSE, APRIL 9, 1987



Note: The dark bars show the maximum and minimum recorded temperatures while the white bars indicate the range of average hourly readings for all sensors within the shed.

for greater control which exist. One user indicated experience with a computer controlled house gave him confidence to raise the temperatures during the winter in other houses in which temperatures were monitored but not controlled by the computer. Improvements occurred in these houses also, although not to the extent of the fully controlled houses. Increased awareness of conditions in the houses on the part of the manager leading to improved management appears to be partly responsible for the increases claimed.

To some extent gains made immediately after the installation may understate the long term gains. This could occur because of fine tuning of the system which occurs as management improves their understanding of the complex interrelationships between temperature, ammonia, fan and baffle position and operation. It is probable the big gains will be made shortly after installation.

Problems

Lightning strikes which knock out electronic equipment was the most important problem noted by the producers. Some expressed the need for research on the suitability of various lightning rods and other means of shielding equipment.

Most producers have suffered some damage to their equipment although the cost and frequency of occurrence varied greatly.

Capital Costs

All of the systems surveyed have a wide range of options available making it difficult to select a system which is representative of this technology. As mentioned previously, there are also differences between the systems in the level of monitoring and control available, although no attempt has been made to quantify and assess these differences.

Because all the producers surveyed had installed the Automated Environments PMS 2000 system, the analysis in this paper is based on the costs of their system. They include the purchase of hardware and software, installation, and training and support for the first year of operation. A breakdown of costs for a 60,000 bird house are given in Table 4. The configuration described includes a number of options and is therefore on the high end of the cost range.

A recent survey of poultry businesses in New York (Ackerman and Park, 1986) showed a total investment per hen of $11.42. The cost of a computer controlled environmental system would therefore be 3 percent or less of the total investment in a poultry operation.

Table 4. Example costs of PMS 2000 system for 60,000 bird operation

Category	Cost $	
Computer System		
Computer, communications equipment, modem, data panel, uninterruptible power supply	5,500	
Software, database setup, training, supprt	6,500	
		12,000
60,000 Bird House - Monitor & Control		
Data panels, control units - fans (20), baffles, lights, feed, power supply, communications, cables	8,100	
Sensors - temperature (20), ammonia (2), alarms, cables	3,500	
Water pressure - sensors (8), panels, cables	1,800	
		13,400
TOTAL COST		25,400

Source: Derived from information supplied by Automated Environments.

Table 5 considers the size economies of installation of controlled environment systems. Costs have been based on multiples of a 60,000 bird house with each house having the same configuration described in Table 4. The computer system remains the same as size expands.

Table 5. Effect of size of operation on costs of controlled environment systems

Number Birds	Base Cost $	Total Cost $	Cost/ Bird $
60,000	12,000	25,400	0.42
120,000	12,000	38,800	0.32
240,000	12,000	65,600	0.27
480,000	12,000	119,200	0.25
960,000	12,000	226,400	0.24

Source: Derived from Table 4.

Cost per bird declines from 42 cents for a 60,000 bird operation to 24 cents for a 960,000 bird operation (Table 5). This occurs because the cost of the computer and software is essentially the same no matter what the size of the operation.

Estimated Returns

Using the capital costs given in Tables 4 and 5 above, and assuming a 1 lb. per 100 birds per day decrease in feed consumption, investment in the environmental control system yields an internal rate of return, after tax, of from 21 percent for 60,000 birds to 38 percent for 960,000 birds (Table 6). This is a conservative figure as the 1 lb. per 100 birds per day (4.5 percent) decrease is less than the 5-8 percent indicated by growers in the survey. It also does not take in to account effects on egg production, egg size, density and other possible benefits. Despite this it is still a highly profitable investment.

Table 6. Rate of return on investment given an assumed 1 lb/100 bird/day decrease in feed consumption[a]

Number Birds	IRR/BT[b] %	IRR/AT %
60,000	28	21
120,000	39	29
240,000	46	34
480,000	50	37
960,000	52	38

a. Calculated based on 22 lb./100 bird/day consumption before installation and including the 4 percent New York State investment credit.
b. Marginal tax rate = 0.
c. Marginal tax rate = 0.28.

When the returns are calculated based on a 1.8 lb. per 100 birds per day (8 percent) feed decrease plus an increase of eggs per bird per year and a 3 percent decline in mortality, the IRRs increase significantly to 103 percent for 60,000 birds and 148 percent for 960,000 birds (Table 7).

An alternative consideration is the reduction in feed consumption required for the investment to break-even. This ranges from .48 lbs. per 100 birds per day (2.2 percent) to .71 lbs per 100 birds per day (3.2 percent) (Table 8).

Table 7. Rate of return on investment assuming decreased feed consumption, decreased mortality and increased egg production[a]

Number Birds	IRR[b] %	IRR[c] %
60,000	136	103
120,000	164	123
240,000	183	136
480,000	193	144
960,000	199	148

a. Calculated based on a 1.8 lb./100 bird/day decrease in feed consumption, an 8 egg /bird/year increase in egg production and a 3 percent decrease in mortality.
b. Marginal tax rate = 0.
c. Marginal tax rate = 0.28.

Table 8. Reduction in feed cost required for break-even result

Number Birds	Feed Decrease[a] lbs	%	Feed Decrease[b] lbs	%
60,000	.69	(3.1)	.71	(3.2)
120,000	.56	(2.6)	.59	(2.7)
240,000	.50	(2.3)	.53	(2.4)
480,000	.46	(2.1)	.49	(2.2)
960,000	.44	(2.0)	.48	(2.2)

a. Decrease in lbs./100 birds/day. Marginal tax rate = 0.
b. Decrease in lbs./100 birds/day. Marginal tax rate = 0.28.

VI. IMPLICATIONS OF ENVIRONMENTALLY CONTROLLED SYSTEMS

Likely Adoption of the Systems

At such an early stage in the adoption curve it is difficult to predict the rate and extent of adoption of computer controlled environmental systems. However, as indicated by the figures shown above, it is likely to be a profitable investment for those operations with more than 60,000 birds. Profitability is a necessary but not sufficient condition for adoption.

A number of qualities of an innovation which influence its adoption have been identified by researchers (Rogers, 1983). These include its relative advantage, or the degree to which the innovation is seen to be better than the idea it replaces. Environmental control systems have high internal rates of return, and value as alarm systems, but this may not be obvious to many producers at this stage.

Further factors are compatibility and complexity, which are respectively, the degree to which an innovation meets the existing situation, values and experience of the farmer, and the degree to which it is seen as being difficult to understand and use. Producers who are familiar with computers will not be discouraged by a computer control system, but those who have no previous experience with them may be wary.

Another quality, trialability, is the extent to which an innovation can first be tried on a small scale. This is a major factor working against the adoption of computerized control systems. It is an "all or nothing" situation, with no opportunity for a test run, and generally involves a large initial outlay. Other purchase options, apart from buying the system as costed in this study, include leasing, or, the installation of cheaper systems with diminished monitoring and control capabilities. This could entice some managers. However, the cheaper options may not provide the same improvement in productivity found in this study.

Observability of the innovation, that is the degree to which the results can be seen or observed, can also be an important characteristic. It is difficult to observe the benefits of computerized control systems. The differences, although significant, are small, and it is not easy to compare situations with and without the innovation. Producers considering adoption face this problem, and when it is combined with the lack of trialability, will slow the pace of adoption.

Discussions with growers and manufacturers of poultry equipment indicate the industry is heading toward a very high level of computer monitoring and control. All aspects of egg production, including feeding, environment, egg collection and processing, and finances are becoming more integrated and it would appear this is the direction of the future. Within the next 10 to 15 years it could be expected most operations with more than 60,000 birds will have some form of computer control of their production systems.

Larger operations may be more likely to adopt the system because of its investment size economies, their larger cash flow, and its value as an alarm system.

The experience in New York state clearly indicates that producers are cautious in responding to these new products. Presently only three firms have adopted an environmental control system during the three years they have been on the market. Potential buyers may be deterred by the lack of documented information on potential savings or by a desire to allow others to experiment first, with the expectation that advanced, trouble free equipment will be available in the future.

Economies of Size

Although the cost per bird is less for larger complexes, the difference is not large when spread over the life of the equipment and in the context of the overall investment in plant and equipment. Producers with 60,000 birds or more should expect substantial benefits.

Larger producers may have an added advantage because computerized control should improve their labor productivity. Some studies have suggested larger complexes have a lower quality of husbandry than family sized units (Schrader et. al., 1978). A system which accurately monitors and controls conditions in the buildings and which warns of potential problem areas with fans, water supply, temperature and ammonia, may benefit larger operations (which rely on hired labor) more than family operations. No valid comparisons are possible with the data from this survey because of the small number of units involved.

Computerized control should also aid large complexes with their integrated feed, egg production and processing units. Movement of inputs and outputs can be monitored and controlled to eliminate bottlenecks and maximize profitability (or minimize costs) of the whole operation.

The management skill required to take maximum advantage of the computer system is also a consideration. Although the systems themselves are user friendly, they are only an aid to management, not a substitute for it. The best managers will be the ones who gain most benefit from the system, so to the extent that smaller operations generally have less flexibility in buying, or acquiring, improved management skills they may be at a disadvantage.

Effect on Competitive Position of New York Industry

New York is a net importer of eggs and its units are generally smaller on average than operations in the major producing states. New York has been at a comparative disadvantage to more southern states because of climate, and higher labor costs. These areas were also able to gain economies of scale through aggregation and establishment of integrated complexes (Lasley, 1983).

The main effect of computerized environmental control is to decrease the costs of production through decreased feed consumption and possible increases in egg production. Since New York producers already have enclosed environment housing, they can take maximum advantage of the benefits of computer control. The major problem for them has been maintaining temperature during the winter. In the southern states however, open-sided houses are more common and the major problem is high summer temperatures. Whereas it is relatively easy to maintain optimum temperature during the winter in a controlled environment house, high summer temperatures are more difficult to control, both in open and closed housing. Installing a computerized environmental system under these conditions may not provide the return obtained in the North.

Producers in southern states will need to improve the degree of insulation and environment control in their houses to take full advantage of the computer systems. This will increase their housing costs relative to New York producers. It may also be the case that they still may not be able to achieve the same degree of control during the summer and hence find it difficult to achieve the same feed consumption ratios. From this point of view computer control of the environment is unlikely to be a disadvantage to New York and may help overcome some of the previous climatic disadvantages

New York is also at a disadvantage to mid-western states because of higher grain prices. The average price of corn meal, a major ingredient of poultry feed, was over 20 percent less in Indiana than in New York from 1981-1985. The price of soybean meal, a major protein source, averaged 8 percent less over the same time period (Table 9). Note that prices in Georgia were similar to New York over the same period.

Table 9. Average prices of corn and soybean meal for Georgia, Indiana and New York states, 1981-85.

	CORN MEAL		SOYBEAN MEAL	
STATE	Av.Price $/cwt.	Av. % of NY Price	Av.Price $/cwt.	Av. % of NY Price
Georgia	9.13	104.3	13.48	97.8
Indiana	6.87	78.5	12.66	91.9
New York	8.75	-	13.78	-

Source: Adapted from USDA, Agricultural Prices, Annual Summaries.

Feed costs make up between 50-60 percent of the cost of producing an egg depending on the cost of feed. Producers in the Mid-West should also be able to reduce their feed consumption ratios to the same degree as New York producers. Nevertheless, as feed costs are less for them, the gains to be made should not be as significant as they are for New York producers. To this extent computer control may help offset the feed cost disadvantage for New York producers to at least a small degree.

In summary, New York producers should not be disadvantaged by this technology and it may help improve their competitive position. Other factors which will impact on this are the level of adoption in the state and the degree to which economies of size factors provide advantages to the larger producers in other states.

Effects on Electricity Demand

Producers interviewed indicated the computer system had no net effect on electricity consumption over the year, although consumption was up during the summer and was lower during the winter. As mentioned in the literature review, electrical consumption in New York averages about 2.46 Kwhr per bird per year, with ventilation accounting for around 40 percent of this. This is similar to the 1986 Poultry Farm Business Summary (Ackerman and Park, 1986) figure for New York state which gave an average consumption for 9 New York farms of $0.36 per hen per year.

Summer consumption is from one and one half to two times winter consumption, largely due to the greater ventilation requirement.

On a daily basis, demand builds in the early morning around 4-5 a.m. when the lights come on and peaks occur as a result of feeders, egg collection, egg graders, washers, coolers, manure scrapers and hammer mills. Stetson et. al. (1981) indicate peaks during the day of up to 17.5 Kw for their study of poultry operations in Nebraska. The computer can reduce peak demand by load-shedding and this may provide some savings to producers. Overall though, electricity demand on existing farms will not be greatly affected.

The aggregate effect for the state will to a large extent depend on the total number of laying hens in the state. Many other factors influence this, but if the competitive position of the state's producers is improved this may help arrest the decline which has been apparent in recent times.

VII. CONCLUSIONS

1. Computerized environmental control systems are a profitable investment for producers in New York state with more than 60,000 birds.

2. Adoption of the systems may initially be slow but within the next decade a majority of operations are expected to have done so. Larger operations are more likely to adopt because the systems provide greater advantages to them.

3. Economies of size exist due to lower investment costs per unit for larger complexes while they may also benefit through gains in management control of labor and the production process.

4. Computerized environmental control systems should help maintain or slightly improve the competitive position of the New York industry provided adoption rates here are comparable to those in competing states.

5. The adoption of these systems should not of itself significantly affect electricity consumption by poultry producers in the state. Other factors which influence the number of birds in the state are more likely to be important.

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