Improved Feed Efficiency in Chickens: Case Study 4

Research goal	To improve feed efficiency and carcass quality in broiler production. To develop a mathematical model to simulate and determine the optimal daily feed intake.
Beneficiaries	Producers and consumers.
Activities conducted in order to achieve the objectives	Large-scale field experiments. Analysis of bird growth between restricted and unrestricted feeding protocols. Development of an algorithm and a mathematical model and its incorporation into a computer software package.
Funding	2 BARD awards: IS-735-84, IS-1234-87C: $400,000 between 1984 to 1989. Other research funds: $100,000. Estimated industry investments: $4.2 million.
Publications	19 publications. 3 were cited more than 100 times each.
Students involved	Two graduate students. Currently: one in the breeding industry.
Stakeholders' collaboration	The model was used as a research tool in Texas A&M University. An extension feeding program for broiler growers was established in Israel.
Environmental impact	The improved broiler feed conversion ratio, reduced resources required for the global industry by 20,000 ha land use and 126 million cubic meters of rainfall water.
Social impact	The model is used to support smallholder farmers worldwide, increasing access to protein-rich food in the developing world.
Commercial engagement	The mathematical model was purchased by the US company, Novus International, and is today implemented worldwide by the private sector.
Patents	None
Practical agricultural applications	The model is implemented in more than 130 countries.
Economic impact	Net present value of the BARD's investment is $788 million, thereof $382 million already attained. The Internal rate of return is 28% Benefit cost ratio is 410, thereof 199 already attained. The NPV for the US economy is $150 million The NPV for the Israeli economy is $2.

Green- Academic information; Yellow - Social and environmental information; Blue - Economic information

1 Objective: Improving Feed Efficiency and Feed Conversion Ratio in Poultry

The cost of feed represents 65%-75% of broilers production costs. [1] The research aimed to improve the efficiency of feed consumption and to develop an innovative mathematical model capable of predicting the magnitude of the compensatory growth effect, and translating it to an optimal feeding.

2 Research Activities

Between 1984 and 1990, S. Hurwitz (ARO) and J.P McMurtry (USDA) developed and tested a feeding model that optimized the birds feed intake and monitored the FCR (Food Conversion Ratio). See Appendix A for full details of the awards.

The results of the first BARD project (IS-735-84) suggested that birds subjected to feed restrictions early in life exhibited “compensatory growth” and surpassed the final weight of unrestricted birds. Compensatory growth reduced the amount of feed needed to attain a targeted body weight. In the second project (IS-1234-87C) the results were validated for a large range of feed restriction conditions and for several broiler strains. S. Hurwitz and H. Talpaz (ARO) developed a mathematic algorithm to support the feeding trials, incorporating several non-linear criteria. The algorithm, named ChickOpt (Chicken Optimization), simulates the broiler-growing curve and determines an economically optimal feeding regime. ChickOpt has been incorporated into a computer software package.

3 Academic Impact

3.1 Publications

19 peer-reviewed journal publications were published based on research from the BARD awards. Three publications were cited more than 100 times each.

3.2 Capacity Building

Two postgraduate researchers were involved in the research in Israel and in the US. One is currently working in the broiler industry in Israel.

4 Stakeholder's Collaboration

H. Talpaz held a teaching post at Texas A&M University, where he used the model as a research tool. In Israel, I. Plavnik (ARO) developed an extension program for broiler growers that trains towards implementation of the new feeding system.

[1] https://www.usitc.gov/publications/332/poultry1.pdf

5 Commercial Engagement

The ChickOpt algorithm was a major development leading to fast and accurate feed optimization calculations. In 1995, Novus International, a food additive producer, acquired the license to use the model for a sum of $800,000 from ARO. In parallel, the researchers established a private company, LIDM (Livestock Information Decision Making), to support Novus Int. in the implementation of the model. Through Novus, a feeding program based on the model has served around 2 billion broilers annually. Throughout the years, no patents were issued. In 2000, the model was purchased by an additional breeder company who continued further development of the software, and implemented its eventual widespread adoption starting in 2006.

6 Practical Agricultural Applications

Our data is based on personal consultations with global and local experts, and on the evaluation conducted for this project in 2000 by BARD. We estimate that about 50% of the US market and 70% of the global market (not including China), are provided with feeding programs created by the model and its updated versions. There are a few other models in the market, all of them controlled by the private sector, as described by E. Oviedo[2]. In Israel, as an example, two of the main three feed mills follow the instructions passed to them with some specific local variations. The third Israeli feed mill uses the instruction as a reference, and they reported that until 2014 they had their own “Hurwitz model” for turkey feeding. They stopped using it only because there was no maintenance service available. The model was implemented between 1997 – 2000 and since 2006 has been implemented at a wide-scale implementation in the US and globally.

7 Social Impact

The model is used to support brooder units that are suited also for the developing world. This enables living income for smallholder farmers, while increasing the public's accessibility to protein-rich food.

8 Environmental Impact

Broiler's feed contains mainly 60% corn and 35% soybeans. In order to produce 1 ton of this diet, 0.15 ha and 900 cubic meters of rainfall water are required. In the US, we attribute to the model a reduction of 24,000 tons of feed in 2018. This can be translated to a reduction

[2] https://books.google.co.il/books?id=r99uBgAAQBAJ&pg=PA128&lpg=PA128&dq=lidm+talpaz&source=bl&ots=_juxsqVXfa&sig=ACfU3U1bnzE3XgfJ8FbxEFdL_QOfyeZ1XQ&hl=iw&sa=X&ved=2ahUKEwiP5KeckrzgAhXVtXEKHei2DWgQ6AEwAHoECAoQAQ#v=onepage&q=lidm%20talpaz&f=false

of 3,600 ha land use and 22 million cubic meters of rainfall water.[3] The same calculation for worldwide production indicates a reduction of 20,000 ha land use and 126 million cubic meters of rainfall water.

9 Economic Impact

9.1 Investment Cost

BARD contributed $400,000 in two research awards between 1984 to 1990, which is $2 million in 2018 dollar-terms. Texas A&M Agricultural Experiment Station, and the poultry board in Israel, contributed approximately $400,000 to the researcher's work, but not specifically for the ChickOpt development. 25% of this funding is considered to have contributed to the model. Industry has financed trials and model development since 1995, continuing until today. We do not know the amount invested by industry, and we estimate that in nominal dollar-terms the industry contributed $4.2 million.

9.2 The Benefits.

The model aims to optimize the economic margin over feed cost. However, this indicator differs between places and between periods, because prices change and consumer's preferences change. Therefore, we use the efficiency biological indicator of FCR (Feed Conversion Ratio) which is the number of kg feed needed to produce one kg live weight. The benefits are calculated by estimating the contribution of the model to decreases in FCR over time.

FCR Improvement

Table 1 shows that in the US, the FCR in 1980 was 2.05, and by 2017 it decreased by almost 11% to 1.83. More than half of this improvement occurred between 2006 to 2017.[4] The table shows a 5-gram average annual improvement from 1980 to 2000. A negative trend follows between 2000 - 2006 and from 2006 to 2017 there is a dramatic improvement of 12 grams annually.

Studies from 2001–2003 indicate that genetic selection is responsible for 85%-90% of the change in feed conversion efficiency. They estimate that improved nutrition has provided

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[3] Analysis of: https://www.nass.usda.gov/Charts_and_Maps/Field_Crops/cornyld.php
https://www.nass.usda.gov/Charts_and_Maps/graphics/soyyld.pdf
https://www.extension.purdue.edu/extmedia/NCH/NCH-40.html
https://academic.oup.com/japr/article/23/4/593/834487

[4] https://www.nationalchickencouncil.org/about-the-industry/statistics/chicken-broiler-and-other-production-head-and-live-weight/
https://www.nationalchickencouncil.org/about-the-industry/statistics/broiler-chicken-industry-key-facts/
https://www.nationalchickencouncil.org/about-the-industry/statistics/u-s-broiler-production/
https://www.nationalchickencouncil.org/about-the-industry/statistics/wholesale-and-retail-prices-for-chicken-beef-and-pork/

10%-15% of the change.[5] A 2014 research study evaluated broiler performance as a function of different feeding programs. It was concluded that the feeding program based on the modern Cobb Vantress manual, resulted in 8% higher gross economic margin over feed than programs based on the traditional diet.[6]

In Israel, the improvement over the last decade has been more dramatic, in some years showing a 40 gram annual improvement.[7] For some Palestinian growers who purchase the same chick breed from the Israeli suppliers but do not follow the recommended feeding programs, the estimated FCR is 200 grams higher.**Error! Bookmark not defined.** We assume that these growers also do not have the same level of training nor the same quality of facilities.

Table 1: FCR for the U.S. Industry, 1980–2017

Performance indicators	**1980**	**1990**	**2000**	**2006**	**2017**
FCR	2.05	2.00	1.95	1.96	1.83
Annual average improvement in grams		5	5	-2	12

Benefit Attributed to the ChickOpt Model

Since 1995 until today the same team constantly develops the Chock-Opt model and its updated versions. It is assumed that in 2006 the feeding program was supplied to 30% of the American market, and that today it is provided to around 50%. We also assume that not all the growers follow the feeding instructions precisely. Therefore, we estimate[8] that:

- Feeding programs based on the model contributed 6% of the FCR improvement since 2006 to the US farmers who followed it. An additional $6.4 million (nominal dollar-terms) contribution is calculated for the firt stage of the models use between 1997 – 2000.
- The model is active in an average of 45% of the US industry
- The US industry is highly vertically integrated making the adoption of these methods much easier to obtain. Therefore, we assume that 50% follow the feeding program instructions with some specific local variations. For the rest of the world we downgrade this assumption to 30% adoption.

This calculation sums the model influence to 1.4% of the US FCR improvement (6%×45%×50%=1.4%). Table 4 (See Appendix B) shows the total US industry FCR improvement between 2006 to 2018 and the economic benefits attributed to BARD based

[5] https://pdfs.semanticscholar.org/bb63/74f399b364f2fea8da948000fb38d776bd4e.pdf
https://pdfs.semanticscholar.org/eb96/88a1f20c1948fea7b1ae195916af326c402a.pdf
[6] https://academic.oup.com/japr/article/23/4/593/834487
[7] In Hebrew: https://www.moag.gov.il/shaham/ProfessionalInformation/Pages/sicum_ona_ofot_2015.aspx
[8] Based also on personal communication with Professor Edgar Oviedo

on this 1.4% contribution. To reflect the economic benefit, we added the share of the retail and wholesale sector in the end-consumer price, that is 33% in the US. As an example, in 2018 the industry saved $1.5 billion of feed cost compared to 2006. We attribute 1.4% of it to the feeding programs based on the model = $23.4 million in 2018.

Expansion of the Industry

US broiler's production annual growth rate was 1.7% between 2010 to 2017.[4] We assume that the future benefit that can be attributed to the model between 2019-2028 will grow at the same rate.

Worldwide Benefit

World broiler production without China is 3.6 times the US production.[9] Based on interviews with experts we assume a 70% global exposure to the feeding program, from which we derive an assumed 30% rate of adoption. Hence, we estimate the benefit in 2018 to the rest of the world as 3.8 times the US benefit (3.6× (30%/50%) × (70%/45%) =3.8). This sums the model's 2018 benefit to the rest of the world as 3.8×20.8=$79 million. We assume that it will grow annually by 1.7%.

10 Economic Results

BARD invested in the initial and hence risky part of the project, when the field trials were difficult, and there was not enough knowledge on how to translate the parameters emerging from the trials into a complicated mathematical and applicative dynamic model. According to the calculation described in the methodology section we attribute 38% of the benefit to BARD.

- Net present value of the BARD's investment is $788 million, thereof $382 million already attained
- The Internal rate of return is 28%.
- Benefit cost ratio is 410, thereof 199 already attained.

The US economy benefit is calculated according to the production in these two countries.

Benefits attributed to the project that were not included in the calculation:

- The Environmental impact and social impact, as detailed above, were not included in the benefit calculation
- The evaluation is focused on broiler production, even though it influenced also the turkey industry

[9] http://www.fao.org/3/CA2129EN/ca2129en.pdf

- Since 1995 until today, an Israeli company is implementing and developing this model. An American based activity uses the model as part of a global business strategy. These contributions to the Israeli and to the US economy were not included.

Table 2: Main Results, 2018 Million Dollar-Terms

	The Project	BARD	BARD Attained	Thereof to the US	Thereof to Israel	Other Countries
BARD's Share in the Cost	23%					
Share in the Benefit		38%				
Cost	8	2	2	1.0	1.0	
Benefit	2,078	790	384			
Net Present Value	2,070	788	382	168	3	617
Internal Rate of Return	33%	28%	28%	27%	7%	
Benefit Cost Ratio	253	410	199	175	3	

10.1 Sensitivity Analysis

The low and high alternative assumptions used in the sensitivity analysis were brought together to estimate results under pessimistic and optimistic scenarios. Table 3 displays the net present value sensitivity results, between the low result: $289 million, to the high result: $1.49 billion.

Table 3: NPV - Sensitivity Analysis, 2018 Million Dollar-Terms

			BARD's Share in the Benefit		
			Low	Central	High
			28%	38%	48%
Change in Benefit	Low	50%	289	393	497
	Central	100%	580	788	996
	High	150%	871	1,183	1,494

11 Appendix A: BARD Awards

Table 4: List of 2 BARD awards granted between 1984-1989

Project No	Full Title				
	Investigators	Institutes	Budget	Duration	Start Year
IS-735-84					
	Hurwitz, S. McMurtry, J.P. Pines, M. Rosebrough, R.W. Plavnik, I.	ARO USDA, ARS ARO USDA, ARS ARO	$200,000	3 years	1984
IS-1234-87C					
	Hurwitz, S. McMurtry, J.P. Pines, M. Rosebrough, R.W. Plavnik, I. Talpaz, H.	ARO USDA, ARS ARO USDA, ARS ARO ARO	$200,000	3 years	1987

12 Appendix B: Feed Efficiency in the U.S. Industry, 2006–2018

Table 5: Contribution of the Model to Feed Efficiency and Feed Cost Reduction in the U.S. Industry, 2006–2018[4]

	A	B	C	D=A*C	E	F=D*E*1.33	G=F*1.4%
Year	**Broiler production, million ton live weight**	**FCR**	**FCR improvement compared to 2006**	**Feed consumption reduction compared to 2006, million ton**	**Cost of Feed $/kg of broiler-grower feed[10]**	**Feed cost reduction compared to 2006, million $, including 33% retail + wholesale share**	**Feed cost reduction attributed to ChickOpt, million $**
2006	22.2	1.96	0	0	0.2	0	0.0
2007	22.4	1.95	0.01	0.22	0.31	104	1.4
2008	22.9	1.93	0.03	0.69	0.42	430	5.8
2009	21.7	1.92	0.04	0.87	0.40	519	7.0
2010	22.3	1.92	0.04	0.89	0.36	479	6.5
2011	22.8	1.91	0.05	1.21	0.47	848	11.4
2012	22.5	1.89	0.07	1.49	0.60	1,340	18.1
2013	23.0	1.88	0.08	1.82	0.56	1,535	20.7
2014	23.4	1.87	0.09	2.15	0.44	1,395	18.8
2015	24.3	1.86	0.10	2.54	0.31	1,173	15.8
2016	24.7	1.84	0.12	2.90	0.34	1,483	20.0
2017	25.3	1.83	0.13	3.28	0.37	1,793	24.2
2018 Est.	25.8	1.83	0.13	3.35	0.35	1,732	23.4

13 Appendix C: Information providers: Personal communication

- Prof. Avigdor Cahaner – the Hebrew University of Jerusalem
- Omer Lavie – Tzemach feed mill, Israel
- Dudu Ginat – Miloubar feed mill. Israel
- Prof. Edgar Oviedo – NC State University
- Reuven Finkelstein – Ambar feed mill, Israel
- Dr. Yaad Dahan – chief veterinar, AT group, Israel
- Benny Keren – EMI Hatchery, Israel

[10] Analysis of data in: https://www.ers.usda.gov/data-products/feed-grains-database/feed-grains-yearbook-tables.aspx

- Nimrod Tzur – Ambar feed mill, Israel