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DISCOVERY

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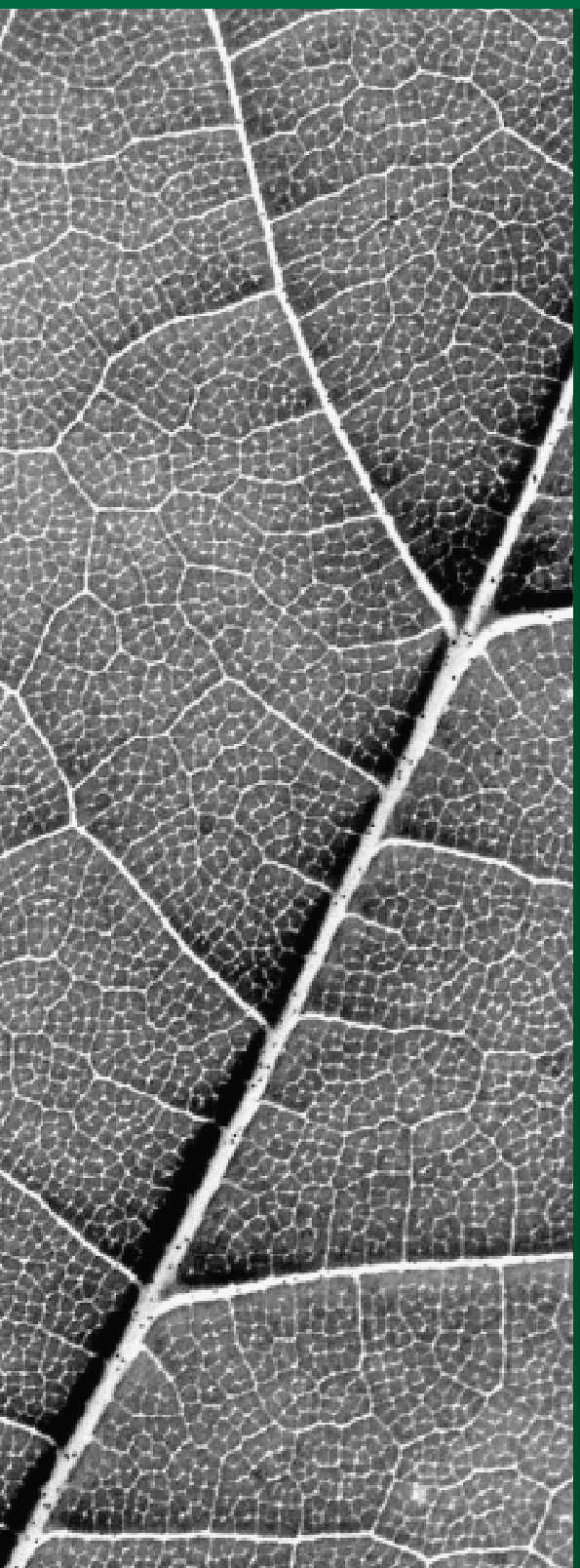

In This Issue

UofA UNIVERSITY OF ARKANSAS DIVISION OF AGRICULTURE

UNIVERSITY of ARKANSAS 1871

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Letter From the Dean

The vision for the Bumpers College of Agricultural, Food and Life Sciences and the Arkansas Agricultural Experiment Station is to be a "nationally competitive, model, student-centered research organization serving Arkansas and the world." In partial fulfillment of that vision, we are placing increased emphasis on the participation and involvement of undergraduate students in the research process. *Participation* and *involvement* are the key words. They indicate greater engagement than simply working on a research project, although that in itself is a tremendous learning activity. Full participation and involvement relate to the use of the experimental method in which the student formulates the research idea, structures the hypothesis, tests the hypothesis through experimentation, and draws the inferences. All of this must be done under the guidance and oversight of the research faculty—an association of faculty and student which represents teaching and learning at the highest level.

Science is not brought to fruition until the outcomes of the research are reported to peers and users of the information. *Discovery* was created to provide a reporting outlet for our undergraduate student-scientists. It will not supersede publication elsewhere, especially in the prestigious scientific journals, but rather it provides a forum for the students and faculty to share their results and findings.

We are excited about taking this step to enhance our programs. The undergraduate student research program will become the centerpiece for the College honors program. Seed grants are being awarded by the College and Experiment Station to support student research. Already our alumni are getting involved. Carroll and Sue Walls have established two undergraduate research fellowships in support of the program. We expect that support to grow as our alumni and friends become more closely acquainted our research programs for undergraduates.

I would like to acknowledge the members of the Arkansas Chapter of Gamma Sigma Delta, as well as the newly formed Honors Committee and the staff of Communications Services, who organized and edited this first issue of *Discovery.* The efforts of all these people have allowed Bumpers College to showcase a portion of the outstanding research accomplishments of our students.

In creating this program, we have attempted to do more than go to the next level of excellence. We are working to move to even higher levels of excellence—to skip levels, if you will—and reach those that will truly challenge our students and faculty and provide the most rewarding undergraduate experience possible. We hope that you can become as excited as we are about this venture. Let us know your thoughts about *Discovery*, the undergraduate research program, and how we might make it better. Best wishes.

Charles J. Scifres, Dean and
Associate Vice President for Agriculture

Stock market reactions to unfavorable product information: A case study of comments on beef safety made on an Oprah Winfrey Show

Elpida Ormanidou[*] and Michael Thomsen[§]

ABSTRACT

This study examines the impact of unfavorable media coverage on the stock market prices of major food companies, an issue of increasing importance to the food industry. The study focuses on the 16 April 1996 *Oprah Winfrey Show,* a popular television program that raised questions about the safety of the U.S. beef supply. The show resulted in considerable controversy, and some cattle feeders blamed the show for a drop in cattle prices. The focus of this study is on the impact of the program at other stages of the food system. We examined the stock returns of two major beef packers and leading fast-food hamburger restaurants during the days immediately following the show. Standard event study methods were used to determine the normal behavior of stock returns and to identify abnormal stock returns that could be attributed to the program. Our results suggest that the program did have a negative and statistically significant impact on the stock returns of a portfolio of fast-food companies. One of the two beef packers also experienced adverse stock price reactions to the television program. The paper concludes with recommendations and avenues for further research.

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INTRODUCTION

An important issue facing the food industry is the impact of major media sources on consumer perceptions of the safety and health attributes of food products. One highly publicized incident occurred on the 16 April 1996 *Oprah Winfrey Show*. This program featured a discussion on consumer safety. One of the three segments of this discussion focused on "mad cow disease" and the extent to which it poses a threat to the American consumer. Statements made by Winfrey's guests questioned the safety of including animal byproducts as ingredients in feed rations and raised concern that mad cow disease poses a potential danger in the United States. At one point in the program, Winfrey stated, "It has just stopped me cold from eating another burger," (Hayenga, 1998). Some cattlemen's organizations were not happy with Winfrey's show and blamed it for a substantial drop in the cash price for fed cattle that occurred during the following weeks. Furthermore, two large Texas cattle feeders and other businesses filed charges under product defamation laws, alleging that the show made false statements that led to lower prices.

Hayenga (1998) provided an outline of the economic issues and analysis that were presented during the lawsuit. One economist who testified at the trial developed a model to analyze Texas cattle price behavior. He used a regression method to estimate a cattle price model for the Texas-Oklahoma market area. This model accounted for supply-and-demand factors that could potentially influence price during the specified period surrounding the program. On the basis of the estimated model, the economist concluded that beef prices were influenced by forces outside of the typical supply-and-demand factors. This implied that the price drop could have been caused by Winfrey's show, but he never directly stated this. Other economists argued that there are many factors influencing price behavior at a given point in time and that it is almost impossible to trace the given price drop to a specific event, for example, Winfrey's show. This case was closed with the decision that there was not enough evidence to connect the *Oprah Winfrey Show* to the drop in cash cattle prices.

In this paper, our major objective was to provide

Elpida Ormanidou

Meet the Student-Author

I am a graduate with honors of the American Farm School, Thessaliniki, Greece. I received my Associate Degree in Agricultural Business from the Dimitris Perrotis College of Agricultural Studies (DPCAS), also in Greece. As an outstanding graduate of DPCAS, I was sponsored for continuing my studies here at the University of Arkansas. I graduated in May 2000 with a degree in agricultural business, with a concentration in agricultural economics. I have been recognized on the Dean's List at all institutions I have attended. In addition, I am a co-recipient of the Sigma Alpha (professional agricultural sorority) Silver Award for maintaining at least a 3.25 grade point average. After my graduation, I plan to further my education at the University of Arkansas, pursing a master's degree in statistics. My plan is to work as a research specialist.

When I first heard about this research project from my advisor, Dr. Michael Thomsen, I got very interested in it and decided to work with him. My research gave me an opportunity to apply my knowledge I have gained from most of my undergraduate courses, especially agricultural statistics, econometrics, and agricultural finance. In addition, I had a chance to become familiar with scientific research, which I think will better prepare me for the future.

more insight into how major media forces affect the food and agriculture industry. Specifically, we used daily stock market data to examine the impact of a demand-shaping force, i.e., a television program, on stock price returns of beef packers and retailers. We looked at major beef packers (IBP and ConAgra) and some of the leading fast-food hamburger restaurants that are publicly traded in the United States. Our analysis was aimed at determining whether abnormal stock returns resulted from the 16 April television program. Our models were based on the standard event study methodology. This methodology uses past company behavior to develop forecasts of stock returns during the days surrounding an event of interest. The method enabled us to determine whether abnormal stock returns resulted from the television program.

Event study methods have been used extensively in finance literature and are widely used as an accurate indicator of stock market behavior. Binder (1998) provides a complete literature review of event study methods. These methods have been used to examine the impact of unfavorable product information, such as the impact of the 1982 Tylenol poisoning incident (Mitchell, 1989) and bank failures (Aharony and Swary, 1996). They have also been used to examine the effects of policy or regulations on affected companies (Lamdin, 1999, Edelman and Baker, 1996).

MATERIALS AND METHODS

Daily stock market prices were obtained by the Center of Research in Securities Prices (CRSP) at the University of Chicago. These data reflect all securities traded on the New York Stock Exchange, the American Exchange, and the NASDAQ. This allowed us to obtain the necessary information on the two major publicly traded beef packers, IBP and ConAgra, and the parent companies of five leading hamburger restaurants, McDonald's, Wendy's, Sonic, Foodmaker, and CKE enterprises. Foodmaker owns the Jack-in-the-Box chain, and CKE enterprises own Hardee's and Carl's Jr. chains. One major restaurant, Burger King, was not included in the analysis because it is a subsidiary of a large, foreign conglomerate for which we do not have data in the CRSP files. In total, the five fast-food companies studied account for at least 60% of the fast-food hamburger market (Horovitz, 1999).

The event study methods we used have been outlined by Campbell, Lo, and MacKinlay (1997). We first looked at the behavior of the stock prices during the estimation period, a period of time before the television program. The estimation period reflects a period of time not affected by the event in question and is used to estimate a model of normal stock performance. We then used our estimated model to forecast stock returns for the period surrounding the time the event took place; we defined this period as the event period. Finally, we compared the projected or normal stock returns during the event period with the stock returns that were actually observed. The difference between these normal and observed returns is defined as abnormal returns due to the event. We then conducted hypothesis tests to determine whether the estimated abnormal returns were statistically significant.

The actual return on a specific day is given by the following formula:

$$R_t = \frac{p_t}{p_{t-1}} - 1 \qquad \text{[Eq. 1]}$$

where R_t is the stock return on day t and p_t is the stock price on day t. The returns measure provided in the CRSP data files also incorporates dividends or cash adjustments that may have an impact on stock prices.

The market model that was used to estimate normal performance was estimated over the estimation period. This model is specified as follows.

$$R_t = \alpha + \beta R_{mt} + \varepsilon_t \qquad \text{[Eq. 2]}$$

where α and β are parameters to be estimated, R_{mt} is the return on market index, and ε_t is an error term. In this study, we used the CRSP value weighted return for the measure of R_{mt}. The value-weighted return reflects the performance of a weighted average portfolio of all stocks traded on the three major U.S. exchanges. The total value of shares outstanding is used as the weights. The results presented in the next section would not be substantially different if other common market indexes, such as the return on Standard & Poor's 500 composite index, were used in place of the CRSP value weighted return measure. We used t to index the trading days and defined day $t = 0$ as 16 April 1996, the day of the television program. The market model in equation 2 was estimated over days $t = -125$ to $t = -5$. This was our estimation period.

The next step was to calculate abnormal returns during the event period. The event period consisted of 26 days from $t = -5$ to $t = 20$. Abnormal returns at each day in the event period were calculated as follows.

$$AR_t = R_t - a - bR_{mt} \quad \text{[Eq. 3]}$$

where a and b are the ordinary least squares estimates of α and β.

Cumulative abnormal returns were calculated by:

$$CAR_{(\tau_1,\tau_2)} = k' \bullet AR \quad \text{[Eq. 4]}$$

where AR is a 1 x 26 vector of the AR_t as calculated in equation 3; $\tau_1,\tau_2 = [-5,20]$ where $\tau_1 \leq \tau_2$. We defined k' as a 26 x 1 vector with the value of 1 in positions between and inclusive of τ_1,τ_2 and a value of 0 elsewhere. The prime symbol is the transpose operator. Equivalently, [Eq. 4] can be expressed as follows:

$$CAR_{(\tau_1,\tau_2)} = \sum_{t=\tau_1}^{\tau_2} AR_t$$

The variance of AR_t is calculated as follows:

$$s^2_{(\tau_1,\tau_2)} = k'Vk \quad \text{[Eq. 5]}$$

where V is the 26 x 26 forecast variance matrix based on the estimated models specified in [Eq. 2].

We conducted the following hypothesis test:

$$H_O: CAR_{(\tau_1,\tau_2)} \geq 0$$

$$H_A: CAR_{(\tau_1,\tau_2)} < 0$$

This is a one-tailed test. The alternative hypothesis is that the Winfrey show would have only a negative impact on stock returns.

RESULTS

The regression result are reported in Table 1. As shown, the R^2 value is not high, especially in the model for IBP. However, this not atypical for event studies. The F statistics, $F_{(2, 118)}$, are used to test the null hypothesis that $R^2 = 0$, i.e., no variance was explained by the model. The F statistics are large enough to indicate significance in all three models. However, the test for the IBP model is marginally significant at the 10% level. Both ConAgra's and IBP's slope terms are less than 1, indicating that these companies did not perform as well as the market portfolio. On the other hand, the slope coefficient for the fast food portfolio indicates that these companies were doing somewhat better than average in the market. The t statistics for the slope coefficients indicated significance at the 1% level, with the exception of IBP, which was marginally significant at the 10% level. We rejected the null hypothesis H_O: $\beta = 0$, in favor of the alternative, H_A: $\beta \neq 0$. All intercepts reported in this table are very close to zero. This is expected because if the market average approaches zero, the firm's returns should also be close to zero.

Looking at the cumulative abnormal returns tables, ConAgra was obviously affected more drastically (Table 2). The market responded instantaneously to the new information provided by Winfrey's program on the day of the show and for about a month of trading afterwards. The t statistics indicated that cumulative abnormal returns were significantly negative, mostly at the 5% level during days immediately following Winfrey's show and were significant at the 10% level on the later days. This provides enough evidence that ConAgra was strongly affected by Winfrey's show. On the contrary, this was not true for IBP, for which there was not sufficient evidence provided by our model to indicate an effect of Winfrey's show on stock returns. According to the t statistics, we failed to reject the null hypothesis that cumulative abnormal returns were greater than or equal to zero. There were only two exceptions to this; however, these reflect aggregations before Winfrey's show and thus are unlikely to have been caused by the program.

The value weighted fast-food portfolio (VWFFP) included McDonald's, Wendy's, Sonic, Jack-in-the-Box, Hardee's, and Carl's Jr. From these, Jack-in-the-Box, Hardee's, and Carl's Jr. are subsidiaries of a larger parent corporation. This is important because even if Winfrey's show had affected the Jack-in-the-Box chain, for example, it would not necessarily have had a drastic impact on

Table 1. Regression results from the estimation period.[z]

	ConAgra	IBP	Fast-food portfolio
Intercept	–0.0001	–0.0010	0.0002
	(–0.15)	(–0.43)	(0.17)
Market Return	0.7905	0.6363	1.1436
(slope)	(5.59)	(1.81)	(5.89)
R^2	0.2082	0.0268	0.2255
F test statistic	31.29	3.28	34.66
N	120	120	120

[z] t-test statistics for the parameter estimates are in parentheses.

Table 2. Cumulative abnormal returns for ConAgra.[z]

Ending period (τ_2)	Beginning period (τ_1)			
	–5	–3	–1	0
–5	0.01307	–	–	–
	(1.26854)			
–4	0.01573	–	–	–
	(1.06678)			
–3	0.00779	–0.00794	–	–
	(0.42810)	(–0.76868)		
–2	0.00769	–0.00804	–	–
	(0.36777)	(–0.54947)		
–1	0.00149	–0.01424	–0.00621	–
	(0.06346)	(–0.79024)	(–0.59976)	
0	–0.02679	–0.04251	–0.03448	–0.02827
	(–1.04076)	(–2.03168) c	(–2.34353) c	(–2.74079) c
1	–0.03867	–0.0544	–0.04636	–0.04015
	(–1.38491) b	(–2.32218) c	(–2.57523) c	(–2.74568) c
2	–0.02314	–0.03887	–0.03083	–0.02462
	(–0.77251)	(–1.50730) b	(–1.47554) b	(–1.36906) b
3	–0.02802	–0.04375	–0.03571	–0.02951
	(–0.87865)	(–1.56432) b	(–1.52244) b	(–1.41475) b
4	–0.02628	–0.04201	–0.03397	–0.02777
	(–0.77869)	(–1.39761) b	(–1.31460) b	(–1.18466)
5	–0.04645	–0.06218	–0.05414	–0.04793
	(–1.30643) b	(–1.93951) c	(–1.92827) c	(–1.85657) c
10	–0.08384	–0.09957	–0.09154	–0.08533
	(–1.91894) c	(–2.44590) c	(–2.44612) c	(–2.39551) c
15	–0.06182	–0.07754	–0.06951	–0.0633
	(–1.21373)	(–1.61251) b	(–1.53915) b	(–1.45000) b
20	–0.07179	–0.08752	–0.07949	–0.07328
	(–1.24327)	(–1.58373) b	(–1.51252) b	(–1.43449) b

[z] Student's *t* statistics are in parenthesis.

b indicates significance at the 10% level (one-tailed test).

c indicates significance at the 5% level (one-tailed test).

Table 3. Cumulative abnormal returns for IBP.[z]

Ending period (τ_2)	Beginning period (τ_1)			
	–5	–3	–1	0
–5	–0.01813	–	–	–
	(–0.70792)			
–4	–0.03536	–	–	–
	(–0.96429)			
–3	–0.04137	–0.00602	–	–
	(–0.91475)	(–0.23418)		
–2	–0.01946	0.01589	–	–
	(–0.37414)	(0.43704)		
–1	–0.05402	–0.01866	–0.03455	–
	(–0.92779)	(–0.41633)	(–1.34268) b	
0	–0.06665	–0.0313	–0.04719	–0.01264
	(–1.04139)	(–0.60142)	(–1.28985) b	(–0.49262)
1	–0.07328	–0.03793	–0.05382	–0.01927
	(–1.05543)	(–0.65109)	(–1.20222)	(–0.52980)
2	–0.04853	–0.01317	–0.02907	0.00549
	(–0.65149)	(–0.20542)	(–0.55938)	(0.12269)
3	–0.04904	–0.01369	–0.02958	0.00497
	(–0.61840)	(–0.19681)	(–0.50710)	(0.09586)
4	–0.03096	0.0044	–0.0115	0.02306
	(–0.36884)	(0.05882)	(–0.17889)	(0.39556)
5	0.00706	0.04242	0.02652	0.06108
	(0.07986)	(0.53205)	(0.37984)	(0.95123)
10	0.05592	0.09128	0.07538	0.10994
	(0.51468)	(0.90162)	(0.81006)	(1.24108)
15	0.02557	0.06093	0.04503	0.07958
	(0.20188)	(0.50945)	(0.40097)	(0.73306)
20	0.06017	0.09552	0.07963	0.11418
	(0.41899)	(0.69507)	(0.60931)	(0.89882)

[z] Student's *t* statistics are in parenthesis.

[y] *b* indicates significance at the 10% level (one-tailed test).

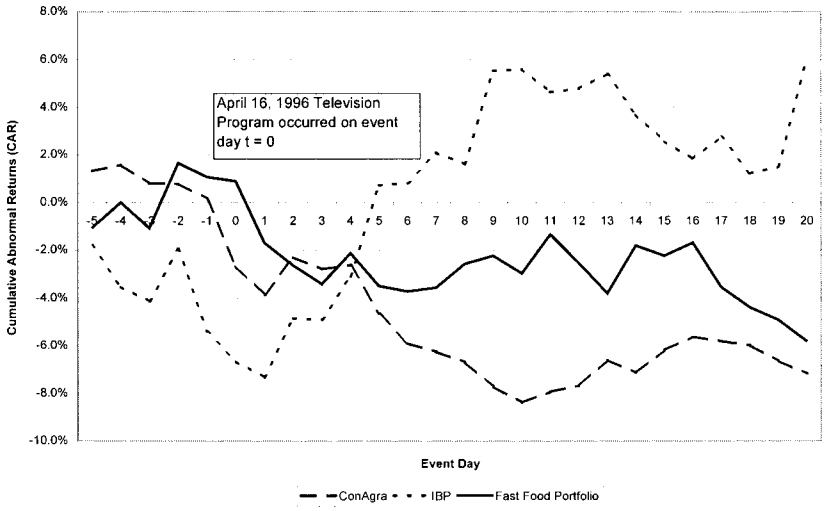

Fig. 1. Cumulative abnormal returns by event day.

Table 4. Cumulative abnormal returns for fast-food portfolio.[z]

Ending period (τ_2)	Beginning period (τ_1)			
	–5	–3	–1	0
–5	–0.01072 (–0.75689)	–	–	–
–4	–0.00007 (–0.00330)	–	–	–
–3	–0.01077 (–0.43096)	–0.01071 (–0.75388)	–	–
–2	0.01642 (0.57124)	0.01649 (0.82033)	–	–
–1	0.01062 (0.32999)	0.01069 (0.43134)	–0.0058 (–0.40806)	–
0	0.00883 (0.24968)	0.0089 (0.30941)	–0.00759 (–0.37536)	–0.00179 (–0.12598)
1	–0.01691 (–0.44046)	–0.01684 (–0.52293)	–0.03333 (–1.34683) b	(–1.36919) b
2	–0.02643 (–0.64181)	–0.02636 (–0.74364)	–0.04285 (–1.49186) b	(–1.49832) b
3	–0.03414 (–0.77879)	–0.03407 (–0.88632)	–0.05057 (–1.56810) b	(–1.56122) b
4	–0.02133 (–0.45979)	–0.02127 (–0.51466)	–0.03776 (–1.06281)	–0.03195 (–0.99167)
5	–0.03498 (–0.71577)	–0.03492 (–0.79231)	–0.05141 (–1.33190) b	–0.0456 (–1.28487)
10	–0.02977 (–0.49558)	–0.0297 (–0.53070)	–0.04619 (–0.89793)	–0.04039 (–0.82476)
15	–0.0224 (–0.32001)	–0.02234 (–0.33790)	–0.03883 (–0.62547)	–0.03302 (–0.55029)
20	–0.05811 (–0.73208)	–0.05805 (–0.76409)	–0.07454 (–1.03180)	–0.06873 (–0.97879)

[z] Student's *t* statistics are in parenthesis.

b indicates significance at the 10% level (one-tailed test).

the stock return of Foodmaker, the parent enterprise that owns the chain. Because of space limitations, specific results are not reported by company. However, among the rest of these six fast-food restaurants, McDonald's stock returns were most adversely affected by the show. It should be mentioned here that McDonald's represents about 43% of the fast-food restaurant market (Horovitz, 1999).

A graphical representation of cumulative abnormal returns by event day are presented in Fig. 1. This figure indicates that for VWFFP and ConAgra, both of which were significantly affected by Winfrey's show, stock return prices dropped and did not recover for at least 20 trading days after the show.

DISCUSSION

As shown by the results presented, the media can drastically impact stock returns by causing a micro-crisis, in a sense, when unfavorable product information is supplied to the stock market. The stock market has the ability to adjust to any new information so fast, that often damage can be done even if the information is inaccurate.

One puzzle raised by these results is that IBP, unlike what we expected, was not significantly affected by Winfrey's show. On the contrary, the VWFFP and ConAgra were significantly affected. Focusing on the two larger beef packers, IBP and ConAgra, it is really interesting to observe that given the same information their stock behaved in a contradictory manner. There are several possibilities that could explain this phenomenon. First, the size and trading volume of each company is a major factor in the firm's responsiveness. We would expect a larger company, established in a given industry to be affected more, than a smaller more controlled company. Another indicator explaining these results may be the degree of diversification of each company. For example, a part of ConAgra's business is their feed-producing business and the television program raised concerns over feed ingredients used in cattle rations. Finally, the established communication networks of the company with its stockholders can be very important when new and adverse information enters the market. The above are only some possibilities and require further investigation.

Overall, the case studied here shows that veggie libel laws may not be very effective in ensuring producers against losses resulting from unfavorable media attention. This study raises another important implication of these laws, that negative publicity can have a spillover effect on food processors and marketers, who even if they have a valid case, may be unable to proceed with claims through the legal system. However, there are ways for the food industry to assure some protection from such exogenous forces. For example, we think the food industry should be more proactive in communicating and educating the public on emerging heath concerns, e.g., mad cow disease. Another approach can be for a company to form better partnerships with third parties, such

as governmental agencies or universities, that can provide credibility to product benefit claims.

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A Study of Reproductive Behavior in the Emu

Reema A. Persad,[*] *Douglas James,*[§] *and Nicholas B. Anthony*[¶]

ABSTRACT

Members of a flock of male and female emus were observed in an ethological experiment designed to investigate trends in reproductive behavior exhibited during the North American mating season, which lasts from October to mid-March. Observations were made at dawn, noon, and dusk from December 1999 to mid-March 2000, and the only behaviors that were consistently expressed during these times were pecking, strutting, exclusive, and male and female sexual activities (defined in text). Though statistical significance was found between male strutting behavior and female sexual activity in the December observation period, no overall significance or significance at other observation periods was found between these two behaviors. No statistical significance was found between male pecking and female sexual behavior—overall or at separate observation periods. The emus also showed more incidences of mating activity at dawn and under cool temperature conditions. Exclusive behavior, however, was more prominent during the dusk observation period.

* Reema A. Persad graduated in May 2000 with a degree in poultry science.
§ Douglas James, faculty sponsor, is a professor in the Department of Biological Sciences.
¶ Nicholas B. Anthony, faculty sponsor, is a professor in the Department of Poultry Science.

Meet the Student-Author

I graduated from St. Joseph's Convent in Trinidad and Tobago, West Indies. In May 2000, I received my bachelor of science degree in poultry science, graduating magna cum laude. I was nominated for the Arkansas Alumni Award last year and was named Most Outstanding Sophomore by Gamma Sigma Delta in 1998. I've received the Lippert Ellis Award from Gamma Sigma Delta, the Randall Tyson Award, an Arkansas Feed Manufacturer's Scholarship, and a U of A Student Involvement Leadership Award.

Reema Persad

I am currently pursuing a master's degree in biological sciences. My thesis will involve working with captive endangered animals from Trinidad and Tobago and investigating related reproductive efforts under way at various zoological institutions.

Understanding an animal's behavior patterns is integral to ensuring that in captivity, those animals remain healthy. Good reproductive performance is an indicator of a high degree of fitness. My emu study allowed me to investigate the sexual behavior of a captive species. As I intend to pursue a career dedicated to improving the quality of life of animals, especially those in captivity, this project was particularly relevant. I discovered that while it is incredibly challenging and rewarding to conduct a project dealing with animal behavior, it can also be entertaining in the most unexpected ways. As I describe in my paper, one of the emus I was observing became affectionate toward me!

INTRODUCTION

Understanding the behavioral patterns and actions of ratites is integral in ensuring a captive existence that produces birds that are physically sound and in general good health. Good reproductive performance (evaluated by egg quantity and hatchability comparisons) is an indicator of a high degree of fitness. Sexual behavior (involving courtship, bonding, breeding, and egg-related behavior) is a precursor to evaluating good reproductive performance.

In the United States, the emu [*Dromaius novaehollandiae* (Latham)], a ratite, is monogamous in most situations (Jensen *et al.*, 1992) and exhibits a breeding season that extends approximately from October to March. In order to learn more about reproductive behavior in the emu, an ethological study was undertaken, in collaboration with the departments of Poultry Sciences and Biological Sciences. We investigated the mating behavior between emu pairs as well as the mating success of the male emu in a flock of 20 emus (10 males and 10 females) presently in residence at the University of Arkansas Poultry Research Farm. However, because of extenuating circumstances, only the data from which trends in mating behavior could be inferred were collected during the study.

MATERIALS AND METHODS

An ethogram based on published information (Jensen *et al.*, 1992) was developed. All the terms and descriptions related to the specific behaviors investigated in this study were defined in order to standardize observations. The four main categories are described as follows:

Gender Identification Behavior:

Male Vocalization: produces grunting sound similar to hog vocalization

Female Vocalization: produces a drumming sound

Courtship Behavior:

Male Strutting: male cocks head backward and over back; also displays neck feathers

Male Pecking: pecks back of female to elicit attention and to encourage breeding

Exclusive Behavior: emu pair eat, walk, rest in a specific spot together

Sexual Behavior (initiated by male):

Male Sexual Activity: male squats behind female, puts legs outside hers so that his breast plate contacts her raised rump, raises his tail feathers into the air, and copulates

Female Sexual Activity: female squats on ground, leans forward, and waits

Rebuff: Incomplete mating activity whereby the female rises before the completion of the mating activity

Egg-Related Behavior:

Male Nesting Behavior: piling of available grass or straw

Incubation Activity: such as a male emu sitting on an egg

Other: any other sexual behaviors noted

This preformulated ethogram of sexual behaviors was validated during trial observation periods that were randomly performed in November and December 1999, with adjustments being made as necessary.

An observation blind of bales of hay (4 x 6 x 6 m) was built in the central region of the corral. A tarpaulin roof provided shelter from the elements, and eye-level spaces between the bales allowed viewing of the birds throughout the corral. The observer spent 5 minutes in the hay-blind before beginning the study in order to allow the birds' curiosity and anxiousness (that occurs upon entry of a stranger) to subside. During the daytime, using the naked eye and binoculars, the observer identified the emus by their numbered and colored legbands, as both males and females had been tagged in order to keep track of possible pair bonding relationships. Approximate gender identifications were made on the basis of characteristic sexual behaviors exhibited and on the distinctive vocalizations emitted by each sex.

Initially, all 20 birds occupied the same corral, and their daily interactions were observed at noon, from 11:30 a.m. to 12:30 p.m. for the period of 1 December to 10 December, 1999. On 10 December at 9:00 p.m., when the birds had settled down in pairs for the night, the gates to individual pens were latched. Five pairs were thus isolated in five separate pens and the interactions of these pairs noted. The emu pairs were then released and allowed to mingle with the other 10 emus in the same corral from January 15th until the end of the study. Observations at noon (11:30 a.m. to 12:30 p.m.) for the period of 16 January to 25 January were then made. Also, hour-long observations were made at dawn from 6:30 to 7:30 a.m. and/or at dusk from 6:30 to 7:30 p.m. daily for the period of 1 February to 15 March (with the exception of 10 and 14 February). Throughout the study and for each observation day, data for ambient conditions (temperature, humidity, wind, and light) were obtained from the Web site of the *Weather Underground Institute* (www.wunderground.com).

Standard correlation analysis was utilized to evaluate the relationship between (1) male strutting and the frequency of female sexual activity and (2) male pecking and the frequency of female sexual activity.

RESULTS AND DISCUSSION

For the observation periods combined, the correlation coefficent was not statistically significant for the relationship between male strutting and female sexual activity (R = 0.129, d.f. = 58, $P > 0.05$). However, in December, the correlation between these two activities was high and was therefore significant statistically (R = 0.810, d.f = 7, $P < 0.01$). Yet there was no significant relationship in the other observation periods: January (R = 0.370, d.f.= 8, $P > 0.05$), February–March dawn (R = –0.08, d.f. = 19, $P > 0.05$) and February–March dusk (R = 0.134, d.f. = 18, $P > 0.05$).

In addition, results of the correlation analysis indicated that for all the observation periods combined, there was no overall statistical significance in the relationship between male pecking and female sexual activity (R = 0.09, d.f. = 46, $P > 0.05$). For the various observation periods, there was also no significant relationship between these two behaviors: December (R = 0.23, d.f. = 5, $P > 0.05$), January (R = 0.053, d.f. = 7, $P > 0.05$), February–March dawn (R = 0.1, d.f. = 19, $P > 0.05$) and February–March dusk (R = –0.276, d.f. =15, $P > 0.05$).

In rebuff and non-rebuff situations, the average of both male and female sexual activities was calculated for each time period (Table 1). This value was then used in the calculation of the overall average for that particular time period. Therefore, the mean of the frequency of the midday sexual interactions was only 0.65 times/hour (Table 1), even though an outside observer noted that three complete matings occurred at midday on 7 March. The average frequency of dawn sexual activity was calculated to be 1.38 times/hour (Table 1), and the mean for the dusk couplings was 0.88 times/hour (Table 1). Fig. 1 shows the relationship between the time of day that the data were collected and the number of emu matings observed over the course of the entire study. Emu matings in this study were found to be more common in the early morning. Exclusive behavior was most common in late afternoon (27 incidences at noon, 21 at dawn, and 130 at dusk).

To obtain the ranges in the ambient temperatures during mating, the overall range of temperatures (–5.6

Table 1. Number of incidences of emu behavior by observation period.

	Noon	Dawn	Dusk
Total hours of observation	20	21	21
Male strutting	64	70	51
Male pecking	37	73	29
Exclusive behavior	27	21	130
Male sexual activity	13	31	20
Female sexual activity	13	27	17
Average sexual activity/hour[z]	0.65	1.38	0.88

[z] (Male + Female/2) / Hours Observation.

to 22ºC) was split evenly into three parts: Range 1 contained values greater than or equal to –5.6 but less than or equal to 3.6ºC; range 2 contained values greater than 3.6 but less than or equal to 12.8ºC; and range 3 contained values greater than 12.8 but less than or equal to 22ºC. Fig. 2 illustrates that matings were most common in range 1 temperatures.

The original objective of this study was to find a relationship between sexual behavior demonstrations and reproductive performance. In order to achieve this goal, records of the interactions of individual birds were required—however, as the peak of activity occurred after dark, the birds could not be identified, even with the use of a night-vision scope. The frequency of sexual activity was therefore recorded for birds that were merely identified as being male or female. From the data collected, however, several trends in emu reproductive behavior were noted.

Although male strutting was common in all periods (Table 1), it was statistically significant with female sexual activity only in December observations. This correspondence of male and female behavior in December at the beginning of our winter coincides with the inception of the breeding season on the Australian continent (Drenowatz, 1995) where their summer is our cold season.

As Fig. 1 illustrates, matings were most common at dawn, which was usually in the lowest temperature range. This correlates to the seasonal variances in temperature occurring in the wild that induce the "complex hormonal mechanisms that cause the bird to come into production" (Minnar and Minnar, 1992). These physiological changes may also be responsible for the increased frequency of rebuffs in the observations as the data collection (and the mating season) neared its end.

The increased frequency of exclusivity in the late evening observations may be due to the increased amount of roosting activities occurring as the birds start settling down for the night.

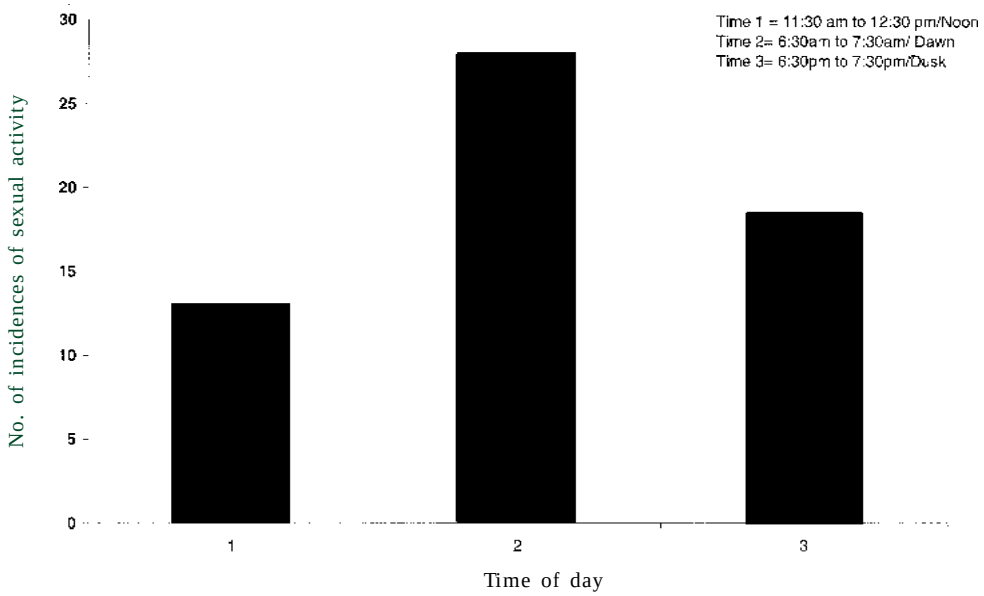

Fig. 1. Time of day versus number of incidences of sexual activity observed from December 1999 to March 2000.

No egg-related behavior was observed. However, it must be noted that at most a couple of days after being laid eggs were often collected from the pens and incubated, an activity that may contribute to the lack of incubation attempts by the male emus.

Two male emus were also removed from the study. The first was eliminated as a result of injuries sustained during an escape attempt. The second one repeatedly tried to peck the observer in the lower-back in an apparent attempt to encourage breeding activity. This latter emu may have imprinted upon human beings during an earlier stage of life, for it was noted to chase away other male emus and was not observed attempting to mate with any of the female emus in the pen.

ACKNOWLEDGMENTS

The authors acknowledge the Dale Bumpers College of Agricultural, Food and Life Sciences/Agricultural Experiment Station for a 1999 Undergraduate Research Mini-Grant that completely funded this study. Thanks to Russell and Melissa Parry, caretakers at the Poultry Sciences Research Farm, for providing the necessary care and maintenance of the research animals and invaluable assistance in the collection of the data used in this research.

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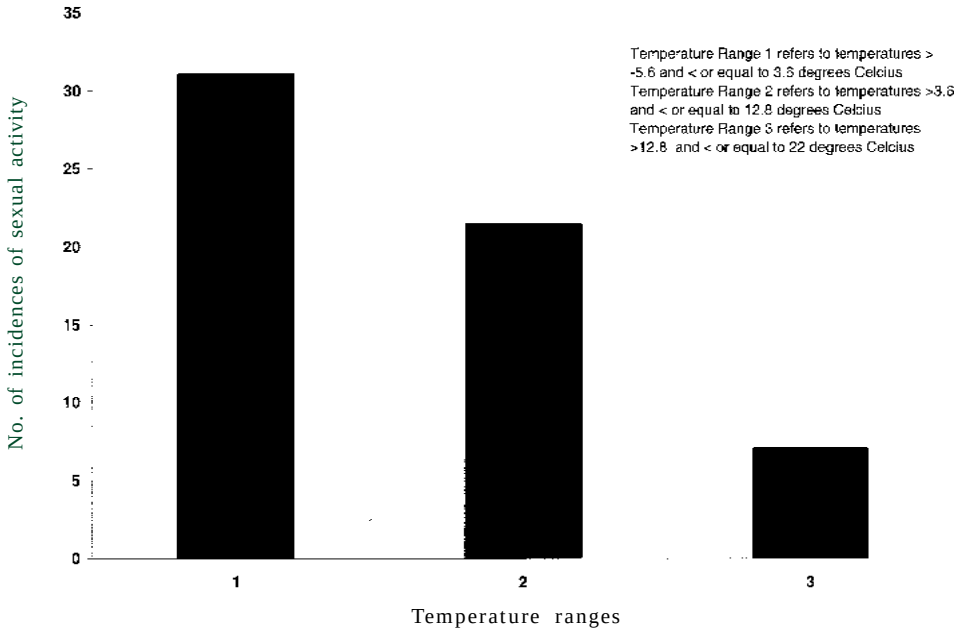


Fig. 2. Temperature range versus number of incidences of sexual activity observed from December 1999 to March 2000.

Determination of the chilling requirement of Arkansas thornless blackberry cultivars

Chrislyn A. Drake[*] *and John R. Clark*[§]

ABSTRACT

Little research has been done to determine the chilling requirement for blackberry cultivars. However, field observations from areas where fewer hours of chilling occur indicate that 'Navaho' requires more hours of chilling than does 'Arapaho'. The objective of our study was to determine a method for measuring the chilling requirement using whole plants of two blackberry cultivars, Arapaho and Navaho. One-year old, bare-root plants were field-dug on 26 October 1999 and placed in a cold chamber at 3ºC. Ten single-plant replications of each cultivar were removed at 100-hour intervals up to 1000 hours. The plants were potted and placed in a greenhouse (daily minimum temperature 15ºC), and plants were arranged on benches in a completely randomized design. Budbreak was recorded on a weekly basis. Data for budbreak were analyzed as a two-factor factorial (2 cultivars and 10 chilling treatments) by SAS and means were separated by least significant difference ($P = 0.05$). Data indicated that the chilling requirement for Arapaho is between 400 and 500 hours. For Navaho, the data indicated the chilling requirement was between 800 and 900 hours. These data support previous observations and indicate that the method used was successful in determining the chilling requirement for blackberries.

* Chrislyn A. Drake is a May 2000 graduate with a B.S. degree in horticulture.
§ John R. Clark, faculty sponsor, is a professor in the Department of Horticulture.

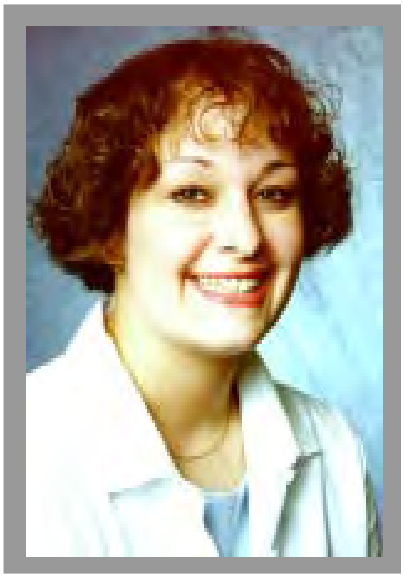
INTRODUCTION

Most temperate-zone perennial woody plants require some degree of rest in order for the buds to break uniformly the following season. This rest period is a type of safety mechanism that keeps buds from breaking under the wrong environmental conditions, such as warm periods in the middle of the dormant season. "Rest period" is defined as the duration that a plant must be exposed to cold temperatures under 7ºC in order for normal shoot or flower development to occur in the spring (Ryugo, 1998). The chilling requirement is the amount of cold needed to satisfy the rest period (Ryugo, 1998). If the chilling requirement of a plant is not met, poor budbreak and growth will occur the following season.

However, the chilling requirement is not the same for all woody plant species. For example, apples (*Malus* x *domestica* Borkh.) need an average of 1200 to 1500 hours of chilling, while almonds [*Prunus dulcis* (Mille) D.A. Webb] need only 200 to 350 hours (Ryugo, 1998). In addition, the chilling requirement is not the same for all cultivars of a particular crop. Extensive research has been done to estimate the chilling requirement for peach [*Prunus persica* (L.) Batsch] cultivars and showed a wide variance: 'Idlewild' requires only 550 hours of chill, while 'Contender' and 'Nectar' require 1050 hours (Parker and Werner, 1993).

Although thorough research has been conducted with peach, no such formal research has been done on blackberry (*Rubus* subgenus *Rubus* Watson), which has become a widely grown horticultural crop in Arkansas and other areas of the United States in recent years. This interest in blackberries is partially exemplified by the development and release of blackberry cultivars from the University of Arkansas. Some of these cultivars are 'Choctaw' (Moore and Clark, 1989a), Navaho (Moore and Clark, 1989b), Arapaho (Moore and Clark, 1993), 'Kiowa' (Moore and Clark, 1996), and 'Shawnee' (Moore *et al.*, 1985). However, growers in southern regions of Arkansas and in subtropical climates have encountered problems with poor budbreak in some of these cultivars, presumably because the chill requirement was not met. Most chilling information on Arkan-

Meet the Student-Author



Chrislyn Drake

I am from Rogers, Ark., and received my degree in horticulture in May. I received the Vaile-Watts Award for outstanding graduate in the Horticulture Department as well as the E. Ted Sims, Jr., Scholarship from the American Society of Horticulture Science—the only one given each year nationally.

I'm staying at the University of Arkansas to get my master's degree; I plan to get a Ph.D. as well but I am not sure where. I chose this research project because Dr. Clark suggested that I get a feel for research before starting my master's program. Nothing had been done to determine the chill hours needed for the Arkansas blackberry cultivars. It seemed like something that really needed to be done, and it seemed like an interesting project. From this experience, I learned that everything doesn't go as planned! I had a rabbit get into the greenhouse and destroy some of my material, but everything worked out in the long run. I also learned that you really have to be on your toes and make sure to get everything done when it's supposed to be done.

I got interested in horticulture through my family's farm. We moved to Arkansas in 1991, after my parents bought a blueberry farm in Rogers. Since then, we've added blackberries, raspberries, and apples. I worked there in the summers and got to see many aspects of horticulture.

sas blackberries has been derived from observed research generated by researchers and growers in southern areas of the United States (such as coastal Mississippi and Florida) or other countries with warm climates. For example, the thornless cultivar Navaho has been observed to have poor budbreak in southern Mississippi (Creigton Gupton, personal communication, U.S. Department of Agriculture, Poplarville, Miss.) and Florida (Peter Andersen, personal communication, University of Florida, Monticello), presumably because of a lack of chilling. Likewise, the cultivar Choctaw has been found to be the most adapted of the Arkansas cultivars in Mexico and South Africa, which are areas that receive little or no chilling during the winter (J.N. Moore, personal communication). These observations suggest that chilling requirements for blackberry cultivars vary.

Because of these observed differences, the objective of our study was to determine a method for measuring the chilling requirement of blackberry cultivars using whole plants in a controlled environment. Since adequate chilling usually occurs in Arkansas, it was necessary to develop a method whereby the amount of chilling could be controlled and the differences in response measured.

MATERIALS AND METHODS

Arapaho and Navaho were the cultivars used in the study. These two cultivars were chosen because field observations from Hope, Ark., in 1999 indicated that a difference in the chilling requirement might exist in these two cultivars and because plants of Arapaho and Navaho were readily available.

One-year old bare-root plants were field-dug from a local nursery on 26 October 1999 following the first killing frost of the season. Upon arrival in Fayetteville, the plants were heeled-in in containers filled with mulch and placed in a cold chamber at 3ºC in darkness. Ten single-plant replications were removed at 100-hour intervals up to 1000 hours. The plants in the 100-hour group were removed from the cold chamber on 30 October 1999, and the plants in the 1000-hour group were removed on 7 December 1999. The plants were cut back to approximately 0.6-m single-cane lengths and potted in 4-L pots using Universal Mix Media (StrongLite Horticultural Products, Pine Bluff, Ark.).

In order to force budbreak, the plants were then transferred to a heated greenhouse with a daily minimum temperature of 15ºC and daily maximum range of

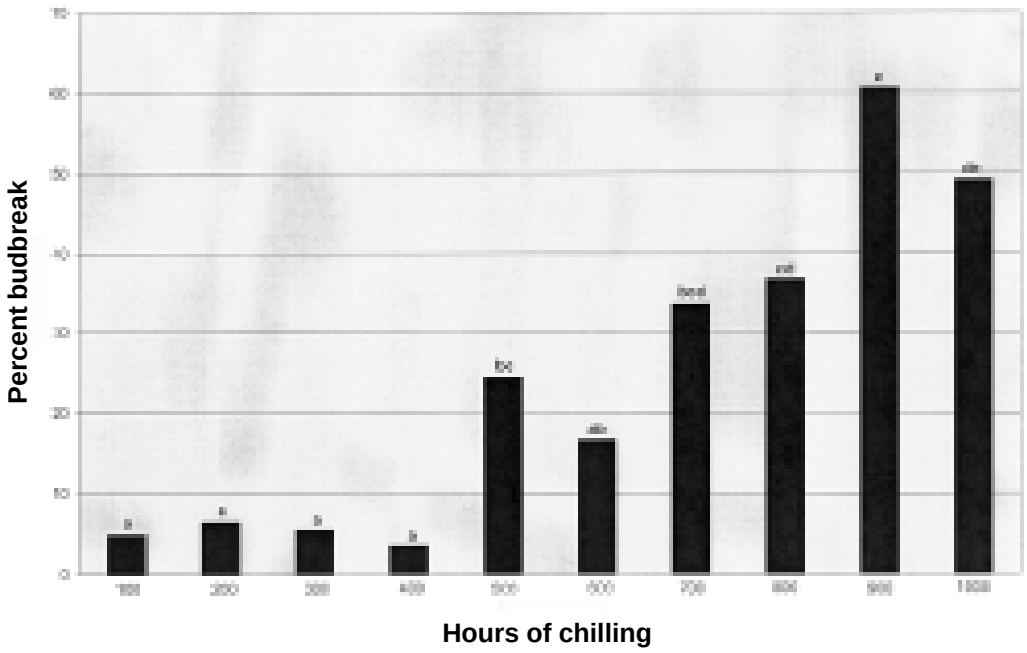


Fig. 1. Budbreak of 'Arapaho' thornless blackberry after 5 weeks of placement in a heated greenhouse following chilling of 100 through 1000 hours at 3ºC. Means not followed by the same letter are significantly different as determined by least significant difference (*P* = 0.05).

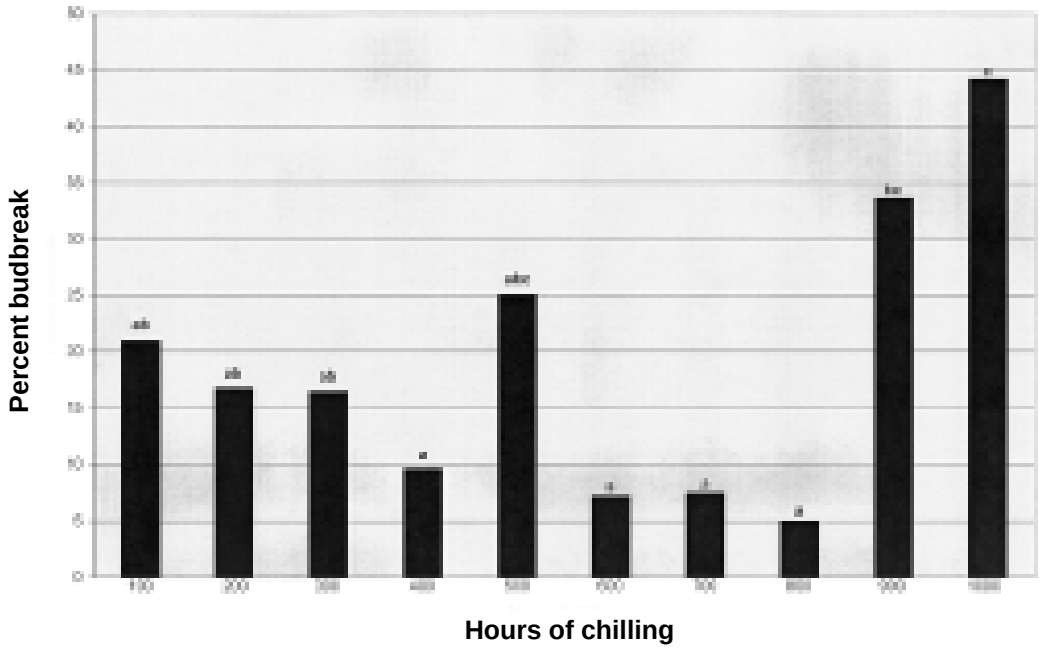


Fig. 2. Budbreak of 'Navaho' thornless blackberry after 5 weeks of placement in a heated greenhouse following chilling of 100 through 1000 hours at 3°C. Means not followed by the same letter are significantly different as determined by least significant difference (*P* = 0.05).

17 to 22°C. The plants were arranged in a completely randomized design. Budbreak data were recorded on a weekly basis. A bud was considered broken when the first leaf became visible as it unfolded from the bud.

Data for budbreak after 5 weeks for each 100-hour chilling treatment were analyzed as a two-factor factorial (2 cultivars and 10 chilling treatments) by SAS (SAS Institute, 1989) and means separated by least significant difference ($P = 0.05$).

RESULTS AND DISCUSSION

Data analysis showed a significant interaction between cultivar and chilling treatment, with the *F* test showing highly significant probability of 0.01. Based on this finding, main effect means for each cultivar are presented in this discussion.

Budbreak levels were very low for Arapaho for the 100- through 400-hour chilling treatments (Fig.1). At 500 hours, budbreak increased from 4% to 24%, thus indicating a major increase that reflects a probable chilling requirement of between 400 and 500 hours for this cultivar. The slight decrease in budbreak at 600 hours can be explained by the fact that three plants in this chilling treatment did not break buds until the sixth week, most likely as a result of poor plant health. However, poor health was limited to those particular plants and was not evident in other plants in the study. Budbreak continued to increase with increased chilling, but at no treatment interval was there a similar or significantly higher budbreak than at the 400- to 500-hour interval.

Unlike Arapaho, Navaho exhibited rather high levels of budbreak at the early chill-hour treatments (Fig. 2). This can be explained by presuming that Navaho did not fully enter into dormancy until it had been exposed to chilling temperatures for some time. However, budbreak was low (5% at 800 hours) until the 900-hour chilling treatment. At this level, budbreak increased from 5% to 33%, which was very similar to the large increase in percentage of budbreak at 500 hours for Arapaho. This increase reflects a probable chilling requirement of between 800 and 900 hours for Navaho. Budbreak did increase at the 1000-hour level, but the increase was not as large as the increase in budbreak at the 900-hour level. The 25% budbreak at 500 hours was a substantial varia-

tion in budbreak trend when compared with adjacent chilling periods. This can be explained by the fact that five of the plants in this treatment failed. Of the surviving five plants, two had an extraordinarily high percentage of budbreak, skewing the results to the unusually high level.

The data found in our study correlate with field observations from Hope, Ark., and other areas of the southern United States. During the winter of 1999, Hope only received approximately 600 hours of chilling. Arapaho, which was found to have a chilling requirement of 400 to 500 hours, displayed good budbreak. However, Navaho, which was found to have a chilling requirement of 800 to 900 hours, displayed poor budbreak. Coastal areas of Mississippi and Florida usually receive less than 500 hours of chilling each winter. Therefore, the poor budbreak of Navaho that has been observed in this area is most likely due to lack of chilling.

Because of the correlation between field observations and the results of the study, the whole-plant system appears to be a valid method for evaluating the chilling requirement for blackberry cultivars. Other cultivars can now be evaluated, allowing growers in areas with shorter chilling periods to know which cultivars are best suited for their area.

Subsequent research in this area would be to evaluate the feasibility of using stem cuttings taken from the field as natural chilling accumulates to estimate the chilling requirement rather than using whole plants. A thermograph or other such instrument could be placed in the field to measure hours of chilling, and stem cuttings could be taken at appropriate intervals and placed in a greenhouse in containers of water to force budbreak. A study using stem cuttings would be a much easier undertaking than that of manipulating whole plants in an artificial environment. Also, a stem-cutting study requires much less plant material than a study using whole plants. This is useful when there is limited availability of plant material, such as when a new cultivar is about to be released.

Another possibility for further research could be to explore the chilling efficiencies of specific temperature ranges, as has been done with peaches. For example, in 1974 Richardson, Seeley, and Walker of Utah State University, Logan, published a chill-unit model for peaches in which 1 chill-unit equals 1 hour of exposure at 6ºC. As temperatures rise above or fall below the optimum value, the chilling contribution is less than 1. Negative chill units are accumulated if temperatures rise above 15ºC, and there is no contribution if the temperature is below 0ºC. As research in this area has been successful with peaches, a study to determine the temperature range chilling efficiencies for blackberries would be a continuation of this project.

ACKNOWLEDGMENTS

The authors wish to thank Simmons Plant Farm, Mountainburg, Ark., for donation of the plants used in this study. Also appreciation is expressed to the Dean and Associate Deans of the Bumpers College of Agricultural, Food and Life Sciences for grant support to conduct this investigation. Finally, thanks to Andy Allen, research specialist in fruit crops, for his assistance.

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Growth performance of broiler chicks during the starter and grower phases in phase-feeding

L. Niki Loupe[*] *and Jason L. Emmert*[§]

ABSTRACT

An experiment was conducted to evaluate the efficacy of a nutrition program referred to as "phase-feeding" (PF) over the first 6 weeks posthatching. Diets were formulated using amino acid recommendations from the National Research Council (NRC) (1994) or from linear regression equations generated from best estimates of lysine (Lys), sulfur amino acid (SAA), and threonine (Thr) requirements. Regression equations were used to predict weekly Lys, SAA, and Thr requirements for use in a PF regimen that involved lowering amino acid levels following each respective week of the experiment, resulting in six diets fed over the 6-week period. Over the entire experiment (0 to 6 weeks), birds fed a PF regimen throughout had an increased ($P < 0.05$) weight gain, feed intake, and weight gain per unit of digestible Thr intake relative to birds fed NRC requirements throughout. No differences ($P < 0.05$) in carcass yield or abdominal fat percentage were noted. These data suggest that PF during the first 6 weeks of age can support growth and carcass yield comparable to diets formulated using NRC requirements. Dietary cost analysis indicates that substantial economic benefits may result from the use of PF during the starter and grower periods.

* L. Niki Loupe is a junior majoring in poultry science.
§ Jason L. Emmert, faculty sponsor, is an assistant professor, Department of Poultry Science.

Meet the Student-Author

I graduated from Crossett High School and am now a junior majoring in poultry science, with a minor in communications. I am the Sigma Alpha Outstanding Pledge, and I have received a number of scholarships, including a freshman academic scholarship, Randal Tyson Scholarship, Crossett Junior Auxiliary, Crossett Riding Club, Ashley County Livestock, Darryle and Peggy Greene Poultry Science Scholarship, and the Romeo E. Short and Maurice Smith scholarships.

L. Niki Loupe

During the summer, I did an internship in Washington, D.C. with the National Chicken Council. After graduating, I plan to go to graduate school to obtain a research-oriented or communications position in the poultry science industry or academia.

I am very involved in campus activities, as a Razorback Belle, a member of Sigma Alpha Sorority, a publicity officer in the Poultry Science Club, an Associated Student Government Senator, and a member of the intramural softball team.

I undertook this project at the suggestion of my faculty advisor, Dr. Emmert, so that I could learn about nutrition in poultry. I learned how much work goes into raising chickens and what happens after the birds have been processed. The calculations and graphs I did for this research will help me in graduate school, and I now have a head start in research. This experience has prepared me to do a much better research project in graduate school than I could have otherwise done.

INTRODUCTION

In the poultry industry, a single set of amino acid recommendations is provided by the National Research Council (NRC) (1994) for birds up to 8 weeks of age. These recommendations have been used by nutritionists in the poultry industry as a guideline for broiler diets, but they have several problems. First, they are broken into only three periods: starter (0 to 3 weeks), grower (3 to 6 weeks), and finisher (6 to 8 weeks), but the industry sometimes grows male broilers (cockerels) to 9 or 10 weeks of age. This poses a problem for nutritionists trying to formulate diets for periods beyond 8 weeks of age. Second, the NRC provides only one set of recommendations for both cockerels and pullets (females). Cockerels require a greater amount of dietary amino acids, so pullets are overfed amino acids when they are reared with cockerels. The industry is also moving toward sex-separate rearing to obtain maximum growth performance and feed efficiency.

Phase-feeding (PF) is a nutrition program that was described by Emmert and Baker (1997) as a flexible alternative to the NRC recommendations. Because amino acid requirements of broilers decrease steadily as the birds grow older, there is a need for diets with various levels of amino acids. Instead of the three-step NRC program, PF involves more frequent reduction in dietary amino acid content and allows for the prediction of broiler amino acid requirements for any age during the grow-out period. Phase-feeding has the potential to be a more efficient feeding system because it should result in lower dietary amino acid levels while still maintaining adequate growth performance and carcass yield. Moreover, amino acid levels in the diet of broilers affect nitrogen excretion, so when dietary amino acid levels are decreased the amount of nitrogen that is excreted should be reduced, which

would have a positive environmental impact. There is also a great potential for decreasing the cost of production because of increased efficiency and decreased amino acid supplementation of poultry diets.

Phase-feeding has been shown to be effective during individual periods (i.e., starter, grower, and finisher periods) (Warren and Emmert, 2000), but it has not been tested over consecutive periods of production. Our objective was to test the effects of PF on growth performance, carcass yield, and the cost of feed consumed during the starter and grower periods (0 to 6 weeks of age).

MATERIALS AND METHODS

All experimental procedures were reviewed and accepted by the University of Arkansas Institutional Animal Care and Use Committee. A commercial strain of male broiler chicks was used in the trial, and chicks were housed in floor pens containing pine-shaving litter. A 24-hour photoperiod was maintained, and water and experimental diets were freely available. Experimental diets were formulated to be adequate in all essential nutrients (NRC, 1994) (Tables 1 and 2). In the first treatment (NRC/NRC), birds were fed a single diet formulated to contain NRC recommendations for lysine (Lys), sulfur amino acids (SAA), and threonine (Thr) during the starter (0 to 3 weeks) and grower (3 to 6 weeks) periods. In the second treatment (PF/PF), birds were placed on a PF system during the starter and grower phases. In the third treatment (NRC/PF), birds were fed NRC recommendations for Lys, SAA, and threonine during the starter period but were placed on a PF system during the grower period. When PF was implemented in this trial, experimental diets were switched at the end of each respective week to a diet containing decreasing amounts of Lys, SAA, and Thr, thereby eliminating excess Lys, SAA, and Thr from the diet. Six PF diets were used during the starter and grower periods for treatment 2, and three PF diets were used during the grower period for treatment 3. Each treatment was replicated 10 times, and each replicate pen contained 35 birds.

At the start of the experiment, chicks were randomly allotted to experimental pens prepared for brooding and were immediately given experimental diets. Birds and feed were weighed at the end of the experiment to deter-

Table 1. Composition of diets for 0- to 42-day-old chicks.

Ingredient	NRC[z] wk 0–3	NRC[z] wk 3–6	PF[y] wk 1	PF[y] wk 2	PF[y] wk 3	PF[y] wk 4	PF[y] wk 5	PF[y] wk 6
	%							
Corn	55.97	60.31	50.42	53.12	55.82	58.78	61.48	64.30
Soybean meal	34.80	30.91	40.42	37.75	35.07	32.34	29.67	26.98
Poultry fat	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Vitamin mix[x]	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Mineral mix[x]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Dicalcium phosphate	2.00	1.50	2.00	2.00	2.00	1.50	1.50	1.50
Limestone	1.00	1.35	1.00	1.00	1.00	1.35	1.35	1.35
NaCl	0.40	0.35	0.40	0.40	0.40	0.35	0.35	0.35
Choline Cl (60%)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
L-Lysine·HCl	0.1270	–	0.0414	0.0367	0.0333	0.0295	0.0258	0.0212
DL-Methionine	0.1540	0.0344	0.1702	0.1469	0.1237	0.1000	0.0767	0.0531
Sacox Salinomycin[w]	0.05[u]	0.05	0.05	0.05	0.05	0.05	0.05	–
BMD-50 Bacitracin[v]	0.05[u]	0.05	0.05	0.05	0.05	0.05	0.05	–

[z] NRC diets contained lysine, sulfur amino acid, and threonine levels recommended by the National Research Council (1994).

[y] Amino acids in PF (phase-feeding) diets were predicted by linear regression equations (Emmert and Baker, 1997): digestible lysine, $y = 1.22 – 0.0095x$; digestible sulfur amino acid, $y = (0.88 – 0.0063x)/2$; and digestible threonine, $y = 0.8 – 0.0053x$, where y = digestible amino acid level, and x = midpoint (day) of the desired age range.

[x] Han and Baker (1993).

[w] Sacox 60, Hoechst-Roussel Agri-Vet Co., Somerville, N.J. Provides 66 mg/kg of salinomycin activity.

[v] BMD-50, AlPharma, Inc., Ft. Lee, N.J. Provides 55 mg/kg of bacitracin methylene disalicylate activity.

[u] Products were withdrawn from the diet during week 6 (prior to processing).

Table 2. Calculated digestible amino acid levels.

	Digestible content (% of diet)[z]				CP	ME_n[y]
	Day	Lysine	SAA	Threonine	(%)	(kcal/kg)
NRC	0–21	1.12	0.79	0.70	22.3	3164
PF	0–7	1.19	0.86	0.78	24.7	3115
PF	7–14	1.12	0.82	0.74	23.6	3140
PF	14–21	1.05	0.78	0.71	22.4	3166
NRC	21–42	0.93	0.63	0.65	20.7	3214
PF	21–28	0.99	0.73	0.67	21.3	3198
PF	28–35	0.92	0.68	0.63	20.2	3223
PF	35–42	0.85	0.64	0.60	19.0	3252

[z] Digestible amino acid, crude protein (CP), and dietary metabolizable energy (ME) content calculated from the analytical values for total lysine, sulfur amino acid (SAA), and threonine in corn and soybean meal and published digestibility coefficients (Parsons, 1991).

[y] Metabolizable energy values for corn, soybean meal, and poultry fat were assumed to be 3350, 2440, and 8800 kcal ME_n/kg, respectively.

mine weight gain, feed intake, and feed efficiency. Birds from each treatment replicate were processed on day 43. Feed was withdrawn from experimental pens for 8 hours prior to processing to facilitate emptying of the digestive tract. A representative sample of five birds from each pen was processed, with three birds from within one standard deviation of the mean and two birds from within two standard deviations of the mean. Selected birds were stunned, bled, defeathered, and eviscerated for determination of carcass yield.

All data were analyzed as a completely randomized design, with pen means considered the experimental unit. The number of replications and birds per pen were chosen to support statistical validity. The General Linear Models (GLM) procedure of SAS (SAS Institute, 1996) was used to analyze variance. Differences among treatment means were established using the least significant difference multiple comparison procedure (Carmer and Walker, 1985).

It is important that growth performance and carcass yield of birds fed diets based on PF not be negatively affected, but the potential economic benefits of PF are of greater potential importance. We calculated the value of feed consumed based on current market ingredient prices, then divided this cost by weight gain, arriving at an estimate of the cost per kilogram ($/kg) of gain.

RESULTS AND DISCUSSION

Chicks fed the PF/PF regimen exhibited the greatest ($P < 0.05$) weight gain, feed intake, and digestible SAA intake, but no differences ($P > 0.05$) in feed efficiency were noted among the treatments (Table 3). In addition, gain per unit of digestible Thr intake was elevated ($P < 0.05$) by the PF/PF regimen relative to birds fed the NRC/NRC regimen (Table 3). No differences ($P > 0.05$) were noted in carcass yield or abdominal fat as a percentage of the live carcass (Table 3).

Previous research has evaluated PF during individual periods within a 9-week grow-out (i.e., starter, grower, and finisher periods) (Warren and Emmert, 2000). Although PF was shown to be effective in supporting maximum growth performance in individual periods, it has not been evaluated over consecutive grow-out periods. Our data indicate that PF during the grower period, whether or not preceded by PF during the starter period, is effective in supporting growth and carcass yield equivalent to chicks fed diets based on NRC recommendations. This observation supports previous work showing that broiler chickens may be switched to a less nutrient-

Table 3. Growth performance of broilers fed NRC- and PF-based diets during the starter and grower period.[z]

	Treatment			
Parameter	NRC/NRC[y]	PF/PF[x]	NRC/PF[w]	SEM
Weight gain (g)	1639 b	1798 a	1660 b	37.2
Feed intake (g)	3054 b	3302 a	3081 b	69.9
Gain:feed (g:kg)	538	544	539	6.96
Digestible lysine intake (g)	29.7	31.4	29.5	0.65
Digestible SAA intake (g)	23.2 b	25.4 a	23.8 b	0.53
Digestible threonine intake (g)	23.0	24.1	22.7	0.52
Gain:digestible lysine intake (g:g)	55.4	57.1	56.3	0.70
Gain:digestible SAA intake (g:g)	70.8	70.8	69.7	0.92
Gain:digestible threonine intake (g:g)	71.5 b	74.4 a	73.3 ab	0.96
Eviscerated carcass (% of live weight)	64.4	64.4	65.6	0.99
Abdominal fat (% of live weight)	1.22	1.27	1.14	0.08

SAA = sulfur amino acid; SEM = standard error of measurement.

Means within a row lacking a common letter differ significantly ($P < 0.05$).

[z] Values are means of 10 pens of 35 male chicks fed the experimental diets from 0 to 42 days posthatching; average initial weight was 46 g.

[y] NRC/NRC birds were fed diets based on National Research Council (1994) requirements from 0 to 42 days.

[x] PF/PF birds were fed diets based on phase-feeding (PF) requirements (Emmert and Baker, 1997) from 0 to 42 days.

[w] NRC/PF birds were fed diets based on NRC (1994) requirements from 0 to 21 days, followed by diets based on PF requirements (Emmert and Baker, 1997) from 21 to 42 days.

dense grower diet earlier than the recommended 3 weeks of age without sacrificing 6-week growth performance or carcass yield (Watkins *et al.*, 1993; Saleh *et al.*, 1995; Saleh *et al.*, 1996a, b).

A potential concern of PF is the decreased dietary crude protein that occurs (Table 2) when diets are formulated to contain lower levels of amino acids. Specifically, one may wonder whether dietary indispensable nitrogen levels are sufficient to support dispensable amino acid synthesis. Our results suggest that despite CP reductions associated with the latter periods of PF, indispensable nitrogen levels were sufficient to support growth performance and carcass yield. Previous research also suggests that growth performance may be maintained when dietary protein levels are slightly to moderately decreased if diets are supplemented with Lys and methionine (Daghir, 1983; Han *et al.*, 1992; Morris *et al.*, 1992; Deschepper and De Groote, 1995). However, other researchers (Fancher and Jensen 1989a, b) have been unable to maintain growth performance and protein accretion when feeding CP levels at which other researchers have noted no impact on performance; this discrepancy may reflect differences in experimental protocols such as assay length and age of chick.

Lower CP levels associated with PF could also potentially affect carcass composition. Birds consuming low-protein diets for a period of weeks have been shown to have elevated abdominal fat levels (Fancher and Jensen, 1989a, b; Deschepper and De Groote, 1995). Low-protein diets contain fewer excess amino acids that require energy expenditure for catabolism, thereby likely increasing the net energy of the diet and the dietary energy available for fat synthesis. However, these data indicate that carcass fat was not affected by the PF regimen, suggesting that the net energy of the diet was not greatly affected.

For NRC/NRC, PF/PF and NRC/PF diets, \$/kg of gain values were 0.215^{a}, $0.212^{b,}$ and 0.214^{ab} ($P < 0.05$; standard error of measure = 0.0007). The calculated savings per bird is therefore as follows: 0.215 – 0.212 = 0.003 \$/kg of gain, which translates into \$0.0054 per bird for the PF/PF regimen (0.003 • 1.798 kg gain). Although seemingly insignificant on a per bird basis, this savings would translate into approximately \$6.3 million per year in Arkansas and \$42 million per year across the United States. Previous economic estimates (Warren and Emmert, 2000) have estimated that an additional \$0.003 per bird may be saved by using PF during the finisher period.

Phase-feeding would not be economically feasible if six or more diets were fed during the grow-out period, because of increased costs associated with diet preparation, transport, and storage. It may be possible to accomplish PF by initially delivering a nutrient-dense starter-type diet and a less dense grower-type diet, which could be blended at a desired rate to achieve gradual decreases in dietary amino acid levels. Further investigation is needed to verify the efficacy of PF over the entire grow-out period including the finisher period. In addition, the impact of factors such as dietary energy level and bird density should be investigated. However, early indications suggest the PF may offer nutritionists a flexible alternative that facilitates application to commercial poultry nutrition programs. Substantial savings in the cost of production may be possible if PF is proven feasible under commercial conditions.

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Fissure Characterization of Rice Kernels Using Video Microscopy

Jerry W. Fendley,[*] *Terry J. Siebenmorgen,*[§] *and Rustico C. Bautista*[¶]

ABSTRACT

Fissures are fractures of a rice kernel that can be created during the drying and tempering process. They cause tremendous postharvest losses in milling yield. Understanding why and how rice kernels fissure will lead to optimal drying and tempering operations. This information could also provide input to plant breeders for producing rice cultivars that are more resistant to fissuring. Rice kernels were dried using various air conditions in a controlled environment chamber. The kernels were viewed by video microscopy to observe the occurrence of fissures. A videocassette recorder recorded the images for a 24-hour period after the drying process. The tapes were reviewed to reveal characteristics of the fissures. The rice cultivars used in this experiment were 'Bengal', 'Cypress', and 'Drew'. The tests showed that Cypress kernels were more resistant to fissuring than were the other two cultivars. The recorded images from the microscopy chamber showed that fissures begin from the inside of the kernel. Also, fissures were observed to form almost instantaneously.

* Jerry W. Fendley graduated in May 2000 with a degree in Biological and Agricultural Engineering.
§ Terry J. Siebenmorgen, faculty sponsor, is a professor and head of the Department of Food Science.
¶ Rustico C. Bautista is a research associate in the Department of Food Science.

INTRODUCTION

The overall goal of this project was to increase the quality and value of rice. Currently, fissures cause immense losses in the value of domestic rice. Rice kernels with fissures tend to break during the milling process. Lower head rice yields, to a large extent, are the result of these broken kernels. Since head rice, or whole kernels, are typically worth twice that of broken kernels, it is imperative that the number of broken kernels be minimized.

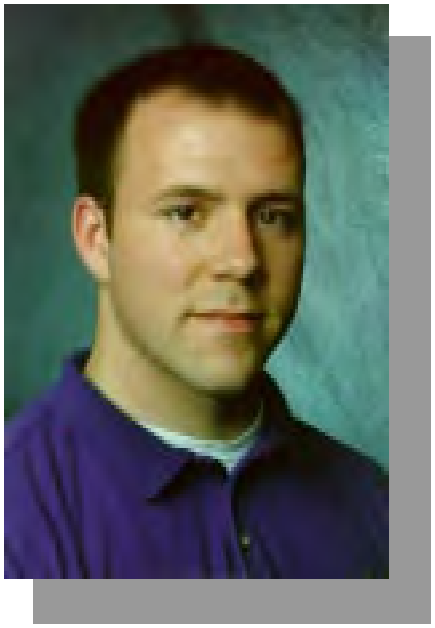
Physical properties such as specific heat, specific volume, expansion coefficients, and viscoelasticity of rice kernels change as the starch is heated past a moisture content-dependent temperature known as the glass transition temperature, T_g. The moisture content (MC) gradient created during drying may cause different regions of the kernel to vary in temperature, either higher or lower than the T_g. Tempering is a step used in the commercial rice drying process to reduce MC gradients. In commercial mills, tempering is done by temporarily storing the rice after drying in tempering bins for a certain period of time to allow the moisture to equilibrate before subsequent milling or storage. It is hypothesized that if the tempering environment produces a change of state of starch, differential stresses within the kernel resulting from the MC gradient could cause kernel fissuring (Perdon and Siebenmorgen, 1999; Cnossen *et al.*, 1999). This hypothesis would indicate that if there were sufficient MC gradients inside the kernel, this state transition by some parts of the kernel would create fissuring. The work in this study was conducted within the framework of this hypothesis to result in characteristics of fissures.

MATERIALS AND METHODS

An environmental chamber (Figure 1) was constructed at the University of Arkansas Rice Processing Lab. The chamber was constructed of aluminum and insulated with polystyrene to reduce heat loss. The chamber had two air ducts that allowed air to be provided at the desired conditions. A glass door allowed viewing of the rice as it was tested.

The environmental chamber was equipped with video microscopy equipment. A CCD camera with a 35X lens was mounted inside the chamber to view an individual kernel as it dried and then tempered. A lamp and fiber optic cable shone light on one end of the rice kernel so fissures of the kernel were visible. The image of the rice kernel was continuously viewed on a monitor and recorded by a VCR.

Samples were prepared from three rice cultivars:



Jerry Fendley

Meet the Student-Author

After graduating from Arkadelphia High School in 1996, I entered the University of Arkansas, where I received a degree in biological and agricultural engineering last May. I have received numerous scholarships over the past several years. In addition, I was a member of a team of engineering students who won first place in the AGCO National Student Design Competition this past year.

I plan to go on to graduate school for my master's degree, and then to either enter a Ph.D. program or seek a career in designing food processing equipment.

I chose my research project because of the importance of rice fissuring in the rice processing industry. In the process of conducting my research, I learned how important it is to set up an experiment properly so that the data observed will be accurate.

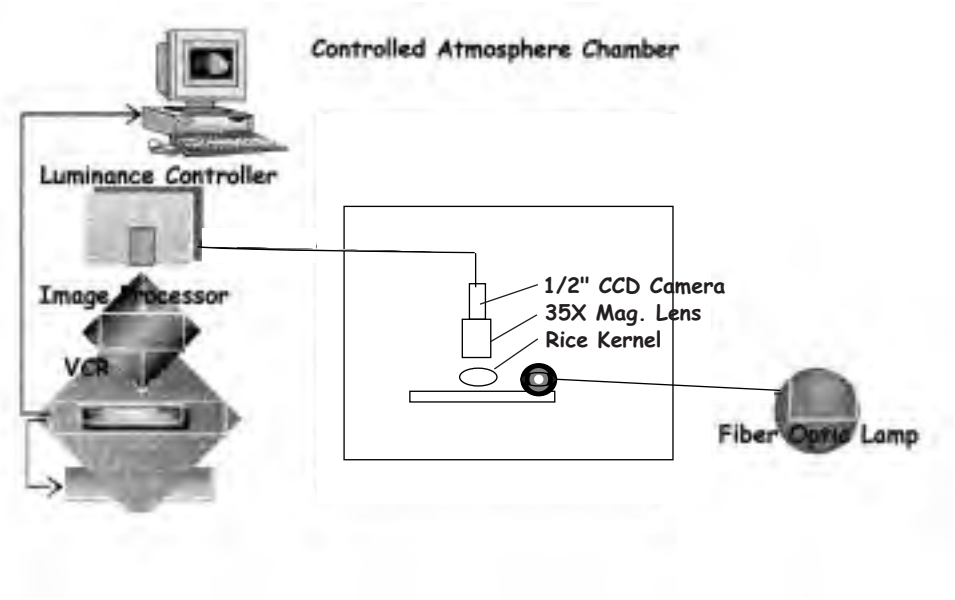


Fig. 1. Schematic of the video microscopy system.

'Bengal', a medium-grain kernel, and two long-grain kernels, 'Cypress' and 'Drew'. The environmental chamber was allowed to equilibrate to the desired conditions before the samples were placed. A single rough rice kernel was hulled, and its weight was recorded and placed under the camera lens for observation using the microscope. Once the rice was inside and the environmental chamber sealed, the VCR started recording images. Simultaneously, 100 rough rice kernels of each cultivar were hulled by hand and placed in a mesh container beside the single kernel in the chamber to investigate the percentage of fissured kernels. Three replications were made for each treatment. Thermocouples were used to monitor the air temperature during the drying process.

During the first set of tests, rice from each cultivar was dried inside the chamber at various temperatures (60, 55, 50, and 45ºC). The rice was dried to approximately 12% MC, and then the chamber was opened to ambient conditions in the lab at approximately 22ºC and 45% relative humidity (RH). During the second set of tests, each cultivar was again dried to approximately 12% MC inside the chamber at 60, 55, 50, and 45ºC. However, for the second set of tests, the dried rice was then tempered at 40ºC and 20% RH for 2 hours. After the tempering process, the chamber would again be opened to ambient conditions in the lab. Thus in the first set of tests, the kernels were not tempered before they were exposed to ambient conditions, while in the second set of tests they were tempered. Tempering is used to reduce the moisture gradient inside rice kernels due to drying. According to the T_g hypothesis, the second set of tests should have resulted in fewer fissured kernels.

The video recordings of the rice kernels were viewed to determine the number of fissures resulting from the

Table 1. Percentage of rice kernels fissured due to drying without tempering.

	Air temperature (ºC)			
Cultivar	45	50	55	60
Bengal	8	61	N/A	94
Drew	17	52	89	97
Cypress	2	24	26	92

Table 2 . Effects of tempering on fissuring of brown rice (cv. Drew).

Air temp. (°C)	Initial MC (%)	Fissure % without tempering	Fissure % with tempering
45	18.5	16.5 (5.5)	5 (4.3)
50	18.5	46 (5.7)	27 (4.7)
55	18.6	58 (3.8)	34 (3.8)
60	18.5	94 (2.6)	51 (3.2)

Values inside parentheses are standard deviations of the mean.
MC = moisture content.

drying and tempering process. Kernels were observed for a 24-hour period after drying to see if one or multiple fissures occurred. The time and kernel location of fissure initiation were observed.

RESULTS AND DISCUSSION

The fissuring characteristics of the three rice cultivars were compared. Table 1 and Fig. 2 show that Cypress was more resistant to fissuring when dried at lower temperatures than were the other two cultivars. Drying air temperatures at and above 50ºC caused Bengal and Drew to fissure substantially more than Cypress until drying air temperature of 60ºC, in which fissuring for all three cultivars was essentially similar, with practically all kernels fissuring. It was found that fissuring response was not significantly different at lower temperatures (37 to 45ºC) for Bengal and Drew; however, Cypress fissured significantly less than Bengal and Drew ($P = 0.05$).

Table 2 shows the percentage of kernels that developed fissures with tempering after drying with and without tempering at the various drying temperatures. The data clearly show that the tempering process reduced the amount of fissured kernels. The effects of temperature on fissuring were similar in tempered rice and non-tempered rice (Fig. 3).

Viewing fissures while they occurred provided two observations. First, a fissure begins from inside of the kernel and progress to the surface of the kernel. Second, rice kernels fissure nearly instantaneously. This process is visually similar to a piece of ice being dropped into a glass of warm water. In both cases, fissures begin rapidly inside and propagate across the cross-section of the kernel or ice cube.

The observation that Cypress was more resistant to fissuring than the other two cultivars could have a big impact on the industry. If this observation is verified, it could result in processors requiring this cultivar for its superior fissure resistance. Plant breeders could also use this information in the development of new rice cultivars.

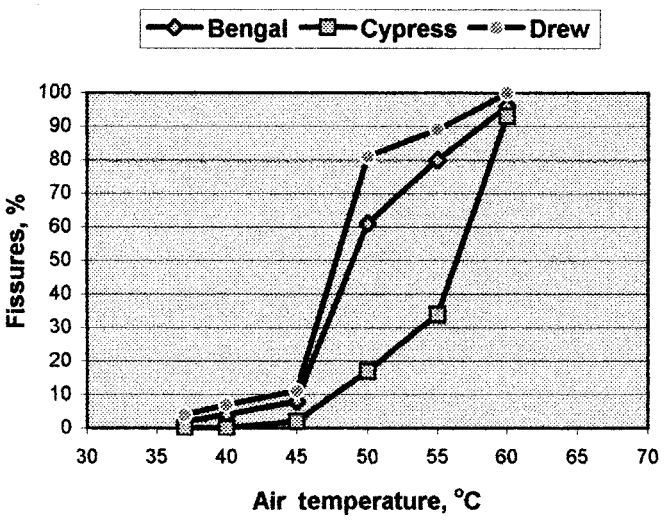


Fig. 2. Effects of drying air temperature on fissuring of three rice cultivars without tempering.

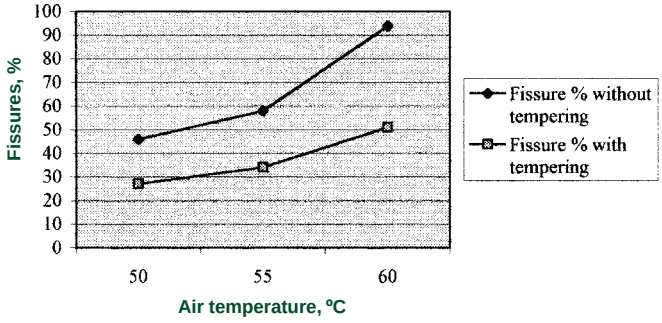


Fig. 3. Effects of tempering on fissure formation in brown rice (var. Drew) after drying kernels to 12.5% moisture content with the indicated drying air temperature.

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Feasibility of inducing overlap immunologic competence in gallinaceous birds with *Ascaridia dissimilis* and *A. galli*

Julie Hamilton**[*] and Thomas A. Yazwinski[§]

ABSTRACT

Chickens and turkeys are routinely infected with the roundworms *Ascaridia galli* and *A. dissimilis*, respectively. The current study was conducted to gather basic information on these worms and to determine whether heterologous infections (chicken worms in turkeys and turkey worms in chickens) would be successful. Chickens and turkeys were obtained at day of hatch, brooded to 7 days of age, and placed in pens (25/pen) according to infection as received at 7 days of age: homologous, heterologous and control (no infection). Bird weights, mortalities, and feed efficiencies were monitored for 3 weeks postinfection, at which time all birds were killed for parasite collection and counting. Feed efficiency, a parameter more adequately measured in large-scale studies, did not vary between experimental groups. Bird weights at necropsy varied significantly ($P < 0.05$) between groups only for the turkeys, with homologous infection (*A. dissimilis*) birds weighing less than controls. All induced, homologous, and heterologous infections were successful. Rates of establishment, however, were significantly ($P < 0.05$) depressed for each heterologous model. Total *A. dissimilis* numbers were only 55% as great as those for *A. galli* in chickens [geometric means (GMs) of 13.2 versus 24.2], and total *A. galli* numbers were only 56% as great as *A. dissimilis* numbers in turkeys (GMs of 5.6 versus 10.0). Given the fact that heterologous infections were successful, albeit reduced, in both types of birds (infections that included tissue-phase forms), additional studies are planned to determine whether these infections might induce interspecies (overlapping) immune competence in the host and aid in reducing natural parasitisms to levels with no economic impact.

* Julie Hamilton is a junior majoring in animal science.
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INTRODUCTION

Parasites of poultry are traditionally grouped as internal or external. Given current housing, management, and control practices, the external parasites have been all but eliminated in the United States. The internal parasites remain a problem around the world. These parasites are primarily found in the intestinal tract and are of two very diverse groups: the protozoan coccidia and the helminths (roundworms). Our study involved the latter.

Chickens and turkeys are a contrast in regard to the roundworms they naturally "carry" (Yazwinski *et al.*, 1996). Depending on production type and/or bird age, four different worms can be routinely found in the chicken, including *Ascaridia galli* Schrank. As for the turkey, only the ascarid (*A. dissimilis* Vigueras) can be found under normal, commercial conditions. One would think that in this country, with its highly developed technologies and capabilities, an ancient affliction such as "worms" would have been conquered years ago. The fact is, however, that worms are alive and well in our chickens and turkeys, and only now is a thoroughly researched and proven medication on the verge of being approved for routine commercial use in turkeys, i.e., fenbendazole (Yazwinski, 1999).

Chemical means of roundworm control are necessary if optimal production is to be achieved in poultry (Willoughby *et al.*, 1995). Alternative measures of control, in addition to basic biology governing these worms, should be researched as well. In the current study, chickens and turkeys were given roundworms naturally occurring in the other species so that the development of these unnatural parasitisms could be documented; this is an initial step in evaluating the feasibility of reducing roundworm disease in poultry by developing protective, immune responsiveness. In a recent article, the scientific foundation for this research was outlined (Meeusen and Balic, 2000). Parasites occur in "permissive" hosts and not in "nonpermissive" ones. Factors that determine the status of a host are for the most part found in the host's innate (naturally occurring) inflammation and immune responses. In our research, we challenged these innate responses and measured the effect.

MATERIALS AND METHODS

Chickens and turkeys (150 of each) were obtained on the day of hatch from two local (Springdale and Gentry, Ark., respectively), commercial hatcheries. Chickens were of Ross **x** Cobb breeding (Tyson Hatchery) and turkeys were Honeysuckle White (Cargill Hatchery). All birds were male.

Within the 3 months immediately preceding the study, intestinal tracts were obtained from area chicken and turkey processing plants. These tracts were opened, and gravid female ascarids were isolated for dissection, uteri maceration, and egg harvest. The eggs were allowed to embryonate at room temperature for 30 days in a shallow layer of water. At the end of the embryonation period, the eggs were counted in accordance with presence or absence of infective (L2) larvae. At the time of infection induction (birds at 7 days of age), the eggs were diluted so that a 1-ml dose would deliver 1000 larvated eggs to each bird. (Table 1 describes the schedule followed for the conduct of this study.)

To determine the success and degree of damage of natural (homologous) and unnatural (heterologous) infections, we used the design shown in Table 2.

All procedures used for parasite collection, isola-

Table 1. Schedule of infection induction.

Bird age (days)	Procedures
0	Birds obtained from hatcheries
0 – 7	Birds brooded
7	Birds, according to random selection, placed into pens at the rate of 25/pen; total pen weight of birds obtained as well as weight of starting feed
	Infections given to all birds in pen according to pen designation (see Table 2); record and weight of all mortalities and feed intakes started on this day and continued for the remainder of study
14	Bird pen weights and weekly feed consumption obtained
21	Bird pen weights and weekly feed consumption obtained
28	All birds euthanized, weighed, and necropsied for parasite retrieval
	Final feed consumptions obtained.

Table 2. Study design.

Pen No.	Bird	Infection given
1	Chicken	None (control)
2	Chicken	*A. dissimilis* (heterologous)
3	Chicken	*A. galli* (homologous)
4	Turkey	*A. dissimilis* (homologous)
5	Turkey	None (control)
6	Turkey	*A. galli* (heterologous)

tion, and counting have been published previously (Yazwinski *et al.*, 1986). Briefly, intact small intestines were removed from each euthanized bird, opened lengthwise, and the contents collected. The cleaned intestine was then soaked overnight for the release of worms in tissue-dwelling stages, with soak fluids collected the day after posting. For each bird's content and soak collection, all worms were isolated and counted according to stage of development.

All roundworm data were analyzed according to currently recognized appropriate procedures. All counts were transformed (logarithmic) to obtain "normal" distributions, and significance of difference between experimental groups was determined at the probability level of 5% by the repeated *t*-test.

Specimens were initially cleared in lactophenol for 24 hours. Illumination and magnification were provided by a Nikon Labophot compound microscope (Nikon, Garden City, N.Y.). Specimen images were then received through a JVC color video camera and digitized using a SNAPPY attachment (Play Incorporated) on line to a Gateway E 4200 – 700 MHz computer (Gateway, North Souix City, S.D.).

RESULTS AND DISCUSSION

Mortality rates by experimental group ranged from 16 to 24% for the chickens and 27 to 37% for the turkeys (Table 3). No correlation was observed between rate of mortality and infection status (data not shown). Average weekly feed efficiencies are also given in Table 3. For both the chickens and the turkeys, experimental groups with homologous infections had the poorest feed efficiencies. This was seen as a consequence of the natural parasitisms (homologous) being the most successful and, correspondingly, the most harmful to the host.

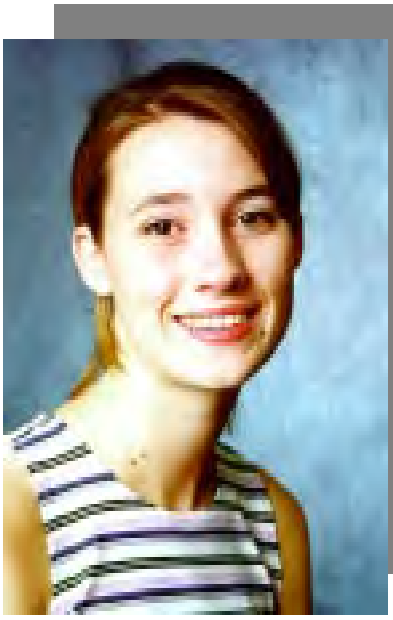
All *Ascaridia* counts are given as geometric means in Table 4. Parasitic larval stages for *Ascaridia* are second, third, and fourth, progressing from earlier to later stages prior to the fourth larval molt into adults. For the second larval stage, heterologous (turkey worm) infections in the chicken produced the greatest burdens. This suggests that the turkey worms were retarded in development in the unnatural chicken host. Further evidence of retarded development of *A. dissimilis* in the chicken was seen at the third larval stage, with significantly ($P < 0.05$) greater levels seen in this experimental group than

Meet the Student-Author

I am from Cabot, Ark., and a graduate of Cabot High School. Currently, I am a junior majoring in animal science. I have received the M.S. Offut Scholarship, the Whitaker Scholarship, and the G. Brown Scholarship. I plan to finish my B.S. degree at the University of Arkansas and then continue my education until I receive a Ph.D. in animal science.

I chose this research project because it was interesting and my professor expressed the need for research in this area. This experience gave me insight into what I might expect from graduate school, while allowing me to feel more confident about my decision to continue my education. I feel that I am now more "competitive" than less experienced students and that I am more capable of applying information from the classroom, dealing with the unexpected, and expressing the results both orally and in writing. It was a great experience for me.

I would like to express my appreciation to Dr. Yazwinski and Dr. Tucker for their availability and direction during this research project.



Julie Hamilton

any other (same occurrence as with the second stage larvae). Levels of larvae at the fourth stage of development were highest in experimental groups given homologous infections. In the case of chickens infected with *A. galli*, these numbers reflected normal, successful patterns of development. For fourth larval stage numbers in turkeys, the comparatively high count was also consistent with the natural situation, wherein fourth stage counts are characteristically of greatest magnitude for naturally infected turkeys (Yazwinski *et al.*, 1993).

Numbers of roundworms at the adult stage were significantly ($P < 0.05$) greater in naturally infected chickens than in any other group. Chickens normally harbor the majority of their ascarids as adults, whereas turkey infections are predominately of the fourth-stage variety. The current data clearly reflect the normal distribution. In regard to total worm burdens (all stages combined), homologous infections were the most successful. For both chickens and turkeys, heterologous infection numbers were only 55 to 56% as great as homologous infection numbers. Life-cycle stage specimens of *Ascaridia* isolated in this research project are presented in Fig. 1.

Table 3. Mortality rate, feed efficiency,[z] and mean necropsy weight by experimental group.

Pen No.	Bird host	Infection status	Mortality rate (%)	Feed efficiency	Mean necropsy weight (g)
1	Chicken	None	24	2.27	574
2	Chicken	*A. dissimilis*	16	2.22	559
3	Chicken	*A. galli*	24	2.30	614
4	Turkey	*A. galli*	37	2.39	396 ab
5	Turkey	None	36	2.40	433 a
6	Turkey	*A. dissimilis*	27	2.54	376 b

Means for experimental groups of the same host species with unlike superscripts were significantly different ($P < 0.05$).

[z] Units consumed per units gained (weekly values averaged over the 3 weeks postinfection).

Table 4. *Ascaridia* geometric means by stage of parasite and experimental group.

Pen No.	Bird host	Infection status	Geometric mean for *Ascaridia* as: Second	Third	Fourth	Adult	Total
1	Chicken	None	0 b	0 c	0 d	0 c	0 d
2	Chicken	*A. dissimilis*	2.0 a	7.2 a	2.2 b	0.1 c	13.2 b
3	Chicken	*A. galli*	0.1 b	1.2 b	5.6 a	15.6 a	24.2 a
4	Turkey	*A. galli*	0.2 b	1.5 b	1.0 c	1.5 b	5.6 c
5	Turkey	None	0 b	0 c	0 d	0 c	0 d
6	Turkey	*A. dissimilis*	0 b	1.6 b	6.4 a	1.0 b	10.0 b

Means in the same column with unlike superscripts were significantly different ($P < 0.05$).

CONCLUSIONS

In our study, homologous infections of chickens and turkeys by *Ascaridia* were consistent with previous observations. Heterologous infections were successful, but with clearly reduced rates of development as well as infection rate. Given the fact that the heterologous infections were successful, additional studies are planned to investigate the degree to which these unnatural infections impart resistance in the host to their natural parasitisms. In addition, the specimens and data collected from the current research will be further scrutinized so that more insight into the basic life styles of these parasites in our birds might be gained.

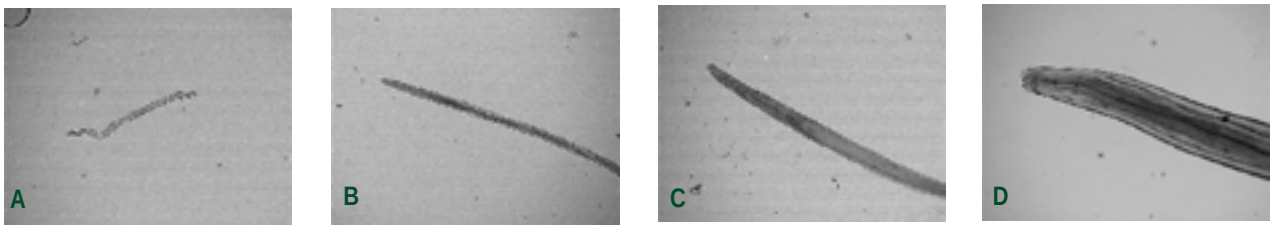


Fig. 1. Parasitic stages of *Ascaridia dissimilis* as isolated in this study. *A.* Second-stage larva. *B.* Third-stage larva. *C.* Fourth-stage larva. *D.* Adult. All specimens at 40X magnification. Actual sizes of the roundworms ranged from 1 mm to 4 cm for second-stage larvae and adults, respectively.

ACKNOWLEDGMENTS

The authors thank Cargill, Inc., and Tyson Foods, Inc., for donation of the birds used in this study and Cargill and Simmons Foods, Inc., for access to their processing plants so that infection-source nematodes could be gathered. Thanks also to Mitch Fincher, Kim Downum, L.B. Daniels, and Chris Tucker for their guidance and assistance during this project.

The authors are grateful to those who provided funding for this research: the Bumpers College Undergraduate Research Grant Program for their monetary assistance and the Baum Teaching Grants Program for funding that allowed for the purchase of the video camera.

Julie Hamilton wishes to thank her Mom and Dad, again.

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Livability of Leghorn balut embryos stored under varying temperatures and storage times

Joyce Jong[*] and F. Dustan Clark[§]

ABSTRACT

Baluts are fertile chicken or duck eggs that have been incubated and removed from the incubator prior to hatching for consumption. Chicken eggs are incubated for 11 to 14 days and duck eggs are incubated for 16 to 20 days. Baluts have an extremely specialized consumer market, with the majority of its consumers of Filipino decent. Current U.S. Department of Agriculture regulations for the storage of baluts prior to sale is 7.2ºC, the same as for infertile commercial table eggs. Consumer preference is to purchase live baluts for consumption. Since exposure to 7.2ºC causes embryo mortality within 8 hours of removal from the incubator, research was performed to assess mortality at various storage temperatures, which has not previously been established. Our study consisted of two identical trials to determine the livability of embryos when exposed to varying temperatures over predetermined storage times. Fertile Leghorn chicken eggs were incubated for 13.5 days and then removed from incubation, grouped, and placed in temperature-controlled environments corresponding to 15.6, 18.3, and 22.2ºC. At predetermined times, eggs were opened to determine embryo viability. Random swab samples of the internal egg environment were also taken aseptically to determine the presence of microorganisms. Results demonstrated that the livability of embryos was longer when exposed to storage temperatures closer to incubation temperatures (37.5ºC), and livability was shorter when storage temperatures neared refrigeration temperature (7.2ºC).

* Joyce Jong graduated in May 2000 with a B.S. degree in poultry science.
§ F. Dustan Clark, faculty sponsor, is extension poultry science veterinarian in the Department of Poultry Science.

INTRODUCTION

Baluts are fertile chicken or duck eggs that have been incubated and removed from the incubator prior to hatching for consumption. Chicken eggs are usually incubated for 11 to 14 days; whereas, ducks are incubated for 16 to 20 days. Under favorable incubation conditions, chicks hatch at approximately 21 days of incubation. Ducklings hatch between 26 and 30 days of incubation, depending on the breed.

Baluts have an extremely specialized consumer market, the majority of which are of Filipino decent. Doreen Fernandez, author of "The World of Baluts," is quoted as saying, "Whoever discovered balut stumbled onto the fact that food has changing excellence (taste, texture) as it evolves and develops. Thus between the egg and the full-grown duck [or chicken], there are stages that bear exploring—and eating. And the Filipino has explored them and evolved the culture of balut." (Magat, 1997) Others known to consume this product include Asian immigrant groups such as Vietnamese, Cambodians, Laotians, Thais, Malays, Indonesians, and Chinese.

Prior to consumption, baluts are boiled for 20 to 30 minutes. Edible parts include the embryo, yolk, and amniotic fluid (also referred to as the "soup") (Fig. 1). Baluts are believed to hold medicinal value and are often looked upon as an aphrodisiac. Consumers prefer to purchase live embryos, which have a better flavor, a "sweetness" to the "soup." Baluts containing dead embryos prior to cooking tend to have a more bland or slight bitter taste, depending on how long the embryos have been dead.

Current U.S. Department of Agriculture regulations mandate baluts be refrigerated at 7.2ºC prior to purchase. "Baluts are potentially hazardous food and must be refrigerated upon removal from incubation and maintained at a refrigerated temperature of 7.2ºC, or less, while transported, stored, or held for retail sale" (Besulieu, 1991).

In a pilot study we conducted, balut embryos removed from incubation after 13.5 days and immediately stored at 7.2ºC resulted in embryonic death within 8 hours of storage (unpublished data). Before that study, the livability of embryos removed from incubation prior to hatch and exposed to various storage temperatures had not been established.

Meet the Student-Author

Joyce Jong

In May 2000, I received my B.S. degree in poultry science with a minor in agricultural business management. During my undergraduate years, I had a number of opportunities to participate in a variety of presentations. In 1998, I placed first in a student presentation competition hosted by the Pacific Egg and Poultry Association, in addition to receiving an award of merit. In 1999 and 2000, I won first place in the undergraduate category of the student paper competitions hosted by Gamma Sigma Delta. In addition, this year the Department of Poultry Science awarded me the Outstanding Undergraduate Award. In the fall, I will be attending the University of California, Davis, to begin work on a master's degree in agriculture and management. I am excited about the many opportunities the poultry industry offers and eager to pursue them after graduation.

This project provided a chance for me to conduct a research project from start to finish. It opened the doors for me to participate in a paper/presentation competition, as well as to write a paper for publication. As a result, I have gained a greater respect for the research process and will use what I have learned in various future applications.

My family is involved in the production of poultry products and was thinking about producing baluts. Prior to our initial production, I had the task of researching the regulations regarding them. In the process, I discovered that there are no available data on balut livability after they are removed from the incubator. This is an important factor in their marketability. The data from my research provided me with insight into how long embryos will live outside the incubator when exposed to various temperatures. My research also serves as a basis for future balut research. The ultimate goal is to provide scientific data for producers and regulatory agencies in order to influence current regulations to better reflect the product itself as well as the production and marketing.

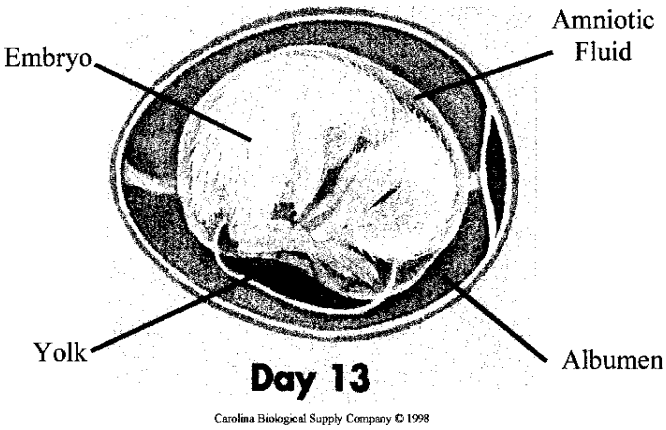

Fig. 1. Four parts of a balut embryo at 13 days of incubation.

The purpose of this research was to determine livability of chicken balut embryos incubated for 13.5 days and stored at various temperatures and periods of time. In addition, the presence of microorganisms in the egg was determined. Based on knowledge gained from the pilot study, it was hypothesized that the livability of balut embryos would vary in relation to the storage temperature; livability would increase as storage temperatures increased and vice versa. In addition, it was hypothesized that few microorganisms would be detected.

MATERIALS AND METHODS

Two identical trials were conducted. Both trials contained over 630 fertile Leghorn chicken eggs, which were obtained from a hatchery in Lincoln, Ark., with eggs supplied by Hy-Line International (West Des Moines, Ia.). These eggs were incubated for 13.5 days in a Jamesway incubator (Model 252B, Jamesway Incubator Co., Ltd., Cambridge, Ontario) at 37.5ºC. Eggs were candled (a process in which a bright light is shone through the egg to view its internal contents) at the end of the 13.5 day incubation period. All unsuitable eggs (infertile eggs and eggs containing embryos that died at early stages of development) were removed and disposed of, and the remaining eggs containing live embryos were randomly divided into three groups consisting of 210 eggs per group. Each group of eggs was stored at temperatures corresponding to 15.6, 18.3, and 22.2ºC. Thirty eggs from each storage temperature group were removed and opened to determine embryo livability by visual observation (a process referred to as "breakout") after 8, 12, 18, 22, 26, 30, and 34 hours of storage. In addition, 10 swab samples were aseptically taken from randomly selected embryos of each group at each breakout interval. Swabs were inoculated onto blood (5% sheep red blood cells) and MacConkey agar plates and incubated at 36.7ºC for bacterial isolation attempts. The number of live versus dead embryos was documented for each temperature group and at each time interval of examination.

RESULTS AND DISCUSSION

Embryo Livability

In trial 1, the embryos stored at the target temperature of 15.6ºC were actually stored at an average temperature of 16.6ºC. In the first three breakout intervals, the percentage of live embryos exceeded the percentage of dead embryos. After the 18 hours of storage, no embryos survived.

Results of the second group of embryos, stored at an average of 18.3ºC in the first trial, showed that embryos were alive throughout the entire storage interval from 8 to 34 hours. In the first four breakout intervals, the percentage of live embryos exceeded that of dead embryos, and in the last four breakout intervals the percentage of dead embryos exceeded that of live embryos.

In all breakout intervals of embryos stored at an average temperature of 37.5ºC, the percentage of live embryos surpassed that of dead embryos, except at the breakout interval during the 22nd hour. During that interval, the percentage of dead embryos exceeded the percentage of live embryos.

In the second trial, embryos stored at 15.6ºC were actually stored at an average temperature of 16.5ºC. For the first breakout, percentage of dead embryos exceeded the percentage of live embryos. After 8 hours of storage, no embryos remained alive.

For all breakout intervals of embryos stored at an average temperature of 18.3ºC in the second trial, the percentage of dead embryos exceeded that of live embryos. At the 18- and 34- hour breakout intervals, no live embryos were observed.

For the average storage temperature of 22.2ºC in the second trail, live embryos were observed in all breakout intervals. The percentage of live embryos was less than the percentage of dead embryos at all breakouts except at 12 and 22 hours of storage, where the percentage of live embryos was the majority.

In both trials, there was a decreasing pattern of embryonic death. For both trials, the percentage of live embryos was greatest when stored at 22.2ºC, followed by 18.3, 16.6, and 16.5ºC, with the lowest percentage of live embryos observed in a storage time interval over 34 hours (Figs. 2 and 3).

Bacterial Isolates

Two species of bacteria were isolated from the collected swabs of the first trial, *Staphylococcus epidermidis* and *S. aureus*. The bacteria were isolated from 12.9% of the eggs sampled that had been stored at an average temperature of 16.6ºC. No bacteria were isolated from eggs sampled from groups stored at average storage temperatures of 18.3 and 22.2ºC. In the second trial, *Staphylococcus* species were also isolated from samples taken from eggs stored at average temperatures of 16.5 and 22.2ºC, 6.2 and 9.0%, respectively. No bacteria were isolated from swab samples taken from eggs stored at an average temperature of 18.3ºC.

In general, the results of both trials demonstrated that embryos held at 22.2ºC tend to have the highest percentage of livability, followed by 18.3ºC with the next highest livability, and finally 16.6 and 16.5ºC, which had the lowest livability.

The graphic patterns of decreasing embryonic death for all storage groups in both trials may be the result of how the eggs were physically stored and the insulating capacity of the egg flats. In both trials, the height and number of flats were identical.

An observation of the eggs and embryos of the second trial revealed that both egg size and embryo size were considerably smaller. Since the stage to which the embryos developed was not different in either trial, it is possible that the small embryos were the result of smaller egg sizes, which may account for the higher percentage of death resulting from their inability to retain heat at the same rate as the larger embryos of the first trial. "Low temperatures slow the development process as embryos are not completely homeothermic even by hatching time. Thus lowering environmental temperatures also lowers the embryo's temperature…." (Card and Nesheim, 1972).

An important factor that determines embryo livability outside of the incubation environment is referred to as "physiological zero," which is the "temperature below which embryonic growth is arrested, and above which it is initiated" (often cited in the range of 21.1 to 26.7ºC) (North and Bell, 1990). "Developing embryos are extremely sensitive to [the] temperature of the environment. Some eggs will hatch if eggs are continuously maintained at a temperature between 35 and 40ºC. Outside this range, essentially no eggs can be expected to hatch." Since development of the embryo will cease, heat production will cease, resulting in embryo death (Card and Nesheim, 1972).

S. epidermidis and *S. aureus* were isolated from a small percentage of the eggs sampled. It is likely that the presence of these organisms was the result of environ-

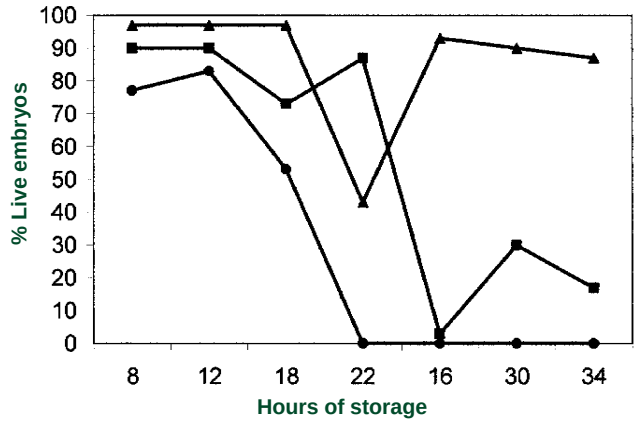

Fig. 2. Trial 1: comparisons of the percentage of live embryos at average storage temperatures of 16.6 (circles), 18.3 (squares), and 22.2ºC (triangles).

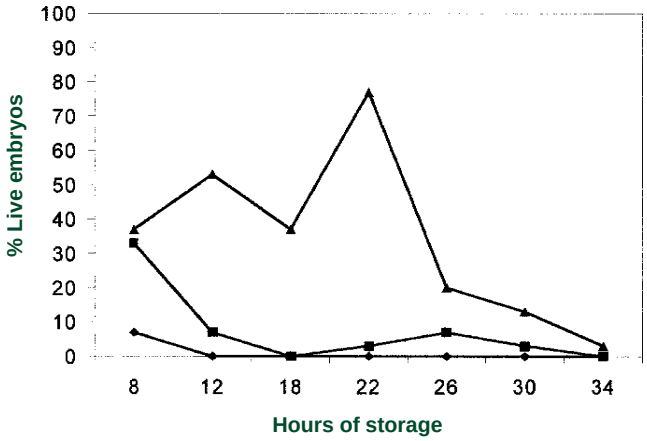

Fig. 3. Trial 2: Comparisons of the percentage of live embryos at average storage temperatures of 16.5 (diamonds), 18.3 (squares), and 22.2ºC (triangles).

mental contamination when the eggs were opened. Prior to incubation, if an egg is contaminated with bacteria, the heat from the incubation environment and the yolk (an enriched medium) provide ideal conditions for bacterial proliferation. This proliferation would lead to an adverse affect on the embryo in the early development stages. In both trials, eggs containing "early dead" embryos were removed in the candling process.

In conclusion, livability of chicken embryos is correlated to the temperature at which they are stored. As the temperature nears that of refrigeration (7.2ºC), embryo livability declines. Storage temperatures closer to incubation temperature (37.5ºC) result in greater embryo livability. To prolong the life of the embryo after removal from the incubator, baluts need to be stored at temperatures greater than 7.2ºC. Bacterial presence inside the eggs and/or baluts appears not to be problematic.

Subsequent trials are planned to determine a storage temperature for maximum livability. In addition, the effects of the bacteria (such as *Staphylococcus* species and *Salmonella* enteritis) on the embryo during incubation and prior to cooking need to be further investigated. This information and that from subsequent research can be utilized by regulatory agencies and balut consumers to determine product safety.

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Prediction of rice sensory texture attributes using spectral stress strain analysis and the jack-knife model optimization method

Marura Lenjo[*] *and Jean-Francois Meullenet*[§]

ABSTRACT

Sensory texture characteristics of cooked rice were predicted using an extrusion test and a novel multivariate analysis method. Eleven sensory texture characteristics were evaluated via a trained descriptive panel and predicted for force/deformation spectra with partial least squares regression. Only four sensory attributes—adhesion to lips (Rcal = 0.83), cohesion of bolus (Rcal = 0.78), cohesiveness (Rcal = 0.69), and hardness (Rcal = 0.72)—were successfully predicted from instrumental measurements.

* Marura Lenjo graduated in August 2000 with a B.S. degree in food science.
§ Jean-Francois Meullenet, faculty sponsor, is an assistant professor, Department of Food Science.

INTRODUCTION

Many researchers have studied the instrumental evaluation of cooked rice texture, and a number of instrumental methods have been examined. At present, one of the most popular and reliable instrumental methods involves the use of an Ottawa extrusion cell (Meullenet *et al.*, 1998; Juliano *et al.*, 1981). The dimensions of the traditional Ottawa cell require rather large quantities (i.e., approximately 100 g of milled rice) of rice for evaluation. More recently, a small extrusion cell was designed at the University of Arkansas, and preliminary results have demonstrated the potential of this method for predicting rice texture.

Juliano *et al.* (1984) showed that an instrumental method utilizing small sample sizes was less reliable than tests performed on bulk samples. However, the successful development of a technique requiring a small sample size would be invaluable to rice-breeding programs to quickly and inexpensively assess texture characteristics of cooked rice. The objectives of this study were (1) to evaluate an experimental extrusion method requiring small samples suitable for predicting cooked rice texture characteristics and (2) to evaluate the use of partial least squares regression (PLSR) for developing predictive models of specific texture attributes.

MATERIALS AND METHODS

Rice Samples

Three rice cultivars were used in the study, and all were harvested from the University of Arkansas Rice Research and Extension Center, Stuttgart, in 1998. Harvest moisture contents of the cultivars were between 17 and 19% (wet base). We studied a total of 102 samples of 'Drew' (D); 'Bengal' (B); and 'Kaybonnet' (K); the samples were taken from rice being used in drying and storage studies conducted by the University of Arkansas Rice Processing Program.

Sensory Evaluation

Sensory Methodology. Eleven trained panelists with 3 years of experience in descriptive analysis techniques according to the spectrum methodology (Sensory Spectrum, Chatham, N.J.) evaluated and intensified 11 texture attributes of cooked rice. Attributes evaluated and definitions are described in Table 1. The attributes evaluated were intensified during four evaluation stages. During the initial stage of the evaluation (i.e., the sample was placed in the mouth but not chewed or manipulated), cohesion of bolus and particles size were evaluated (Table 1). In the second stage (i.e., partial compres-

Marura Lenjo

Meet the Student-Author

I am from Kenya and graduated from high school there. I am majoring in Food Science and plan to graduate in the summer of 2000. I have received several scholarships from the Ozark Food Processors' Association. After graduation, I plan to continue with a graduate degree in Food Science.

I chose this research project because I am particularly interested in sensory science and would like to work in this field in the future. Through this project, I improved my laboratory and research skills greatly. I was also able to experience first-hand working in the area in which I'd like to make my career.

sion), adhesiveness to lips was evaluated by compressing samples between the lips, releasing, and then evaluating the degree to which samples adhered to lips.

Hardness was evaluated after the first bite by compressing or biting through the sample one time with the molars and evaluating the force required to bite through. Cohesiveness was evaluated (i.e., first bite attribute), by placing the sample between the molar teeth, compressing fully, and evaluating the amount the sample deformed rather than split apart, cracked or broke.

Cohesiveness of mass, roughness of mass, and toothpull were evaluated during the chew-down stage. Cohesiveness of mass was assessed by chewing the samples with the molars four or five times and evaluating the degree to which the chewed sample held together. Roughness of mass was evaluated by chewing the sample with the molars eight times and evaluating the amount of roughness perceived in the chewed sample. Toothpull was determined from the force required to separate the jaws during the mastication after chewing the sample three times.

Table 1. Vocabulary for sensory texture attributes of cooked rice.

Attribute	Definition	Technique
	Initial Stage	
Cohesion of bolus	The degree to which the unchewed sample holds or sticks together.	Place 3/4 teaspoon of sample in mouth and immediately evaluate how tightly the mass is sticking or holding together. Do not chew or manipulate!
Particle size	The amount of space the particle takes up in the mouth. (How big are the particles?)	Place sample in center of mouth and evaluate. Do not chew or manipulate!
	Partial Compression Stage	
Adhesion to lips	The degree to which the sample adheres to the lips.	Compress sample between lips, release and evaluate the degree to which the product remains on the lips.
	First Bite/Chew Stage	
Hardness	The force required to compress the sample.	Compress or bite through sample one time with molars or incisors.
Cohesiveness	The amount the sample deforms rather than splits apart, cracks or breaks.	Place sample between the molar teeth and compress fully. May also be done with incisors.
	Chewdown Stage	
Cohesiveness of mass	The amount that the chewed sample holds together.	Chew sample with molar teeth up to 15 times and evaluate (loose mass—tight mass).
Roughness of mass	The amount of roughness perceived on the surfacethe of the chewed sample. Hint: You are looking for large lumps, bumps, hills and valleys, etc.	Chew the sample with molars and evaluate the irregularities on the surface of the sample mass.
Toothpull	The force required to separate the jaws during mastication.	Chew sample 2–3 times and evaluate.
	Residual Stage	
Residual film	The amount and degree of residue felt by the tongue when moved over the surface of the mouth.	Swallow the sample and feel the surface of the mouth with the tongue to evaluate.
Toothpack	The amount of product packed into the crowns of your teeth after mastication.	Chew sample 10-15 times, expectorate and feel the surface of the crowns of the teeth to evaluate.
Loose particles	The amount of particles remaining in and on the surface of the mouth after swallowing.	Chew sample with molars, swallow and evaluate.

Toothpack, loose particles, and residual film were evaluated last in the residual stage after swallowing. Toothpack was evaluated from the amount of the sample packed into the crowns after mastication. The loose particles were assessed from the amount of particles remaining on the surface of the mouth. Residual film was assessed by evaluating the amount of residue felt by the tongue when moved over the surface of the mouth.

Panelists used paper ballots and a rating between 0 and 15 (Meilgaard et al., 1991) with one significant digit to intensify sensory scores. References were provided to panelists to use as anchors for specific attributes.

Sample preparation for the sensory evaluation. Rice samples (300 g) were cooked in household rice cookers (National, model SR-W10FN, Tehran, Iran) with a 1:2 rice-to-water ratio according to methods described by Meullenet et al. (1999). Samples were presented at 75 ± 2°C in preheated glass bowls insulated with polystyrene cups and covered with watch glasses labeled with three-digit codes. Panelists were instructed to monitor temperature closely during the test and to complete the evaluation before the temperature of the sample reached 60°C. Water and soda crackers were provided to panelists to clean their palate between each sample. Serving order was randomized across treatments but not across panelists because of sample availability and the importance of the temperature of the sample. Samples were presented one at a time to the panelists, who sat in individual booths featuring incandescent lighting and positive pressure. Eleven to fifteen samples were presented for evaluation at each of the testing sessions. Samples were evaluated twice by panelists on two consecutive testing sessions. At the beginning of each session, a reference rice sample was presented as a warm-up sample.

Sample preparation for instrumental analysis. Because temperature greatly influences rice texture (Okabe, 1979), it must be very closely monitored so that mechanical testing is accurate and reproducible. Previous work by Meullenet et al. (1998) used rinsed cooked rice at room temperature. It was determined (Meullenet et al., 1998; Meullenet et al., 1999) that cooked rice texture evaluated at room temperature does not represent optimal testing conditions and does not closely mimic sensory evaluation protocols. Thus a cooking protocol similar to that used for sensory testing was developed. However, because the objective of this study was to develop a method for rice breeders who do not have large amounts of sample available, 10 g of milled rice was combined with 17 g of water in a 100-ml beaker and cooked in a rice cooker under steam conditions. For uniform and equal absorption of water by all grains, the beaker was placed on a screen inside the rice cooker without direct contact with the heating element. Three hundred fifty milliliters of water was added to the cooker, and the rice was steamed for 30 minutes (i.e., covered steamer on "cook" position).

Extrusion Cell Design. The extrusion cell used in this study was created in response to the needs of a rice-breeding program. Therefore, it considers several constraints related to its size, price, and the rice quantities necessary for instrumental testing. The cell developed (90 mm in length and 20 mm in diameter) was made from a 3/4-in. PVC (polyvinyl chloride) compression fitting bored to size and fitted with an extrusion plate consisting of a stainless steel mesh (0.5-mm mesh). An extrusion cylinder (19.5 mm in diameter and 95 mm in length) was turned to size from a 1-in. Teflon rod (Fig. 1).

Instrumental Measurements. Extrusion cells were removed one at a time from the rice cooker, and instrumental testing was performed immediately. The instrumental evaluation was carried out using a texture analyzer (Texture Technologies, model TA-XT2i, Scarsdale, N.Y.) in combination with a 25-kg load cell. The crosshead speed was set at a test speed of 2 mm/second for a total distance of 85 mm. Force-distance curves were recorded. A typical force deformation curve is shown in Fig. 2. The curve can be divided into four sections corresponding to the main stages of the instrumental test: packing, compression, extrusion, and tension (Fig. 2).

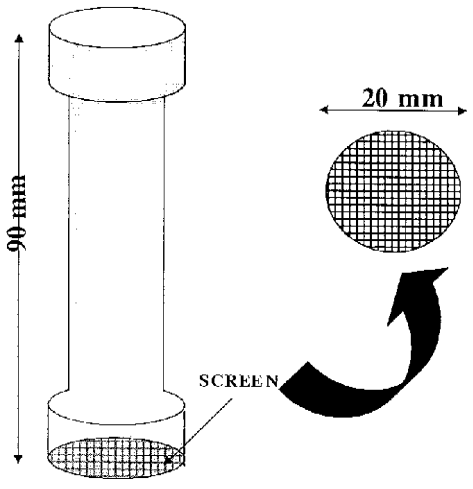

Figure 1. Plastic extrusion cell used to evaluate texture of cooked rice.

These phases were derived from examining partially extruded samples. For example, the extrusion phase was determined to start from the distance at which the rice kernels began to be extruded through the screen and to end when the extrusion cylinder started its upward movement.

Statistical Analyses

The six subsamples of the force-distance curve from each sample were compared, and an average force-distance curve was determined. The average force-distance curve was exported to an Excel spreadsheet to extract forces corresponding to specific cylinder travel distances. A force value was assessed for each deformation increment and was used as a predictive variable. Unscrambler (version 7.5, CAMO, Throndheim, Norway, 1996), a multivariate analysis software, was used to determine predictive models of sensory texture attributes. The concept for this analysis—Spectral Stress Strain Analysis (SSSA)—is based on the prediction of sensory texture characteristics from the shape of the force-deformation curves, rather than on the calculation of instrumental parameters such as maximum force or total work (Fig. 2). Partial least squares regression (option PLS1) was used for predicting sensory attributes from force-distance data. The full cross-validation method was used to evaluate the robustness of the model. The accuracy of the model was expressed using the root mean square error of prediction (RMSEP). The jack-knife model optimization method was used to remove instrumental variables creating "noise" in the model.

RESULTS AND DISCUSSION

The use of instrumental data for predicting sensory texture attributes of rice was proven feasible for a number of the sensory attributes studied. The removal of sample outliers or statistically insignificant predictive variables allowed the optimization of the model.

Cohesion of bolus was reasonably well-predicted (Rcal = 0.71, Table 2). The optimization of the model resulted in a significant improvement of the model statistics. The correlation coefficient (0.78, Table 3) for the optimized model was slightly higher than that of the full model. Correspondingly, the root mean square error of calibration (RMSEC) of the optimized model was slightly lower (0.43, Table 3) than that of the full model (RMSEC = 0.52, Table 2). The optimized model was well-validated (Rval = 0.72, Table 3), with a reasonably low RMSEP of 0.49.

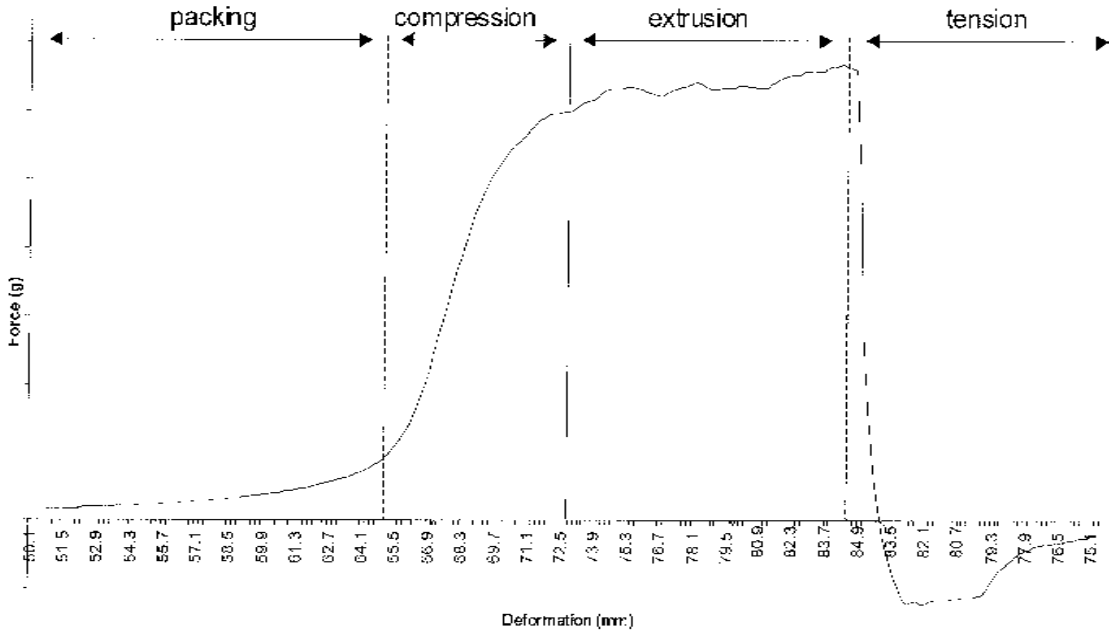

Figure 2. Results of the spectral stress strain analysis used to determine predictive models of the sensory texture attributes.

Particle size was poorly predicted (Rcal = 0.30, Table 2). Optimization of the model resulted in only a slight improvement of the correlation coefficient (Rcal = 0.46, Table 3). However, the relationship between particle size and instrumental data is too weak to hope to accurately predict this attribute.

Adhesion to lips was well-predicted (Tables 2 and 3). All samples were used in the calculation of the final model. To optimize the results, only the significant predictive variables were used. (i.e., jack-knifing). The correlation coefficient for the full model (0.75, Table 2) was found to be high. Correspondingly, the RMSEC was relatively low (0.57, Table 2). The optimized model was significantly improved (Rcal = 0.83, Table 3) and validated well (Rval = 0.76, RMSEP = 0.67, Table 3).

Hardness was well-predicted, with a relatively high correlation coefficient of 0.69 (Table 2) for the full model and correspondingly a low RMSEC of 0.28 (Table 2). The model was optimized by removal of insignificant predictive variables and sample outliers. The optimized model had a correlation coefficient of 0.72 (Table 3), which was a slight improvement over that of the full model. This model was well-validated (Rval = 0.69, RMSEP = 0.28, Table 3).

The full model for cohesiveness had a fairly low correlation coefficient (0.44, Table 2). However, the RMSEC was fairly low (0.29). An attempt to optimize the model by removal of statistically insignificant variables resulted in poorer model statistics. As a result, the model was optimized by removal of sample outliers, which resulted in a significant improvement in the model statistics. The correlation coefficient (0.69, Table 3) was close to satisfactory, with a corresponding low RMSEC of 0.17 (Table 3). This model was well-validated using the full cross-validation method (Rval = 0.61,Table 3). The RMSEP of the optimized model was much lower than that of the full model (RMSEP = 0.19, Table 3).

Cohesiveness of mass was not extremely well-predicted. The correlation coefficient for the full model (Rcal = 0.55, Table 2) was relatively low. Optimization of the model by removal of one sample outlier and of the statistically insignificant variables resulted in slightly improved model statistics (Rcal = 0.58, Table 3). However, the optimized model was not well-validated (Rval = 0.46, Table 3).

Roughness of mass was fairly well-predicted. Attempts at optimizing the model resulted in poorer model statistics. The correlation coefficient for the full model (0.62, Table 2) was moderately high, with a correspondingly low RMSEC (0.26, Table 2). The full model validated well, with a low RMSEP of 0.28 (Table 2).

Toothpull was also moderately well-predicted by instrumental texture data (Rcal = 0.56, RMSEC = 0.19, Table 2). Model optimization was performed by removing two sample outliers, which resulted in improved model statistics (Rcal = 0.60, RMSEC = 0.18, Table 3). The optimized model did not validate well (Rval = 0.46, Table 3), but the RMSEP remained low (RMSEP = 0.20, Table 3).

Table 2. Full predictive model statistics of rice sensory texture attributes.

	Rcal[z]	RMSEC[y]	Rval[x]	RMSEP[w]
Cohesion of bolus	0.71	0.52	0.64	0.57
Particle size	0.30	0.07	0.22	0.07
Adhesion to lips	0.75	0.68	0.68	0.75
Cohesiveness	0.44	0.29	0.33	0.31
Hardness	0.69	0.28	0.58	0.32
Cohesiveness of mass	0.55	0.46	0.42	0.51
Roughness of mass	0.62	0.26	0.53	0.28
Toothpull	0.56	0.19	0.47	0.20
Residual film	0.12	0.19	-0.10	0.20
Toothpack	0.59	0.22	0.47	0.25
Loose particles	0.32	0.35	0.19	0.36

[z] Rcal = calibration model correlation coefficient.
[y] RMSEC = root mean square error of calibration.
[x] Rval = full cross validation—correlation coefficient.
[w] RMSEP = root mean square error of prediction.

Table 3. Optimized (jack-knifed) predictive model statistics of rice sensory texture attributes.

	Rcal[z]	RMSEC[y]	Rval[x]	RMSEP[w]
Cohesion of bolus	0.78	0.43	0.72	0.49
Particle size	0.46	0.06	0.42	0.06
Adhesion to lips	0.83	0.57	0.76	0.67
Hardness	0.72	0.27	0.69	0.28
Cohesiveness	0.69	0.17	0.61	0.19
Cohesiveness of mass	0.58	0.46	0.46	0.50
Roughness of mass	0.51	0.28	0.47	0.29
Toothpull	0.60	0.18	0.46	0.20
Residual film	0.32	0.19	0.27	0.19
Toothpack	0.60	0.22	0.44	0.25
Loose particles	0.18	0.36	0.08	0.36

[z] Rcal = calibration model correlation coefficient.
[y] RMSEC = root mean square error of calibration.
[x] Rval = full cross validation—correlation coefficient.
[w] RMSEP = root mean square error of prediction.

Residual film was poorly predicted (Rcal = 0.12, Table 2). Model optimization resulted in a slight improvement, but the correlation coefficient remained unsatisfactorily low (0.32, Table 3).

Toothpack was not very well-predicted from the instrumental texture data (Rcal = 0.59, Table 2). However, the full model's RMSEC was low (0.22, Table 2). Model optimization was performed by removing statistically insignificant variables and one sample outlier. This optimization resulted in only a slight improvement of the correlation coefficient (0.60, RMSEC = 0.22, Table 3). However, the optimized model did not validate well (Rval = 0.44, Table 3).

The attribute of loose particles was poorly predicted and had a low correlation coefficient of 0.32 (Table 2). An attempt to optimize the model resulted only in a lower correlation coefficient (0.18, Table 3).

In summary, the use of an extrusion test in combination with multivariate analysis techniques and the jackknife optimization method allowed the satisfactory prediction of adhesion to lips, cohesion of bolus, cohesiveness of mass, and hardness. These attributes are of utmost importance to the quality of rice texture, as they are related to the two most important qualities of rice—stickiness and hardness. Although this method might be less accurate in predicting sensory texture characteristics of cooked rice than other commonly used instrumental tests are, it has the advantage of being less demanding on rice sample quantities necessary to perform the test. This feature may be of special interest to rice breeders.

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Student presentations of the Arkansas Chapter of Gamma Sigma Delta

Competition of February 9, 2000

COMPETITION WINNERS

Posters

First Place: Svetlana Zivanovic–Food Science
Second Place: Marlene E. Janes–Food Science
Third Place: Karen Gomez–Crop, Soil, and Environmental Sciences

Undergraduate Papers

First Place: Joyce Jong–Poultry Science
Second Place: Chrislyn Drake–Horticulture
Third Place: Jerry Fendley–Biological and Agricultural Engineering, Food Science

Master's Papers

First Place: Thomas Barber–Crop, Soil, and Environmental Sciences
Second Place: Jeff Weyers (Animal Science)
Third Place: Mike Lovelace–Crop, Soil, and Environmental Sciences

Ph.D. Papers

First Place: Richard Musser (Entomology)
Second Place: Satyendra Rajguru–Crop, Soil, and Environmental Sciences
Third Place: Scott Payne–Crop, Soil, and Environmental Sciences

DETERMINATION OF CHILLING REQUIREMENT OF ARKANSAS BLACKBERRY CULTIVARS

Chrislyn A. Drake and John R. Clark,
Department of Horticulture

Little research has been done to determine the chilling requirement for Arkansas blackberry cultivars. However, field observations from areas where low amounts of chilling occur indicate that Navaho requires more hours of chilling than does Arapaho. The objective of the study was to determine a method for measuring chilling requirement using whole plants of two blackberry cultivars, Arapaho and Navaho. One-year-old bare-root plants were field-dug and placed in a cold chamber at 3ºC. Ten single-plant replications of each cultivar were removed at 100-hour intervals up to 1000 hours. The plants were then potted and placed in a greenhouse (daily minimum temperature 15ºC) in a completely randomized design. Budbreak was recorded on a weekly basis. Data for budbreak were analyzed as a two-factor factorial (2 cultivars and 10 chilling treatments) by SAS and means separated by LSD ($P = 0.05$). Data indicated that the chilling requirement for Arapaho is between 400 and 500 hours. This is evident as a sixfold increase, which was the largest increase between two chilling treatments, occurred between 400 and 500 hours. For Navaho, the largest increase (also sixfold) occurred between 800 and 900 hours, which indicated a chilling requirement for Navaho of 800 to 900 hours. These data support previous observations and indicate the method used was successful in determining chilling requirement for blackberries.

FISSURE CHARACTERIZATION OF RICE KERNELS USING VIDEO MICROSCOPY

Jerry W. Fendley and Terry J. Siebenmorgen,
Departments of Biological and Agricultural Engineering and Food Science

Fissures (cracks) in rice kernels created during the drying and tempering process cause tremendous postharvest losses in milling yield. Understanding the mechanism of fissure formation in rice kernels will lead to optimizing rice drying and tempering operations. This understanding will enable current dryers to be operated in the most productive and efficient manner possible, thus conserving energy, improving milling yields, and maximizing throughput of dryers. It will ultimately lead to innovative drying equipment and processing design. The ability to produce kernels with little or no fissuring could also dramatically improve end-use processing operations that rely on cooking and puffing procedures. Finally, this information could provide inputs to plant breeders for producing rice cultivars that are more resistant to fissuring. An environmental chamber with video microscopy equipment was used to detect fissures in rice kernels. The video microscope system captured the images of brown rice kernels while being dried. Images of kernels were recorded continuously. Fissure formation, particularly initiation and propagation, was investigated by reviewing the recorded images. This feature of the research is anticipated to be of direct importance to end-users of rice, including cereal and cooked-rice product manufacturers that rely on kernel physical integrity for optimum processing performance. To ensure accurate results, at least five kernels were tested from each harvest moisture content (MC) lot from each cultivar for each drying air condition selected. Differences in fissuring behavior were expected with different kernel MCs. This is of importance because of the different MCs under which rice is harvested and processed.

LIVABILITY OF LEGHORN BALUT EMBRYOS STORED UNDER VARYING TEMPERATURE AND STORAGE TIMES

Joyce Jong and Dustan Clark,
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Baluts are fertile chicken or duck eggs that have been incubated and removed from the incubator prior to hatching. Chicken eggs are incubated for 11 to 14 days and 16 and 20 days for duck eggs. This is a food product with an extremely specialized consumer market, with the majority of its consumers of Filipino decent. Current USDA regulations for the storage of baluts prior to sale is 7.2ºC, the same as for infertile commercial table eggs. Consumer preference is to purchase live baluts for consumption. Since exposure to 7.2ºC causes embryo mortality within 48 hours of removal from an incubator, research was performed to assess mortality at various storage temperatures. Livability of embryos, after removal from incubators, when exposed to various storage temperatures has not been established. A study consisting of two identical trials was conducted to determine liv-

ability of embryos when exposed to varying temperatures over predetermined storage times. Fertile Leghorn chicken eggs were incubated for 13.5 days and then removed from incubation, grouped, and placed in temperature-controlled environments of 15.6, 18.3, and 22.2°C. At predetermined time intervals, eggs were opened to determine embryo viability. Random swab samples of the internal egg environment were also aseptically taken to determine presence of microorganisms. Results demonstrated that the livability of embryos was longer when exposed to storage temperatures closer to incubation temperatures (37.5°C), and livability was shorter when storage temperatures neared refrigeration temperature (7.2°C).

GROWTH PERFORMANCE OF BROILER CHICKS DURING THE STARTER AND GROWER PHASES WHEN UTILIZING PHASE-FEEDING

Niki Loupe and Jason L. Emmert,
Department of Poultry Science

An experiment was conducted to evaluate the efficacy of a nutritional program referred to as phase-feeding (PF) over the first 6 weeks posthatching. Diets were formulated using amino acid recommendations from the National Research Council (NRC) (1994) or from linear regression equations generated from best estimates of lysine (Lys), sulfur amino acid (SAA) and threonine (Thr) requirements. Regression equations were used to predict weekly Lys, SAA and Thr requirements for use in a PF regimen that involved lowering amino acid levels following each respective week of the experiment, resulting in 6 diets fed over the six-week period. During the starter period (0 to 3 weeks), PF resulted in a slight increase ($P < 0.05$) in weight gain and weight gain per unit of digestible Lys and SAA intake. Phase-feeding also resulted in improved weight gain during the grower period (3 to 6 weeks). Over the entire experiment (0 to 6 weeks), the PF regimen resulted in an increased ($P < 0.05$) weight gain, feed intake, and weight gain per unit digestible Lys, SAA and Thr intake compared to birds fed diets based on NRC requirements. These data suggest that PF during the first 6 weeks of age can support growth comparable to diets formulated using NRC requirements. Because PF diets contain substantially less protein and lead to an increased efficiency of utilization of Lys, SAA and Thr, substantial economic benefits may result from the use of PF.

GRADUATE PH.D. ORAL PAPER COMPETITION

EVALUATION OF TANK-MIX COMBINATIONS OF CLORANSULAM AND GLYPHOSATE FOR WEED CONTROL IN SOYBEAN

Jeff W. Barnes and L. R. Oliver,
Department of Crop, Soil, and Environmental Sciences

Field and greenhouse experiments were conducted in 1998 and 1999 to determine the weed control potential of cloransulam and glyphosate tank-mix combinations. The experimental design for all experiments was a factorial arrangement of treatments conducted in a randomized complete block design with four replications. The factors consisted of four cloransulam application rates (0, 4.5, 9, and 18 g ai/ha) and four glyphosate rates (0, 420, 560, 840). In field experiments, weed control evaluations were taken 2 and 3 weeks after treatment. In the greenhouse, the plants were harvested 2 weeks after treatment and fresh weights were determined. The fresh weight data were converted to percent of the untreated control treatment. All data were subjected to analysis of variance and were combined over runs of each respective experiment type. To determine whether the tank-mix combinations provided additive, antagonistic, or synergistic responses, expected values were calculated by Colby's method. Cloransulam at 18 g ai/ha provided at least 60% control of the morningglory species and velvetleaf under both field and greenhouse conditions. Glyphosate provided at least 55% control of sicklepod, prickly sida, Palmer amaranth, and smooth pigweed. Of the 112 treatment combinations evaluated, 56 antagonistic and 56 additive responses were observed. Of the 56 antagonistic interactions observed, only nine resulted in weed control that was significantly lower than the herbicides provided when applied alone. These nine severe antagonistic interactions were confined to entireleaf morningglory and sicklepod. The other six weed species exhibited varying levels of antagonism. In general, combinations of cloransulam with glyphosate resulted in a broader weed control spectrum than when the herbicides were applied alone.

WATER DEFICIT AND K PARTITIONING IN COTTON

Dennis L. Coker and Derrick M. Oosterhuis,
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The impact of water deficit on K deficiency and partitioning in the cotton (*Gossypium hirsutum*) plant beginning at the peak boll development stage is not well understood. Inconsistent yield responses to soil and foliar-applied K fertilizers may be related to water deficit stress from irrigated or rain fed systems. Cotton growth, lint yield, and K partitioning under limited K and water were studied in a field environment. Eight treatment combinations of well-watered or dryland conditions, high or low soil K, and with or without foliar-applied K were arranged in a split-split plot design with six replications. Growth, dry matter, leaf photosynthesis, and K concentration in above-ground organs were measured at key phenological stages [pinhead square (PS), first flower (FF), first flower + 3 weeks (FF+3), and first flower + 5 weeks (FF+5)]. Final lint yield was determined by a mechanical harvester, and components of yield were determined by hand-harvesting. At FF+3 (peak boll development stage), stem and petiole K concentration was significantly reduced ($P \leq 0.05$) from high to low soil K under the well-watered but not the dryland condition. Foliar K consistently increased stem, petiole, and leaf K concentration under the low soil K condition only. Foliar K increased leaf K concentration by a greater margin under dryland, low soil K compared to well-watered, low soil K conditions. Lint yield responded best to foliar K under low soil K and under well-watered conditions. Potassium deficiency in cotton appeared to be enhanced by water deficit, although water deficit did not reduce the efficacy of foliar-applied K.

CATERPILLAR SALIVARY ENZYMES: ROLE IN THE MANIPULATION OF HOST PLANT DEFENSES

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Department of Entomology

Saliva from *Heliocoverpa zea* (corn earworm) larvae was examined for the suppression of the inducible plant defenses of *Nicotiana tabacum* (tobacco). Larval spinnerets were ablated, inhibiting normal secretions of saliva. These larvae and sham larvae were individually caged on a single plant for 24 hours. Three days after feeding, the damaged leaf was analyzed for nicotine, an inducible defense. It was determined that leaves that were fed on by the sham larvae had significantly lower levels of nicotine compared to the ablated treatment. The salivary enzyme glucose oxidase (GOX) was purified from the larval labial glands. Leaves were damaged with a cork borer to simulate insect damage. A leaf was treated with one of four treatments: (1) purified GOX, (2) labial gland extract, (3) autoclaved GOX, or (4) water. Leaves treated with glucose oxidase or labial gland extracts had significantly lower levels of nicotine and polyphenol oxidase compared to other treatments. Neonate growth was also analyzed on leaves treated with either GOX or water. Larval weight was significantly higher for larvae that fed on leaves treated with GOX than those that fed on leaves treated with water. This was the first time that insect saliva in situ has been shown to alter a host plant's inducible defenses and the first time that any characterized insect-derived chemical has been shown to suppress induced resistance in plants.

EFFECT OF LOW CONCENTRATIONS OF GROWTH REGULATORS ON GLYPHOSATE EFFICACY

Scott A. Payne, N. R. Burgos, and L. R. Oliver,
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Studies were conducted to examine the effects of the addition of low concentrations of growth regulators and growth regulator-type herbicides on glyphosate efficacy and soybean injury. In preliminary field and greenhouse studies, the addition of indole-acetic acid and gibberellic acid to glyphosate did not improve the control of entireleaf morningglory, hemp sesbania, velvetleaf, or prickly sida. A separate field study consisted of glyphosate applied alone at 0.56 or 1.12 kg ai/ha or glyphosate applied at 0.56 kg/ha with a growth regulator herbicide (2,4-D, dicamba, quinclorac, or triclopyr) applied at 1/10 its labeled rate. The addition of dicamba, quinclorac, and 2,4-D to 0.56 kg/ha glyphosate improved glyphosate activity on entireleaf morningglory at 2 weeks after treatment (WAT). Hemp sesbania control by glyphosate was improved by the addition of 2,4-D or dicamba from 80 to 95%, respectively. A greenhouse study was conducted using a factorial arrangement of treatments that included a growth regulator herbicide at 1/10 or 1/100 the labeled rate applied alone or with 0.56 kg/ha glyphosate. Growth regulators included 2,4-DB

and clopyralid as well as those used in the field study. Soybean Asgrow 5601 RR and weed species previously mentioned were harvested for dry weight at 2 WAT. The addition of dicamba to glyphosate resulted in 33% soybean dry weight reduction, but 2,4-DB or quinclorac plus glyphosate had no effect. Biomass reduction of entireleaf morningglory by glyphosate + 2,4-D, quinclorac, or triclopyr was increased over that by glyphosate alone (about 70% as compared to 55%). Clopyralid or quinclorac plus glyphosate produced among the highest hemp sesbania dry weight reduction. No growth regulator plus glyphosate combination caused greater dry weight reduction of velvetleaf or prickly sida as compared to glyphosate alone.

DEVELOPMENT OF A TRANSFORMATION CONSTRUCT FOR ENHANCED DISEASE RESISTANCE

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Magainins are 23-residue antibiotic peptides derived from the skin of the African clawed frog (*Xenopus laevis*). They inhibit the growth of numerous species of bacteria and fungi by depolarizing cell membranes and making cells leaky to the environment. Importantly, they arrest the growth of some important fungal and bacterial pathogens that affect cotton and various other crop species. The objective of this research was to study the cytotoxicity of magainin on chloroplasts and to incorporate the gene-encoding magainin into tobacco and eventually cotton to enhance the resistance to various disease causing pathogens. Chloroplasts isolated from pea seedlings were treated with magainin. Lysis of chloroplasts was measured as a function of decrease in the chlorophyll concentration in the treated samples as compared with the untreated controls. Polymerase chain reaction (PCR) was utilized to synthesize the magainin gene, and the PCR product was cloned into binary vector pBIN-GFP. Tobacco leaf discs were co-cultivated with *Agrobacterium* and transgenic plants were generated. Preliminary confirmation of transgenic plants was performed by PCR. Future studies involve confirmation of the integration event by Southern blot and the gene product by Western blot. Transformed tobacco and cotton plants will be tested against a variety of fungal and bacterial pathogens. We expect that the incorporation of magainin into cotton plants should increase their resistance to various pathogens and would provide an alternative approach to controlling diseases in crop plants.

EVIDENCE OF HEPATIC AND EXTRA-HEPATIC STIMULATION OF GLUTATHIONE RELEASE BY NOREPINEPHRINE in vivo

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The present study was conducted to determine the effect of norepinephrine (NE) on glutathione (GSH) export from hepatic and extra-hepatic tissues in vivo. In Experiment 1, anesthetized single-comb white Leghorn males were implanted with cannulae in the carotid artery, hepatic vein (HV), hepatic portal vein (PV) and left bile duct. Norepinephrine [2 and 10 μg/minute/kg body weight (BW)] was infused into the PV for 20 minutes in each bird. Mean arterial pressure (MAP), hepatic venous pressure, portal venous pressure, as well as GSH and oxidized GSH levels in HV, PV, and bile, were monitored at 5- to 20-minute intervals prior to, during, and following NE infusions. NE-induced increases in MAP were concomitant with decreases in heart rate, but no changes in pre-, post-, and trans-hepatic pressures were observed except with the higher dosage of NE (10 μg/minute/kg BW). Although NE had no effect on biliary GSH secretion, both NE infusions raised GSH levels in the HV. GSH levels in the PV increased only in response to the higher dosage of NE. In Experiment 2, pretreatment of birds with phentolamine, an alpha-adrenergic receptor antagonist, abolished the ability of the liver to export GSH and the ability of the infusion of NE (10 μg/minute/kg BW) into the PV to stimulate GSH release by hepatic and extra-hepatic tissue. The results are the first to demonstrate that export of GSH into plasma in vivo is mediated by an alpha-receptor mediated mechanism in hepatic and extra-hepatic tissues.

INFLAMMATION-INDUCED CHANGES IN CHICKEN SERUM

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Inflammation and infection induce changes in the levels of hormones, cytokines, and other regulatory proteins that function to restore physiological homeostasis. These acute-phase changes often manifest in blood, which can potentially be used as markers of health problems. We

have used this concept to study the changes in chicken sera derived from experimental inflammation induced systemically by intravenous injection of bacterial endotoxin or locally by subcutaneous injection of croton oil. Endotoxin induced elevation in the serum level of interleukin-6, a proinflammatory cytokine, within 24 hours, which subsided by 48 hours. We also found that both endotoxin- and croton oil- induced inflammations resulted in changes in the levels of several serum proteins that included elevation in transferrin and alpha-1 acid glycoprotein, and reduction in the level of albumin. To investigate the significance of these acute-phase changes, we tested the effects of inflammatory sera from 48-hour croton oil injected chickens on a chicken macrophage cell line in culture. The results showed that inflammatory sera augmented the endotoxin-induced production of both reactive oxygen and nitrogen species by macrophages without having any effect on interleukin-6 production. These results suggest that components of inflammatory sera can modulate innate immunity by influencing effector cells such as macrophages. The changes in serum can be used as markers of health status of poultry during production as well as antemortem inspection for the purpose of food safety.

GRADUATE M.S. ORAL PAPER COMPETITION

ALTERNATIVE HERBICIDE PROGRAMS FOR DICLOFOP-RESISTANT RYEGRASS IN WHEAT

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Ryegrass (*Lolium* sp.) is a major problem weed in Arkansas wheat production. With the increasing spread of diclofop (Hoelon)-resistant ryegrass across the state, alternative herbicide programs are needed to provide adequate control of the ryegrass. Studies were conducted at Fayetteville on a silt loam and at Willow Beach on a clay loam. A population of diclofop-resistant perennial ryegrass (*Lolium perenne*) was present at both locations. Pioneer wheat cultivar 2684 was drilled in 7-in. rows at a rate of 100.9 kg/ha. The study was a randomized complete block with four replications and a plot size of 3.1 by 7.4 m. Treatments were sprayed with a backpack sprayer at 186.8 L/ha. Visual ratings were taken 3, 6, and 12 weeks after emergence (WAE) and at 30 WAE or harvest. Data were subjected to analysis of variance, and means were separated by least significant difference at the 0.05 level of significance (LSD = 0.05). Ryegrass control and yield were averaged across locations. All herbicide treatments improved wheat yields over the untreated check, which showed a 35% yield loss as a result of diclofop-resistant ryegrass. The PRE and early POST applications of herbicides—Glean, Finesse, Axiom, Achieve, or MKH 6562—provided around 75% control, but yield was not different from sequential herbicide treatments of Glean, Sencor, or Finesse that provided 92% control. However, with less control, a large amount of resistant ryegrass seed escaped, allowing this weed to be a problem in the future. Treatments containing sequential herbicide applications provided no significant increase in wheat yield but allowed the least amount of diclofop-resistant ryegrass seed to be added to the soil seedbank.

CHEMICAL AND PHYSICAL REMOVAL OF COTTON FRUIT AT INSECTICIDE TERMINATION TO IMPROVE YIELDS AND CONTROL BOLL WEEVILS

Robert "Scott" Brown, D.M. Oosterhuis and F.M. Bourland, Department of Crop, Soil, and Environmental Sciences

Increasing yields in cotton (*Gossypium hirsutum*) is an ongoing concern for many researchers. It has been shown that removal of upper-canopy squares at nodes above white flower five plus 350 heat units (NAWF = 5+350 H.U.) may actually divert carbohydrates to developing bolls with a yield advantage. This study evaluated various chemical and physical methods of removing upper-canopy, late-season squares to potentially increase seedcotton yields and help control boll weevils (*Anthonomus grandis*) by removing their late-season food sources. The research was performed in Northeast and Southeast Arkansas on an early-maturing Deltapine DP20B cultivar. To allow for any potential problems in the research due to weather and to provide two growth patterns, two planting dates were included in the study (early and mid-May). The treatments for the 1999 season included a hand square removal and a mechanical topping treatment (physical removal), cyclanilide (Finish), ethephon (Prep), chlormequat (CCC), maleic hydrazide (M-H30) (chemical removal) and a control with no fruit removal. The cotton products cyclanilide and ethephon were the most effective at removing unwanted upper-canopy fruit above NAWF = 5 and helping to control

boll weevils by limiting their late-season food sources. However, weight and quality of first-position bolls at NAWF = 5 were decreased ($P < 0.05$) by cyclanilide applications. Conversely, the largest bolls were observed from the hand removal of squares and control treatments. No differences ($P < 0.05$) occurred with respect to increasing seedcotton yields, but the control gave the highest numerical yields.

TOMATO RESPONSE AND RESIDUE DETECTION FROM SIMULATED DRIFT RATES OF QUINCLORAC

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Quinclorac (Facet) drift has been speculated as causing injury to tomato crops in Northeast Arkansas. A study was conducted in Fayetteville in 1999 to determine injury and residue level in tomatoes after treatment with simulated drift rates of quinclorac. A factorial treatment structure in a randomized complete block was used, with number of applications (one, two, or three) at weekly intervals beginning at first bloom and quinclorac rate (0, 0.42, 4.2 and 42 g ai/ha) as factors. Plant biomass was analyzed for quinclorac concentration using high-performance liquid chromatography weekly for 6 weeks after initial treatment (WAT). Injury ranged from 55 to 65% at 2 to 9 WAT with two and three applications of quinclorac at 42 g/ha, which was greater than injury from a single application (40 to 47%). Injury from multiple applications at 4.2 g/ha was 45 to 60%. Injury was less than 18% for all treatments at 0.42 g/ha. Plant fresh weight was greater from a single quinclorac application at 42 g/ha (3100 g/plant) compared to multiple applications (2100 to 2500 g/plant). Tomatoes treated with one or three applications at 4.2 g/ha resulted in a fresh weight of 5000 g/plant by 9 WAT, which was greater than fresh weight after two applications (3900 g/plant). Quinclorac at 0.42 g/ha did not affect plant fresh weight. Quinclorac concentrations were approximately 1000 and 100 ppb immediately after each application at 42 and 4.2 g/ha, respectively. Instrumentation could not detect quinclorac in plants treated with 0.42 g/ha. Tomato plants receiving one or three applications of quinclorac at 0.42 g/ha yielded 27 to 29 kg tomatoes/10-m row, which was not different from yield of the untreated check (32 kg/10-m row). Yield ranged from 10 to 12 kg/10-m row when treated with 4.2 kg/ha and 3 to 5 kg/10-m row when treated with 42 kg/ha.

ANTIOXIDANT LEVELS IN RICE BRAN AS INFLUENCED BY COMMERCIAL MILLING AND PROCESSING AND EXTRACTION METHOD

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Rice bran is known to contain high amounts of beneficial antioxidants including tocopherols (vitamin E), tocotrienols, and oryzanols. These lipid-soluble vitamins found in rice bran oil have been attributed to several positive health effects such as lowering serum cholesterol in humans, reduction in aortic fatty streaks in cardiovascular patients, and even anti-cancer activity. Thus rice bran is being viewed as a potential functional food source for these high-value nutrients to use as additives in foods, pharmaceuticals, and cosmetics. Current rice-milling technology produces rice bran from the various pericarp layers of the kernel bran layer usually by multi-break milling. The bran produced from these layers at different milling breaks are combined and then often steam-extruded to form a stabilized rice bran pellet, which is storage-safe prior to oil extraction. The bran produced from each stage of the milling process is expected to vary in antioxidant content. In addition, antioxidant contents are also speculated to change through the commercial stabilization process. For this project, bran from both long- and medium-grain rice was sampled and antioxidant content measured at different points in a commercial rice mill and bran processing facility. Antioxidant quantities were shown to significantly change for selected antioxidants through the process. Second, rice bran was extracted using super-critical CO_2 extraction to selectively extract more antioxidants than conventional hexane extraction. Significantly higher amounts of total oil, vitamin E, tocotrienol, and oryzanol were extracted using super-critical CO_2 extraction.

GROWTH AND YIELD OF TRANSGENIC COTTON UNDER VARIOUS WEED MANAGEMENT PROGRAMS

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Herbicide-resistant cotton and ultra-narrow spacing are emerging technologies that could potentially improve weed management and profitability of cotton production. A field study was conducted to compare development of transgenic cotton in conventional and ultra-narrow rows and to determine whether a soil-applied herbicide is needed in weed management programs for transgenic cultivars. Studies were conducted in Fayetteville and Little Rock in 1999. In Little Rock under conventional row spacing without a soil-applied herbicide, BXN47 was shorter and had narrower canopy than SG125, PM1220, and DP450 at any period. Plants grown in conventional row spacing were larger than those in ultra narrow rows regardless of cultivar. Plants in conventional rows also had a higher first-fruiting node, more bolls retained at second position, and more sympodia first-position bolls. In ultra-narrow row spacing, there was no difference in total bolls between PM1220 and BXN47, but in conventional row spacing, PM1220 had more total bolls than BXN47. In general, treatments with a preemergence herbicide followed by a postemergence had higher yields. Row spacing did not influence yield. In Fayetteville, canopy height and width measurements were larger for PM1220 at 45 and 60 days after planting (DAP) compared to BXN47. At 75 DAP, there was no difference in plant height regardless of cultivar, row spacing, and herbicide program. In conventional row spacing, more first- and second-sympodia bolls were produced as well as more total bolls. PM1220 retained more first- and second-position bolls than BXN47. PM1220 also had more total bolls than BXN47 in both row spacings. Plants in conventional row spacing had higher yields than those in ultra-narrow rows.

EFFECT OF pH ON DECOMPOSITION OF ORGANIC MATERIALS

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Not much definitive information on soil pH and decomposition is available in the literature. The objective of this study was to characterize the effect of soil pH on decomposition of organic materials. Three soil pH regimes were established in a Captina silt loam (fine-silty, siliceous, mesic Typic Fragiudult) over a 6-month period. Final pH values, determined on 1:2 (wt/wt) soil-to-water slurry, were 4.2, 5.7, and 7.4, and final microbial biomass values were 150, 139, and 208 mg C/kg soil for the alum, control, and lime treatments, respectively. After soil pH adjustment, one-half the plots were amended with fescue (*Festuca arundinacea*) hay. One month later, paper mill sludge, sorghum sudan grass (*Sorghum bicolor*), and biosolids contained in mesh bags were inserted into the soil, and decomposition was measured by substrate weight loss. Soil samples were collected periodically during the field study and assayed for pH, microbial biomass C, and laboratory incubation studies. Percentage laboratory decomposition was calculated by CO_2 evolution. Decomposition of the organic materials was not affected by soil pH in the field study. In the laboratory, where the differences were found among the treatments, decomposition was most commonly smaller in the soil treated with alum as compared to lime.

THE ROLE OF TREHALOSE IN DESICCATION TOLERANCE OF ENDOPHYTE-INFECTED TALL FESCUE

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Tall fescue infected with a fungal endophyte (*Neotyphodium coenophialum*) has increased survival under heat and drought conditions compared to uninfected tall fescue. However, the mechanism for drought tolerance in endophyte-infected plants is unclear. Trehalose, a disaccharide, is known to accumulate in a broad range of desiccation-tolerant organisms including plants, fungi, bacteria, and invertebrates. It appears to act as a membrane and enzyme protectant in these organisms under severe water stress conditions. To determine whether trehalose is a factor in desiccation protection of endophyte-infected tall fescue, carbohydrate analysis using gas chromatography was conducted on endophyte cultures and endophyte-infected tall fescue plants. Initial carbohydrate analysis of endophyte cultures showed the presence of trehalose as well as analysis of endophyte cultures grown on osmotically adjusted media. Trehalose was synthe-

sized by endophyte cultures grown on selective carbohydrate source media. Field studies comparing well-watered and water-stressed grasses were conducted using a rainout shelter to produce consistent drought stress. Significant changes in carbohydrate profiles were found. Trehalose was present in endophyte-infected plants, but there were no significant differences between water treatments.

AN INTERACTIVE, WEB-BASED SOILS INFORMATION SYSTEM USING DIGITAL GEOGRAPHIC DATABASES FOR ARKANSAS

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Soils are a finite and vital natural resource. Soil characteristics have a major effect on how soil and land can best be used, for example in agriculture, construction site selection, forestry, rangeland, water management, and wildlife habitat issues. Information on Arkansas soils exists in soil survey reports published by the Natural Resource Conservation Service and in SSURGO (Soil Survey Geographic) and STATSGO (State Soil Geographic) digital databases. The printed soil survey reports must be obtained for each county in which the user is interested and are cumbersome and inefficient to use. The SSURGO and STATSGO digital geographic databases require the user to have specialized geographic information systems (GIS) software to interpret the information. Thus neither of these is widely accessible or convenient to the public. Geographic information systems allow qualities of soils to be displayed in map form as well as queried to provide an efficient and meaningful way to analyze and interpret soil characteristics. The Arkansas Soils Information System (ARK-SIS) provides this technology over the Internet, serving information contained in the SSURGO and STATSGO databases directly and instantaneously to the user. Combining the technologies of GIS and the Internet allows ARK-SIS to serve the digital soils information effectively and to the greatest possible number of users, allowing online mapping and query of soils information to persons in research, the government, private industry, and the public.

ALTERNATIVES TO ATRAZINE FOR WEED CONTROL IN TRANSGENIC CORN

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The advent of transgenic corn cultivars that tolerate in-crop applications of nontraditional herbicides have transformed the methods by which a grower can attain superior weed control. Field experiments were conducted in 1999 at the Northeast Research and Extension Center, Keiser, on a Sharkey silty clay and at the Main Experiment Station, Fayetteville, on a Taloka silt loam to compare the weed control in glufosinate-, glyphosate-, and imidazolinone-resistant cultivars and to evaluate the need for atrazine in these systems. Each experiment was conducted as a randomized complete-block design with four replications. Experimental units were 4 by 8.2 m broadcast sown with velvetleaf (*Abutilon theophrasti*), pitted morningglory (*Ipomoea lacunosa*), entireleaf morningglory (*Ipomoea hederacea* var. *integriuscula*), large crabgrass (*Digitaria sanguinalis*), and prickly sida (*Sida spinosa*). Following incorporation of weed seeds, Dekalb 580RR, Pioneer 34A55LL, or Pioneer 3395 IR corn was planted at 65,000 seed/ha to a depth of 4 cm. There was no difference in yield between treatments receiving sequential applications of glufosinate, glyphosate, or single applications of imazapyr + imazethapyr as compared to a standard program of *S*-metolachlor + atrazine PRE followed by atrazine on four-leaf corn. The addition of atrazine did, however, improve control of pitted morningglory as compared to glyphosate at 0.84 followed by 0.63 kg/ha and single applications of imazapyr + imazethapyr at 0.063 kg/ha. Injury (16%) was noted on the glyphosate-resistant cultivar treated with metribuzin + flufenacet tank-mixed with isoxaflutole, and there was also a significant yield loss in the imidazolinone-resistant cultivar.

GLYPHOSATE APPLICATION TIMING BASED ON WEED CANOPY LEAF AREA INDEX VALUES IN SOYBEAN

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A field study was conducted during the summers of 1998 and 1999 at the University of Arkansas Main Agricultural Experiment Station in Fayetteville to determine, by total weed leaf area index (LAI), the most effective

timing for the initial application of glyphosate in narrow- and wide-row soybean production systems. The experiment was a completely randomized design. Weed seed for several species were spread across the field in varying densities in order to achieve varied weed densities. Asgrow 5601 RR soybean was planted at two-row spacings: 51 cm (wide row) and 19 cm (narrow row). Plots were 6.25 m^2 and were trimmed to 4 m^2 at soybean harvest. Glyphosate was applied over-the-top at a rate of 1.12 kg ai/ha from 7 to 56 days after emergence (DAE) and was repeated, as needed, through the growing season to prevent weed reinfestation. Prior to glyphosate application, crop and weed LAI were measured for eight wide-row and nine narrow-row plots based on plant samples taken from two 0.25 m^2 subplots. Data were analyzed using surface response analysis. Percent yield loss was predicted based on models for the two-row spacings. Predicted percent yield loss data were then analyzed by analysis of variance. Percent yield loss in wide rows was significant when the weed canopy achieved an LAI of 1 after 10 DAE. Initial glyphosate timings could be delayed up to 30 DAE for total weed LAI values less than 1 in wide rows. Percent yield loss in narrow rows was significant at weed canopy LAI greater than 0.4. Similar to wide rows, glyphosate application can be delayed in narrow-row soybean as long as the weed canopy LAI remains small. However, yield loss in narrow rows significantly increases at smaller weed canopy LAI values than wide rows, indicating a need to remove weeds earlier in narrow rows.

EFFECTS OF SUPPLEMENTATION AND NITROGEN FERTILIZATION ON STOCKER CATTLE PERFORMANCE

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This research evaluated the effects of an energy supplement at two N fertilization rates (111 or 149 kg N/ha) on grazing cattle performance. In 1999, 76 steers were assigned to 12 pastures 0.81 ha in size. The supplement was fed at 0.65% of body weight (BW), and treatments within each N fertilization rate consisted of (1) nonsupplemented (NS) at a normal stocking rate, (2) supplemented (S) at a normal stocking rate, or (3) S at a high stocking rate. At the normal stocking rate, average daily gain (ADG) and gain/ha (GH) were less ($P < 0.05$) for the NS steers than S steers across fertilizer rates, but ADG and GH were greater ($P < 0.05$) for the S steers at the normal stocking rate than the high stocking rate. Steers grazing pastures fertilized at the low N rate had a greater ($P < 0.05$) ADG than steers grazing pastures fertilized at the high N rate, while the GH was greater ($P < 0.05$) for high N pastures than for low N pastures. The ratio of supplemental dry matter (DM) to added GH was lower ($P < 0.05$) for low N pastures than for high N pastures at the normal stocking rate. At the high stocking rate, the ratios of supplemental DM to added GH for steers grazing low N pastures was lower ($P < 0.05$) than for those grazing high N pastures. In conclusion, at the low N fertilization rate, supplementation seemed advantageous, but at the high N fertilization rate, poor supplemental conversions indicated that forage may have been limiting.

GERMINATION AND SURVIVAL OF FIVE PLANT SPECIES IN A PETROLEUM-CONTAMINATED SOIL

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and Chemical Engineering

Phytoremediation is an alternative technology that could be used to remediate petroleum-contaminated soil at drilling rig sites. The goal of phytoremediation is to enhance the biodegradation rate and to lower contamination concentrations to acceptable levels. A necessary prerequisite for phytoremediation is vegetation of the contaminated soil. The objectives of the greenhouse study was to evaluate germination, survival, and growth of alfalfa, bermudagrass, crabgrass, fescue, and ryegrass in a crude oil-contaminated soil with and without amendments. Amendments evaluated were inorganic fertilizer, broiler litter, paper mill biosolids, and hardwood sawdust. Broiler litter significantly decreased seed germination, but increased shoot and root biomass in the contaminated soil. Fescue and ryegrass had the highest germination percentages. Ryegrass and crabgrass had significantly greater root surface areas than did fescue or

alfalfa. Results from the study can be used to select plant species to establish at crude oil-contaminated sites and demonstrate the benefits of adding soil amendments.

PHYSIOLOGICAL COMPARISON BETWEEN ASCITES-RESISTANT, ASCITES-SUSCEPTIBLE, AND THE RELAXED LINE OF BROILERS

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Ascites is a metabolic disease of fast growing meat-type birds. Proper management can reduce ascites. The permanent solution to this poultry disease is genetic selection for ascites-resistant lines. The objective of this research was to determine the differences in ascites-resistant, ascites-susceptible, and the relaxed line of broilers. Broilers were reared in floor pens with feed and water for ad libitum consumption. Birds were cold-stressed at 4 hours after hatch and again on day 14 (10ºC for 5 hours) to initiate an ascitic response. At 6 weeks, the trial was terminated. Whole-body, liver, spleen, and split heart and lung weights were recorded. The lung cavity was measured, and birds were scored for ascites. Results showed body weights were not statistically different among all groups. Susceptible birds showed more right ventricular hypertrophy ($P > 0.0001$) than controls and resistant birds. Ratio of total heart to body weight was significantly higher ($P > 0.002$) in the susceptible and resistant birds. Ascites mortality was not significantly different among the lines. Lung weights in the resistant birds were significantly heavier ($P > 0.05$) than those of control and susceptible birds. Lung cavity width was significantly smaller ($P > 0.06$) in the resistant birds than the control birds. Results indicate selection for a larger heart and lungs and narrower lung cavity in the resistant line of broilers.

GRADUATE POSTER COMPETITION

WEED CONTROL IN A CLOD-FURROW SOYBEAN PLANTING SYSTEM

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Water imbibition by the soybean seed is a crucial step in soybean growth. The clod-furrow soybean planting system is used to ensure that the soybean seed has sufficient moisture to germinate and was developed to give producers an alternative planting system in a dry spring or early summer. The field is prepared by hipping the ground and leveling the top of the bed with a field cultivator. The beds are re-hipped, leveled, and finally rolled before irrigation. Studies to evaluate weed control in the clod-furrow system were established at Pine Tree (silt loam) and Keiser (heavy clay), on 26 May and 22 June 1999, respectively. Treatments were Treflan at 0.75 lb ai/A preplant incorporated (PPI), Squadron at 0.87 lb ai/A PPI, Dual II Magnum at 1.27 lb ai/A preemergence (PRE), Frontier at 1.27 lb ai/A PRE, Canopy XL at 0.23 lb ai/A PRE, Canopy at 0.375 lb ai/A PRE, Squadron at 0.87 lb ai/A PRE; and postemergence applications of Reflex at 0.375 lb ai/A V3 (soybean growth stage), Storm at 0.75 lb ai/A V3, Typhoon at 0.546 lb ai/A V3, Roundup Ultra at 1.0 lb ai/A V3, Roundup Ultra at 1.0 lb ai/A V3 and V6, Roundup Ultra at 0.75 lb ai/A V3, V6 and R1. AG-98 surfactant was added to all postemergence herbicides except Roundup Ultra. Each study utilized a randomized complete-block design, and means were separated by least significant difference at the 0.05 significance level. Storm, Reflex, and Typhoon were weaker than the other treatments on all weeds. Treflan, Squadron, Reflex, Storm, and Typhoon reduced soybean yields. Preemergence herbicides provided season-long control of grass species. Dual II Magnum and Frontier controlled prickly sida and entireleaf morningglory less than other treatments. Single and sequential applications of Roundup Ultra provided soybean yield and controlled weeds all season.

PHOSPHORUS AND FORAGE ANALYSIS OF POULTRY-LITTER AMENDED PASTURES

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An expanding poultry industry in Arkansas produces increasing amounts of animal waste in the form of litter. Poultry litter is commonly surface-applied on pastures as a fertilizer to promote forage growth for beef cattle production. Phosphorus build-up from long-term applications can lead to runoff losses and reduced water quality. Pastures in Arkansas consist of highly variable soils and landscape features. Litter application rates need to be varied according to the local soil conditions in order to avoid high-risk areas of runoff. Detailed analysis of the farm soils, forages, and landscape can aid in targeting litter rates in ways consistent with forage production

and water-quality goals. A commercial beef farm that uses poultry litter for fertilizer was intensively sampled for soil test phosphorus (STP) and forage composition. Maps were then compiled of STP, field boundaries, and forage species using a geographic information system (GIS). A 20-m grid pattern was sampled to study variation on a 10 to 15% slope that bordered an intermittent stream. Vegetative cover on the 20-m grid was nearly 100%. Soil test phosphorus levels far exceeded the 112 kg/ha level considered the maximum requirement for grass growth. Variation maps show a decreasing gradient of STP sloping toward the stream. The very high STP levels on this slope suggest a risk of phosphorus runoff despite the dense vegetative cover. The area of field bordering the stream is a high-risk zone of entry of phosphorus into the stream, and therefore would call for placement of a no-litter-application buffer strip. The GIS technology furnishes a useful tool for developing site-specific forage management plans that are consistent with environmental objectives.

EFFECT OF INSECTICIDE TERMINATION AT 250, 350, AND 450 HEAT UNITS ON CARBON PARTITIONING FROM UPPER-CANOPY LEAVES TO THE DEVELOPING BOLL LOAD

Robert "Scott" Brown, D.M. Oosterhuis, Charles T. Allen, and F.M. Bourland,
Department of Crop, Soil, and Environmental Sciences

The crop monitoring program COTMAN uses the concept of 350 heat units after anthesis of the last effective flower population at NAWF = 5 for termination of insecticide applications. It has been reported that terminating insecticides at 350 heat units after NAWF = 5 results in a higher yield than when terminating at either lower or higher heat unit values, although evidence is lacking. It is hypothesized that insect damage to upper-canopy (above NAWF = 5) squares results in improved partitioning of carbon to lower developing bolls. Two field studies were conducted to determine how removing this upper-canopy fruit at various heat units affected yield, as well as boll weight and fiber quality of first position bolls at NAWF = 5. Treatments consisted of a control with no fruit removal and hand removal of all upper-canopy fruit above NAWF = 5 at 250, 350, and 450 heat units. The data from the 1998 season supported the COTMAN concept of insecticide termination at 350 heat units after NAWF = 5. However, the results from the 1999 study suggested that yield and fiber quality were the highest when fruit was not removed. Further field verification is required.

PRODUCTION AND UTILIZATION OF CUCUMBER FLAVORS FOR INHIBITING YEAST GROWTH IN PICKLE BRINES

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Department of Food Science

Excessive yeast growth in cucumber pickle brines causes bloating, loss of lactic acid, and off-flavors. Sorbic acid is widely used by pickle manufacturers to inhibit yeast growth, but it is unstable and expensive. Preliminary studies indicated that cucumber flavors, trans-2-cis-6-nonadienal and trans-2-nonenal, were inhibitory to yeast growth. Objectives were to determine the effectiveness of trans-2-cis-6-nonadienal and trans-2-nonenal on yeast inhibition and factors that affect flavor production. Samples of commercial pickle brines [105 to 106 colony-forming units (CFU)/ml] were obtained as the yeast source. Effects of trans-2-cis-6-nonadienal and trans-2-nonenal concentrations on yeast growth in brines for pH (2.3 to 4.3) and NaCl (2.5 to 10%) were determined. Samples were extracted by pentane and analyzed by GC-FID (gas chromatography-flame ionization detector). Effects of cucumber juice storage, fermentation, temperature, and substrate addition on production and stability of the cucumber flavors were examined.

EFFECT OF DRILLED ROUNDUP READY SOYBEAN POPULATIONS ON ECONOMIC RETURN

Jeff T. Edwards, J.K. Norsworthy, and L.R. Oliver,
Department of Crop, Soil, and Environmental Sciences

Roundup Ready technology is an effective tool for control of many problem weeds, and Roundup Ready cultivars have been readily adopted. Increased seeding costs due to technology fees have led to a transfer of production costs from herbicide to seed expense. In 1998, a 2-year study was initiated on a Sharkey clay at the Northeast Research and Extension Center, Keiser, to determine the optimal seeding rate of Roundup Ready soybean in terms of both yield and economics. Soybean seeds were drilled in 19-cm rows with a John Deere 750 no-till drill on 2 June 1998 and 25 May 1999 at 12 rates ranging from 185,000 to 1,485,000 seeds/ha. Each plot received

a single application of either 0.56 or 1.12 kg ai/ha glyphosate when weeds reached a height of 5 to 7 cm. Weed control ratings were visually taken every 2 weeks following initial glyphosate application. Plots were resprayed with the original rate of glyphosate when control of any weed species fell below 90%. Gross margins were calculated by subtracting total weed control cost from total revenue received from sale of seed. The 988,000 seed/ha rate had the highest yield of 3,317 kg/ha and a gross margin of $539.87/ha. The 247,000 seeds/ha provided the highest gross margin of $625.00/ha. The lowest gross margin was $393.47/ha at the 1,482,000 seeds/ha planting density. The greater yields and quicker canopy closure associated with higher seeding rates were not sufficient to offset increased planting costs; therefore, the low cost of glyphosate applications relative to Roundup Ready seed indicates that producers can easily offset higher herbicide and application costs with savings from reduced seeding rates.

EFFECT OF CORONJ SLOW-RELEASE FOLIAR NITROGEN FERTILIZER ON COTTON GROWTH AND YIELD

S. Karen Gomez, D.M. Oosterhuis, and C.R. Meek, Department of Crop, Soil, and Environmental Sciences

Evidence has shown that soil fertilization cannot always meet cotton's high demand for nitrogen, and supplementation with foliar fertilizer has become a widespread practice. However, yield responses to foliar-applied nitrogen have not always been consistent. CoronJ, a slow-release nitrogen fertilizer, has been proposed as a potentially superior alternative method of foliar feeding with nitrogen. The value of CoronJ for enhancing growth and yield of cotton was evaluated in a 6-year field study in Arkansas. Foliar application of CoronJ to field-grown cotton resulted in significant ($P = 0.05$) yield increases in 2 of 6 years, with an overall average increase of 51 kg lint/ha compared to the control. CoronJ had a small, nonsignificant yield advantage compared to foliar urea alone. Furthermore, CoronJ caused a significant increase in boll weight in 1 of the 4 years that the measurement was taken, with no significant effect on boll number. The effect of CoronJ on petiole nitrate concentrations was inconsistent. From this work it can be concluded that CoronJ as foliar nitrogen fertilizer does not consistently improve cotton production.

LECITHIN AND MEDIUM-CHAIN TRIGLYCERIDES–BASED EMULSIONS IN AN ICE CREAM–LIKE PRODUCT

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Many consumers are concerned about calories, saturated fat, and cholesterol, and there is a trend to limit fat intake, especially dairy fat. These concerns have had an impact on consumption of ice cream, butterfat, and other dairy products. Lecithin is currently used in pharmaceuticals and biomedical research as an emulsifier to create an emulsion as a medium to meet a specific nutritional requirements of target groups such as the elderly, people with human immunodeficiency virus, and children. Medium-chain triglyceride (MCT) is a modified lipid derived from saturated fats such as palm kernel oil or coconut oil that provides 6.9 cal/g. This project was undertaken with the main goal of developing an ice cream-like product using MCT, lecithin, and water. The principal objectives were (1) to optimize the process/formulation of an ice cream-like product containing various levels of MCT, lecithin, stabilizers, soy flour, and sugar by examining its rheology, texture, and structure and (2) to evaluate the sensory trails of the formulated products with a trained descriptive panel and by consumer testing. The result showed that the MCT levels influenced the size of the lipid globules in the emulsion. In addition, viscosity of the ice cream mixes increased with increasing aging time and stabilizer level. An instrumental penetrometer test allowed the optimization of the hardness of the various ice cream formulations tested. Sensory evaluation data (i.e., both descriptive and consumer testing) showed that the use of soy products such as lecithin and defatted soy flour should be minimized to maximize consumer acceptance.

MICROBIAL POPULATIONS IN PETROLEUM-CONTAMINATED ARCTIC, SUB-ARCTIC, AND TEMPERATE SOILS

Heather L. Nichols, D. C. Wolf, C. M. Reynolds, and B. A. Koenen, Department of Crop, Soil, and Environmental Sciences

Biodegradation of organic contaminants in soil is largely determined by the composition and activity of the microbial population. As part of a field program assessing the influence of temperature, nutrients, and plants on

remediation, we characterized the initial microbial status of contaminated soils from Barrow, Galena, and Annette Island, Alas. These three locations have mean annual temperatures of –11.5, –1.8, and 8.8ºC, respectively. Total plate counts were used to enumerate bacteria and fungi. Cyclohexanol-, benzoate-, and motor oil-degraders were determined using most probable number (MPN) methods. Prior to treatment, Barrow and Annette Island had significantly lower cyclohexanol-degraders than Galena with log10 MPN/g soil levels of 5.39, 5.95, and 6.91, respectively. Barrow had significantly lower benzoate-degraders compared to the Galena and Annette Island sites. Bacterial numbers, N, P, K, and Ca levels were highest at Galena, followed by Annette Island and Barrow. Initial median total petroleum hydrocarbon levels were 3,500, 2,000, and 21,000 mg/kg for the Barrow, Galena, and Annette Island sites, respectively. Microbial numbers and chemical levels of plots within a block were generally not significantly different. Biological and chemical parameters will continue to be evaluated through time to determine the effects of nutrient addition and plants on remediation of the petroleum-contaminated sites.

EFFECTS OF CALENDAR DATE AND SUMMER MANAGEMENT ON in situ DRY MATTER DIGESTIBILITY OF STOCKPILED BERMUDA

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Five ruminally cannulated, cross-bred steers (mean body weight = 387 kg) were used to determine the effects of calendar date and previous summer management scheme on the kinetics of in situ dry matter (DM) disappearance of stockpiled Greenfield bermudagrass. At one site, forage was stockpiled after summer hay management with high inputs of N fertilizer from poultry litter and commercial sources. At the second site, forage was stockpiled after summer pasture management with moderate N inputs. Forage samples were taken from each site under caged enclosures at 4-week intervals, beginning 17 October 1997 and ending 9 January 1998. On the basis of in situ analysis, forage DM was partitioned into three fractions. Fraction A was defined as being immediately soluble. Fraction B was defined as being digestible at a measurable rate; fraction C was defined as that part of the forage that was unavailable to the animal. At the hay site, the degradation rate decreased ($P < 0.05$) from 0.048 to 0.035/hour over the sampling period, while the potential extent of digestion decreased ($P < 0.05$) from 65.6% in October to 44.9% in January. Fraction B decreased ($P < 0.05$) between October (43.9%) and January (27.5%); fraction C increased ($P < 0.05$) from 34.4 to 55.0% over the same time period. Similar trends were observed for the forages harvested at the pasture site; however, degradation rates did not differ across dates. These data indicate that stockpiled bermuda should be utilized in late fall or early winter for optimal animal performance.

CONTROL OF *Listeria monocytogenes* ON THE SURFACE OF REFRIGERATED, READY-TO-EAT CHICKEN COATED WITH EDIBLE ZEIN FILMS CONTAINING NISIN

Marlene E. Janes, Rammakrishn Nannapaneni, and Mike G. Johnson, Department of Food Science and Center for Food Safety and Quality

Refrigerated, ready-to-eat foods can cause health problems if the prepared food is undercooked or becomes cross-contaminated with *Listeria monocytogenes* (LM). This study was conducted to determine the inhibitory activities of nisin directly added to zein edible films coated onto the surfaces of refrigerated, ready-to-eat chicken for protection against growth of LM. Cooked chicken samples (5 g) were immersed into 24-hour broth cultures of LM strain V7 for 30 seconds and allowed to drip free of excess inoculum. The meat samples were dipped into an edible zein film (Z) dissolved into either propylene glycol (ZP) or ethanol (ZE), with and without added nisin (N) (1000 IU/g) and/or 1% calcium propionate (CP). Chicken samples were placed into sterile bags and stored at 4 or 8ºC for up to 24 days. Bacterial counts were examined at 0, 4, 8, 16 and 24 days by spread-plating samples on agar medium and incubating at 37ºC for 24 hours. Upon an initial inoculation of 6.5 log colony-forming units (CFU)/g, LM grew to 8 log CFU/g by 4 days at 8ºC and by 8 days at 4ºC. Under these conditions, LM growth was reduced from 4.5 to 5 log CFU/g with ZEN, ZPNCP, and ZENCP by 16 days at 4ºC. Furthermore, ZPNCP was the most effective treatment, reducing LM by 5.0 log CFU/g by 24 days. The antimicrobial effect of nisin was lower at 8ºC, causing a 3-log CFU/g reduction for ZPN and ZPNCA by 24 days. A challenge level of 2.7 log CFU/g of LM was reduced to undetectable levels with ZEN, ZENCP, and ZPNCP from day 0 to

day 24 at 4°C. Our results indicate that zein edible films with or without nisin and calcium propionate coated on refrigerated, ready-to-eat meat products can provide additional safeguards needed to prevent possible growth of LM, which can gain entry and recontaminate meat or poultry products between the cooking and packaging steps.

A JASMONIC ACID-INDUCIBLE RICE *myb* GENE ASSOCIATED WITH FUNGAL INFECTION AND HOST CELL DEATH

Min Woo Lee and Yinong Yang,
Department of Plant Pathology

Plants defend themselves against many pathogens through induced resistance responses. Endogenous plant molecules such as salicylic acid and jasmonic acid are known to mediate complex defense signaling pathways that lead to the transcriptional activation of defense genes. As a result, pathogen-induced plant transcription factors play an important role in regulation of defense gene expression and establishment of local and systemic resistance. Recently, virus- and bacterium-induced plant *myb* transcription factors have been isolated from tobacco and *Arabidopsis*, respectively, and shown to be associated with disease resistance. In this study, we have cloned and characterized a jasmonic acid-induced rice *myb* gene (*JAmyb*) that is associated with fungal infection and host cell death. The *JAmyb* gene was induced by rice blast fungus (*Pyricularia grisea*) in both resistant and susceptible interactions. It was also induced during spontaneous lesion formation in lesion mimic mutants of rice. Interestingly, *JAmyb* was specifically activated by jasmonic acid, an effective inducer of systemic acquired resistance in rice. Together, these results suggest that the blast fungus-induced *JAmyb* transcription factor is related to host cell death and is likely involved in jasmonic acid-mediated disease resistance in rice.

DROUGHT TOLERANCE AND FOLIAR SPRAYS OF GLYCINE BETAINE

Cassandra R. Meek and D.M. Oosterhuis,
Department of Crop, Soil, and Environmental Sciences

Water is the most limiting factor in cotton production, and numerous efforts have been made to improve crop drought tolerance. Field studies were conducted in 1998 and 1999 to determine whether foliar application of glycine betaine would enhance yield in cotton under both drought and irrigated conditions. In 1998, glycine betaine-treated plants had numerically but not significantly ($P = 0.05$) greater boll numbers, bollweights, and lint yields, but no differences were significant ($P = 0.05$). In 1999, yields were inconsistent, with glycine betaine generally having no effect. No differences in photosynthetic rate between treated and untreated plants were encountered either year of the study. In 1999, plant water relation trends suggested that glycine betaine might assist in osmotic adjustment.

SPATIAL ANALYSIS OF *Alphitobius diaperinus* (COLEOPTERA: TENEBRIONIDAE) IN BROILER PRODUCTION FACILITIES

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Spatial analysis of the lesser mealworm, *Alphitobius diaperinus*, was conducted to aid integrated management of this beetle pest. A mealworm population was monitored weekly using tube traps in a broiler facility for five consecutive flock grow-outs. Litter temperature, pH, and relative humidity were measured concurrently at the same locations as tube trap placement. A geographic information system was used to display weekly spatial relationships of adult and larval beetles during each flock grow-out. A model was then created to predict areas of the facility that had high beetle numbers by analyzing weekly environmental conditions within the broiler facility. Spatial maps of beetle populations showed that the beetles occurred in the east end and center of the facility early in each grow-out and then moved toward the west end of the facility in later weeks of each grow-out. The predictive model of the beetle population reached accuracy as high 86.7% and readily displayed areas in the facility where control efforts would have the greatest impact on beetle numbers without the need to use tube traps.

TEXTURAL CHANGES IN MUSHROOMS (*Agaricus bisporus*) ASSOCIATED WITH CELL WALL COMPOSITION AND ULTRASTRUCTURE

Svetlana Zivanovic, Ron W. Buescher, and Kyung S. Kim,
Departments of Food Science and Plant Pathology

Although texture is an important quality parameter of fresh mushrooms, the understanding of what causes adverse textural changes of mushroom tissue is still incomplete. The objective of this study was to determine

ultrastructural and compositional changes in fresh mushrooms associated with adverse changes in texture after harvesting. Freshly harvested mushrooms were stored at 12ºC for 0, 3, 6 and 9 days. Softening and toughening were measured by a TA.XT2 texture analyzer by puncture and compression measurements, respectively. Scanning and transmission electron micrographs were obtained from top and center of pilei. Proteins, carbohydrates, and chitin were analyzed in sequential extracts of alcohol insoluble solids (AISs). Monosaccharides, in hydrolyzed AISs, were analyzed by gas chromatography as alditol acetates. Force for puncturing pilei declined from 2.6N to 1.5N. Toughening, expressed as gumminess, increased during the first 6 days from 19.2N to 40.3N and than declined to 33.0N. During storage, protein and total carbohydrate content declined (57.7% and 41.1%, respectively), but chitin content increased (96.7%). The dominant monosaccharide in AISs was glucose (approx. 70% of total). Other detected monosaccharides were galactose, mannose, and in lower concentrations, ribose, xylose, and fructose. Most polysaccharides were extracted after deacetylation and depolymerization of chitin, indicating that structural glucans are mainly bound with acetylglucosamine polymers. Softening paralleled expansion of intercellular space at the pilei surface, hyphae shrinkage, central vacuole disruption, and losses of proteins (R = 0.94) and polysaccharides (R = 0.84); increased chitin content was related to toughening (R = 0.95).

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Jones, G.R., W.F. Smith, and T.Q. Brown. 1999. Seasonal nitrate content of tall fescue. Agronomy J. 55(3):49-53.

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National Research Council. 1994. Nutrient Requirements of Poultry. 9th rev. ed. National Academy Press, Washington, D.C.

Ryugo, K. 1998. Fruit Culture: Its Science and Art. John Wiley and Sons, London.

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