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FUEL-INSULATION TRADEOFFS FOR ARKANSAS BROILER HOUSES

William B. Riley, Jr. and J. Martin Redfern

Production of broilers requires very large quantities of heating energy. Optimum growth of broilers requires that the broiler house temperature be maintained within a narrow range. In Arkansas, chicks are normally started at a house temperature of 75°F with a 3°F per week reduction until a temperature of no less than 60°F is reached and maintained. Feed represents about sixty percent of total production cost, and most studies indicate that feed consumption increases rapidly as the temperature around the birds drops below 65°F. Most grower contracts contain an efficiency clause in which part of their payment depends on how efficient they are in converting feed to meat. They must maintain a certain minimum degree of efficiency to continue growing for their contractor. House temperatures can thus be lowered somewhat, but must be maintained within rather narrow limits for growers to continue to produce. This is mentioned to point out just how vulnerable growers are to rising fuel prices. Approximately 80 percent of Arkansas broiler growers use propane. The retail price of propane ranged from $0.18 to $0.41 per gallon in Arkansas from January 1973, to September 1977.

Fuel prices have risen greatly since 1973 causing the following question to become important: Should a grower install more roof insulation in a broiler house with the objective of decreasing heating fuel consumption? To answer this question, a methodology was developed to determine optimum quality of insulation providing a particular broiler house with a specified inside environment using the least costly combination of heating fuel and insulation (for specified prices of fuel and insulation, broiler growing practices and weather conditions).[1]

The methodology is general enough to determine optimum quantities of insulation for all types of broiler houses, under a variety of assumptions concerning inside and outside environments and at any price of LPG and insulation.

There is a trade-off between insulation and energy consumption which will provide the same inside conditions. The graphical configuration of these combinations is an isoenvironment curve, which will tend to be convex to the origin. This trade-off was determined for a typical broiler house in Northwest and Southwest Arkansas through computer simulation. A simulation model developed by Collins & Walpole [1] at the University of Delaware was first validated and then applied to generate yearly estimates of fuel consumption for typical houses with different amounts of insulation.

The simulation model contains two programs: The first determines heat loss of a building through the ceiling, walls, doors, curtains and perimeter, and then sums these to determine total heat loss from the structure; the second determines the supplemental heat required (SHR) to maintain desired inside conditions. Heat loss through the building (BHL), heat loss through ventilation (VHL), and heat loss

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[1] One reviewer of this paper stated that an additional important consideration is whether to heat broilers with artificial heat or heat them by feeding additional nutrients. These data do not allow this trade-off between LPG and nutrients to be examined. Changing relative prices could cause the contracts to be changed from that which is now considered typical, where the grower pays the fuel bill and the vertically integrated company pays the feed bill: the two are related in that if the grower lets the house get too cold, feed intake will rise and cause the grower to be penalized (in terms of less income because of poor feed conversion). It seems more likely that, in the next few years, the contract will be adjusted in such a way that the grower will be compensated for his higher fuel bill, rather than allowing the grower to maintain lower inside house temperature and feeding the birds greater amounts of feed.

through evaporation (EHL) are summed, and from this summation bird heat production (BHG) is deducted. The resulting value is the supplemental heat required for the building, i.e., SHR = BHL + VHL + EHL − BHG.

Building Heat Loss

BHL is a function of the building's surface area and resistance factors for each segment of this area. The first program determines BHL for a particular house in BUTs per degree difference in inside and outside temperatures. As a result of a field study in Arkansas on house temperatures [2], talks with vertically integrated companies and with the Cooperative Extension Service, it was decided to use a house temperature schedule of 75°F for the first week, with weekly drops of 3° per week until a house temperature of 60°F was reached. All supplemental heat was cut off after the 42nd day of the production period. A density of 0.8 square foot per bird and a production period of 63 days were used in the model.

Ventilation Heat Loss

VHL is a function of the ventilation rate (in cubic feet) of air per bird per minute (CF/bd/min); the difference in inside and outside temperature; and the number of birds in the house. Ventilation rates used in this study are those recommended for winter conditions in Arkansas [6].

Evaporation Heat Loss

Moisture is exhaled from broilers' lungs (respired moisture), as well as being given off in by-products from feed consumption (fecal moisture). Heating energy is consumed in removing this moisture from the house. EHL is a function of feed consumption, weight and number of broilers, and desired litter conditions.

Bird Heat Gain

Broilers produce body heat that can supplement the heating unit of a broiler house. The model requires data concerning heat production of broilers in BTUs per pound per hour. This information was obtained from heat regression equations developed for broilers averaging from 0.3 pounds to marketing weight [3].

Validation of the simulation model involved a comparison of simulated and observed yearly fuel consumption for 60 Arkansas broiler houses in 1974. Broiler house data sheets were completed for each house to provide necessary input for the simulation model. Flock placement and pickup dates and quantities of broilers placed and processed were determined, and this information was used in the model to compute expected fuel consumption for each house throughout the year.

Analysis of results revealed no significant difference in observed and predicted fuel consumption for 1974.[2] Thus it is argued that the simulation model provides valid results for real life broiler houses.

The simulation model was used to generate estimates of fuel consumption for typical houses in Northwest and Southwest Arkansas with different amounts of insulation.[3] The building heat loss program of the simulation model determined heat loss for each of these houses as amount of roof insulation, measured by R values, was varied. Twenty-six R values ranging from 1.7 to 20.38 were used in the model.

The heat balance program of the simulation model was used to estimate gallons of fuel consumed in each of the four seasons for each area. Monthly high and low temperatures were combined to determine winter, spring, summer and fall high and low temperatures normal for each broiler-producing area. These seasonal fuel consumption estimates were averaged and multiplied by average yearly production figures to determine the total number of gallons that a typical grower would consume per year.[4] This procedure was followed for each different amount of roof insulation. Averaging of consumption estimates is justified on the basis that broiler production in Arkansas is not particularly seasonal.

In this manner, estimates of yearly fuel consumption for houses with 26 amounts of insulation were obtained for the state's northwest and southwest broiler-producing areas. Isoenvironment curves for typical houses in northwest and southwest Arkansas were generated.

The broiler grower can minimize his cost by employing energy and insulation in such amounts as to equate the marginal rate of technical substitution

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[2] A matched pair T test was used to compare observed with predicted gallons of fuel consumed per house for the year. A T value of −0.58 with an associated probability of .56 calculated for a two-tailed test. The hypothesis that there is no significant difference in observed and simulated fuel consumption for the sixty houses is accepted at a predetermined level of significance of .05.

[3] A typical house in northwest Arkansas is 32 by 375 feet with a steel or wood frame and a corrugated metal roof. It generally has seven-foot sides and four to five foot side curtains. The typical house in southwest Arkansas is similar except the side curtains tend to be five to six feet high.

[4] An Arkansas housing inventory determined that a typical grower produces 4.3 flocks of 15,000 birds per year per house (64,500 birds).

(MRTS) with the input price ratio (P_I/P_F). The $MRTS_{IF}$ is measured at any point on the isoenvironment curve by determining the slope of a tangent to that point. In order to determine the slope of the curve, it was necessary to describe the relationship with an equation. The simulation model specified the nature of the relation to be in the form $Y = \frac{a}{X} + c$ where Y equals fuel consumption and X equals the ceiling R value.[5] Ordinary least squares regression analysis was used to estimate the equations.[6] The equations resulting from this analysis for northwest and southwest Arkansas, respectively, are:

$$Y_{NW} = 2035 + \frac{6597}{X} \qquad Y_{SW} = 1775 + \frac{4809}{X}$$

Optimum quantities of insulation can now be determined for any price of energy and insulation as long as assumptions concerning the isoenvironment curve are correct. It is necessary to equate the price ratio of insulation and energy to the absolute value of the slope of the isoenvironment line ($\frac{P_I}{P_F} = MRTS_{IF}$). The slope of the curves as determined by differentiation of the regression equations for northwest and southwest Arkansas, respectively, are:

$$\frac{dy}{dx}(NW) = \frac{-6597}{x^2}$$

$$\frac{dy}{dx}(SW) = \frac{-4809}{x^2}$$

The price of LPG in September 1977 in northwest Arkansas was $0.35 per gallon. Because the price normally increases in the winter, the LPG price chosen for this analysis was $0.40 per gallon. The price of insulation varies by brand and distributor. That used in this analysis was for Styrofoam board-type insulation sold in NW Arkansas in September 1977.[7] The market for broiler house insulation in September 1977 was characterized by shortages and very high prices compared with two years earlier. Whether or not these prices will decrease in the future is difficult to determine. Insulation prices are normally quoted per inch, quarter of an inch or tenth of an inch of thickness and not in terms of R values. An R value of insulation is a measure of the efficiency of the material in resisting heat transfer.[8] For purposes of this study, it was advantageous to have prices in terms of R values. The price of styrofoam insulation is $0.22 per square foot for a one inch thick board, which has an R value of 6 (this includes $0.03 per square foot for a felt paper lining). An average price per R value of $0.036937 per square foot was computed. This price per square foot is an average price and varies somewhat as insulation with larger and larger R values is purchased. It is, however, approximately correct in that insulation with an R value of 10 costs roughly twice as much as insulation with an R value of 5.

A 32 × 375 foot house has 12,649 square feet of roof to insulate. The cost of insulation for this house is presently $467.22 per R value ($.036937 ×

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[5] This equation can be related to the characteristics of the broiler house in the manner shown here:

SHR = BHL + VHL + EHL — BHP

only BHL is a function of R ∴ VHL + EHL — BHP can be grouped as a constant c.

$$BHL = \frac{\text{ceiling area}}{\text{R value}}(\Delta T) + \frac{\text{upper wall area}}{\text{R value}}(\Delta T) + \frac{\text{all other area}}{\text{R value}}(\Delta T)$$

since only the R value of the ceiling area was varied, the other terms in the BHL equation can be combined and grouped with the constant c.

Thus:

$$SHR = \frac{\text{ceiling area}}{R}(\Delta T) + c$$

Or:

$$Y = \frac{a}{x} + c$$

[6] For Y_{NW}:
$R^2 = .99985$
Standard error = 6.0
F statistic = 106,374

For Y_{SW}:
$R^2 = .99978$
Standard error = 5.2
F statistic = 150,584

With the nature of the relationship between insulation and fuel consumption completely specified, the R^2 should be 1.0 and the standard error should be 0.0. The very small deviation of the R^2 from 1.0 and of the standard error from 0.0 is attributed to rounding error.

[7] An inventory of Arkansas broiler houses made by the researchers revealed that the majority of existing houses in the state are insulated with styrofoam although other types are used. In other parts of the United States other types of insulation may be more common.

[8] The magnitude of the R value refers to the difference in degrees F which can exist between the warm and cold sides of a wall while allowing just one BTU of heat to pass through an area of one square foot in one hour.

12,649). Assuming a ten year straight line depreciation schedule and using an interest rate of nine percent to amortize the payments over ten years, the annual material cost is approximately $72.80 per R value. Value of a broiler house increases with addition of insulation, and this increased value will be reflected in higher property taxes and insurance premiums. The annual incremental insurance premium is approximately $4.30 per R value and the annual incremental property tax is approximately $6.07 per R value. Annual cost of insulation including insurance and taxes is $83.17 ($72.80 + $4.30 + $6.07) per R value.[9] Thus, total material cost of insulation for a 32 × 375 foot house with an R value of 8 would be $3,582, and annual cost would be $358.20. Additional insurance of $21.12 and additional property taxes of $29.92 bring the total annual cost for insulation to $409.24.

The optimum quantity of insulation can now be determined by equating $\frac{P_I}{P_F}$ to the $MRTS_{IF}$.

$$\frac{83.17}{.40} = \frac{6597}{x^2}$$

x = approximately 6 for northwest Arkansas

$$\frac{83.17}{.40} = \frac{4809}{x^2}$$

x = approximately 5 for southwest Arkansas

At present prices, the optimum amount of insulation has an R value of approximately 6 and 5 for houses in northwest and southwest Arkansas, respectively. These R values apply to the overall R value of the roof and include roofing, vapor barrier and surface resistance as well as insulation. It should be stressed that this study does not recommend these specific R values for all houses in each respective broiler producing area. These R values are optimum if and only if other conditions of an actual broiler house are the same as those assumed in the model. These values were determined on the basis of specific LPG and insulation costs; normal, high and low outside temperatures; a specific depreciation schedule; specific insurance rates and property taxes; and specific inside environments.

If prices of insulation and fuel change, those changes can be incorporated into the model and a new R value estimated.

If it is desired to use the model for other geographic areas the appropriate outside temperature, broiler house parameters and broiler growing practices can be incorporated together with appropriate local prices of fuel and insulation. Table 1 shows the optimum amounts of insulation for various prices of LPG assuming a 1977 price of insulation in northwest and southwest Arkansas.

The problem of the appropriate price for insulation has already been mentioned. The problem of the appropriate price for LPG also exists. Implicit in the table is the assumption that fuel prices will remain at various levels over the life of the insulation. While this is possible, it is not likely.

The cost of insulation is incurred today, whereas fuel costs are incurred each successive year over the life of the asset. Fuel prices can be expected to rise in the future; therefore, it becomes necessary to consider what price of LPG is relevant when making a decision concerning the optimum amount of insulation to install. This decision can be made once a grower's expectations concerning future fuel prices can be quantified. Relevant price of fuel is the present value of expected yearly fuel prices over the ten-year life of the asset discounted at the appropriate rate (PV_F). Relevant price of insulation is the present value of yearly insulation payments over the same period (PF_I).[10] In addition, insulation price will vary by brand and location. A grower should deter-

TABLE 1. TOTAL ANNUAL COST OF FUEL AND INSULATION AT VARIOUS R VALUES AND LPG PRICES[a]

Roof R Value	Total Cost at $.40 LPG	Total Cost at $.50 LPG	Total Cost at $.60 LPG	Total Cost at $.70 LPG	Total Cost at $.80 LPG	Total Cost at $.90 LPG
			Northwest Arkansas			
3	$1,944	$2,367	$2,790	$3,214	$3,637	$4,061
4	1,807	2,175	2,543	2,912	3,280	3,649
5	1,758	2,093	2,428	2,764	3,099	3,435
6	1,753[b]	2,067	2,380	2,694	3,007	3,321
7	1,773	2,071	2,368	2,666	2,964	3,261
8	1,809	2,095	2,381	2,667	2,953	3,239
9	1,856	2,133	2,410	2,687	2,963	3,240
10	1,910	2,180	2,449	2,719	2,988	3,258
			Southwest Arkansas			
3	1,601	1,939	2,277	2,615	2,952	3,290
4	1,524	1,822	2,119	2,417	2,715	2,929
5	1,511	1,785	2,058	2,332	2,606	2,879
6	1,530	1,788	2,045	2,303	2,561	2,818
7	1,567	1,813	2,059	2,305	2,552	2,798
8	1,615	1,853	2,091	2,328	2,566	2,803
9	1,673	1,904	2,134	2,365	2,596	2,827
10	1,734	1,960	2,186	2,411	2,637	2,862

[a]These costs apply to a typical broiler house which produces 4.3 flocks and 64,500 birds annually.

[b]The total annual cost figure underlined in each column is the lowest for the price of LPG assumed.

[9]The insurance rate used was $9.20 per $1,000 value. The property tax rate was $65 per $1,000 of assessed value, with assessed value equal to 20% of fair market value.

[10]This assumes that the borrowing and lending rate are equal.

mine insulation cost per R value for his area. The insulation cost relevant for Arkansas at this time is \$83.17 per R value.

A hypothetical example is included to clarify this point. Assume that a grower expects the price of LPG to be \$.40 per gallon in year one, increasing by 10 percent each year through year ten. Present value of this array of fuel prices is \$3.80 and present value of the insulation payments is \$533.80.[11] The optimum quantity of insulation can again be determined by equating $\frac{P_I}{P_F}$ to the $MRTS_{IF}$.

$$\frac{533.80}{3.80} = \frac{6597}{R^2}$$

R = 7 for northwest Arkansas

$$\frac{533.80}{3.80} = \frac{4809}{R^2}$$

R = 6 for southwest Arkansas

If a grower has an opinion about the price of LPG over the next 10 years, he can use this procedure to determine the optimum quantity of insulation for his particular operation by incorporating his relevant price of insulation as well as his expectations concerning future fuel prices.

ADDING INSULATION TO EXISTING STRUCTURES

Broiler houses in northwest and southwest Arkansas typically have existing roof insulation with R values of 5 and 4, respectively. At present prices of insulation and fuel, this is not the optimum amount of insulation for these houses. In addition, approximately five percent of the broiler houses in use in Arkansas have no ceiling insulation.

Adding insulation to a broiler house that has too little or no insulation can be a costly endeavor. If board type insulation is used, it normally involves removal of the roof, replacement of insulation and subsequent replacement of the roof.[12] Removal of the roof generally means loss of any existing insulation.

An *uninsulated* house in northwest Arkansas can be expected to consume approximately 5,966 gallons of LPG per year. The same house insulated with an optimal R value of 6 would use approximately 3,135 gallons per year. This represents an annual fuel saving of \$1,132 at \$0.40 per gallon LPG. Assuming a ten year life of insulation, yearly cost (including installation) would be \$831.[13] Thus, even at today's prices of LPG, addition of insulation to houses with no insulation *can* be justified on a cost basis. Similar results were found for houses in southwest Arkansas.

As previously mentioned, existing houses in Northwest Arkansas typically have ceiling insulation with an R value of 5 whereas an R value of 6 would be optimal. This represents a fuel savings of about 219 gallons or \$88 per year. This yearly cost of insulation (with installation) is about \$831. Thus, going from insulation with an R value of 5 to insulation with an R value of 6 *cannot* be justified at present prices. The same procedure for southwest Arkansas revealed that increasing the R value from 4 to 5 cannot be justified at present.

Many growers may furnish their own labor in insulating broiler houses and to the extent that their opportunity cost is very low, they can save the \$1,897 labor cost. While this reduces the yearly cost of insulation substantially, benefits remain far less than the cost.

CONCULSION

As fuel prices have continued to rise, heating cost has become an increasingly relevant production cost for the contract grower segment of the broiler industry in Arkansas. Adjustments can be expected in this particular segment of the industry.

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[11] $$PV_F = \sum_{*=1}^{N} \frac{\$0.36\ (1+g)^*}{(1+k)^*} = \$3.80$$

$$PV_I = \sum_{*=1}^{N} \frac{83.17}{(1+k)^*} = \$533.80$$

where N = 10
K = 9%
g = 10%

[12] The Arkansas Cooperative Extension Service recommends board-type insulation over the spray-on type. However, the spray-on type is an alternative that is being chosen by some growers. At present prices the cost of spray-on insulation is greater than the cost of board-type insulation. The annual cost of spray-on insulation with an R value of 7 is \$1,081 whereas the annual cost of board-type with an R value of 7 is \$904 including installation. Again, because of current distortions in the insulation market, prices of the two types should be compared at the time insulation is being planned.

[13] Installation cost includes a labor expenditure of \$1,897 (\$.15 per square foot) as well as the cost of nails (\$175) and duct tape (\$60). Total installation cost is \$2,132. This is an expenditure not incurred when a house is being built because the incremental cost of adding insulation to a roof as the roof is installed is insignificant.

Typical existing broiler houses in northwest and southwest Arkansas have too little roof insulation. Although, at present prices of LPG and insulation, these houses have less than the optimum amount of insulation as determined in this study, the incremental cost of adding more appears to be greater than the incremental benefit. As older houses are remodeled and newer houses built, more insulation should be added consistent with growers' expectations concerning future fuel prices. This, however, does not indicate any major near-term adjustments with respect to altering the amount of roof insulation in most existing houses.

Near-term adjustments should be in the area of insulating houses with no roof insulation. Estimates indicate that only five percent of approximately 500 of the houses presently in use fit into this category. Other near-term adjustments to rising fuel prices appear to be in the area of reducing infiltration heat loss and ventilation heat loss through reducing the width of side curtains, winterization of side curtains, and further research in partial house brooding.

This study revealed that at $0.40 per gallon LPG and $0.036937 per square foot per R value of insulation, overall ceiling R values of 6 and 5 are optimum for broiler houses in northwest and southwest Arkansas, respectively. This finding was for a "typical" house in Arkansas with a specified inside and outside environment. The procedure used can determine optimum quantities of insulation for broiler houses in any geographical area, for any assumed inside environment and at any price LPG and insulation.

REFERENCES

[1] Collins, N. E. and E. W. Walpole. "Computer Simulation of Fuel Requirements for Growing Broilers," Paper presented at the 1974 annual meeting of the American Society of Agricultural Engineers, June 7-15, 1974.

[2] Hines, Douglas. "A Field Study of Fan Ventilated and Naturally Ventilated Poultry Houses," M.S. thesis, University of Arkansas, 1973.

[3] Ota, H., J. A. Whitehead and R. J. Lillie. "New Bioengineering Data for Designing Production Houses," Paper presented at 1973 annual meeting of the American Society of Agricultural Engineers, December 1973.

[4] Riley, William R., Jr. "An Economic Analysis of Heating Energy Consumption and Conservation in Contract Broiler Production in Arkansas," Unpublished Ph.D. Dissertation, University of Arkansas, 1976.

[5] Riley, William R., Jr. and J. Martin Redfern. "Consumption and Conservation of Heating Energy in Contract Broiler Production in Arkansas," Arkansas Agricultural Experiment Station Bulletin 817, January 1977.

[6] Rokeby, T. R. C. and G. S. Nelson. "Controlled Ventilation for Broiler Houses," Arkansas Farm Research X(5):8, September-October 1961.