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Developing Technologies to Address Emerging Challenges in Poultry Production

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Think about the world that our children will inherit:

The future of World Agriculture

2

Global Challenges

- Demand for protein products
- Threat of disease epidemics
- Environment and climate change
- Competition for nutrient resources

Besbes et al. (2007); www.fao.org

3

Innovators

Change the Playing Field

"If I had asked people what they wanted, they would have said faster horses."
— Henry Ford

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Improvement in Broiler Performance: Past, Present, & Future

	1957	2003	2018	2026
42 d, Live Wt, g	540	2805	3500	**4000**
42 d Feed/Gain	2.35	1.70	1.42	**1.40**
Days to 1.8 kg	+112	32	27	**23**
FCR for 1.8 kg	+4.00	1.50	1.23	**1.10**

- **>50 g weight/year**
- **>1% increase/year**

Havenstein et al., (2003)
Recent Ross 708 Growth Trial at NCSU
Projected Growth Performance

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Current Issues in the Poultry Industry

- Impact of disruptive new technology
- Novel diseases and Biosecurity
- New regulations, analytical sensitivity
- Opportunities for growth and expansion
- Rising costs and availability of raw materials
- Hiring and retaining staff
- Antimicrobial resistance and gut health
- Poultry product quality
- Food safety and traceability
- Reproductive efficiency

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Developing Technologies to Address Emerging Challenges in Poultry Production

- Digital Technologies and Precision Animal Farming
- Computational/Analytical technologies
- Nutrient Management and environmental emissions technologies
- Perinatal and Hatchery Innovations
- Nutritional manipulation of Enteric Health and Microbial ecosystem

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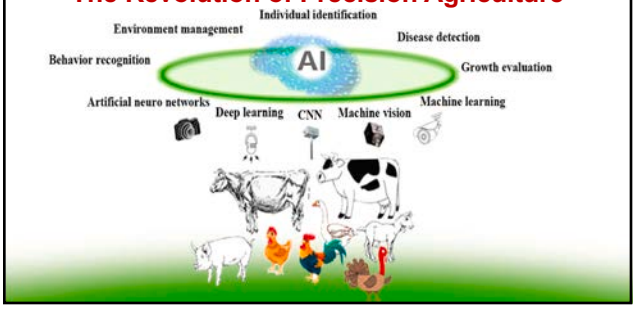
The Revolution of Precision Agriculture



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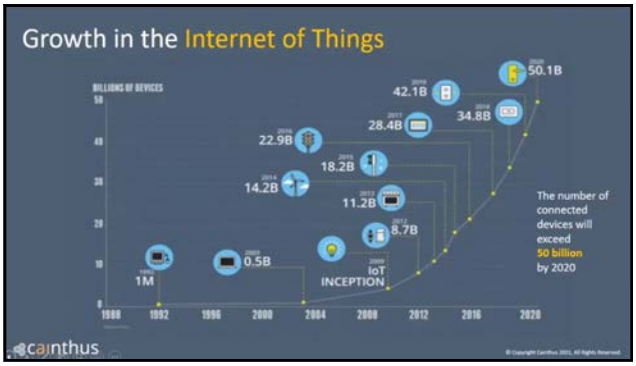

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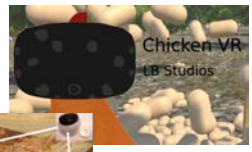
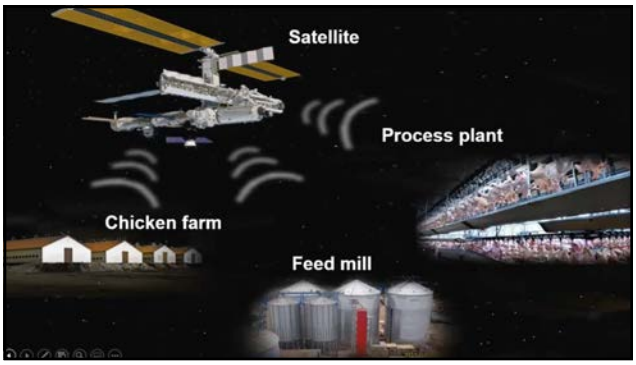
Sensors Enable IoT by Collecting Data for Faster Decision Making

- $2.5 billion by 2025
- Monitor flock and environment
- Analyze results displayed graphically
- Virtual Reality
- Wearable sensors
  - Monitor movement
  - Healthy vitals
  - Behavior patterns



Cost & ROI?

10



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Poultry's Data Gaps

Individual data in real time?

- Weight
- Feed & water consumption
- Comfort
- Stress
- Health
- Livability
- Egg Quality

= How is it measured; 1 metric or 15?

Real-time Environment?

- Air quality: NH3, CO2, moisture
- Temperature
- Feed quality
- Safety: Campy, Salmonella
- Traceability; openness for 'Prosumers'

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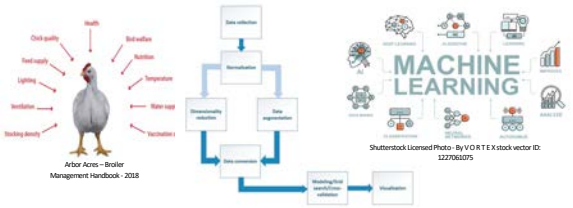
The Poultry Industry Collects a Lot of Data!

How do we make sense of it all?
How do we get answers to our questions?

13

The Machine Learning Opportunity



- "Teach" computers to learn without explicitly programming (El-Alfy and Mohammed, 2020)
- Solve problems without programming what the machine must do (Russell, 2021)

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Data Mining to Generate Hypotheses

Data Mining: the process of sorting through large data sets to identify patterns and relationships that can help solve problems

- Gain insight from complex data not possible otherwise

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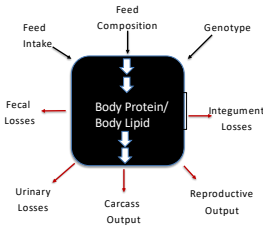
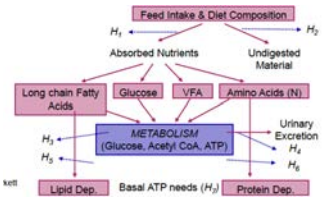
Animal Growth Simulation Models

Empirical Biological Model



Biological Mechanistic Model



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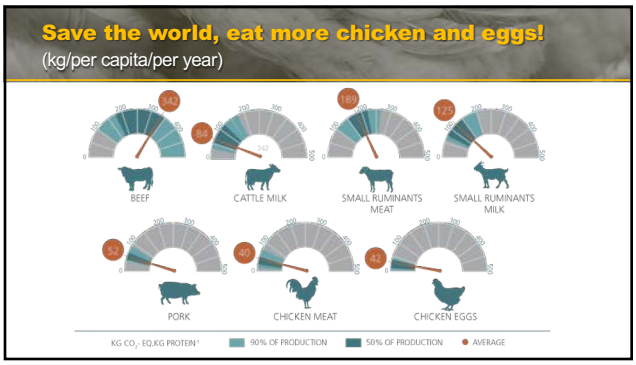

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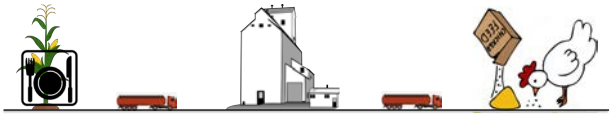
Greenhouse Gas Emissions Mitigation Strategies

As feed production contributes to the most GHG emissions from pig and poultry production, the efficiency to convert feed into edible products is a key determinant.



- Genetic selection for improved growth and feed efficiency
- Feed formulation strategies to minimize nutrient excess
- Use of food co-products and up-cycled food waste
- Feed additive and ingredient selection for improved digestibility
- Precision feeding and management strategies

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Life Cycle Sustainability Assessment

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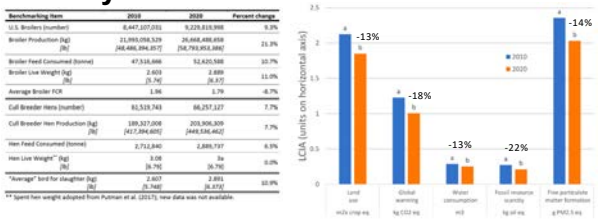
US Broiler Production System Life Cycle Assessment 2010 vs 2020



Thoma and Putman, 2020; Resilience Services, PLLC

- utilized the ReCiPe lifecycle impact assessment framework (Huijbregts et al., 2016)

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Commercialization Precision Technologies

verax Asimetrix Cargill Alltech Jefo

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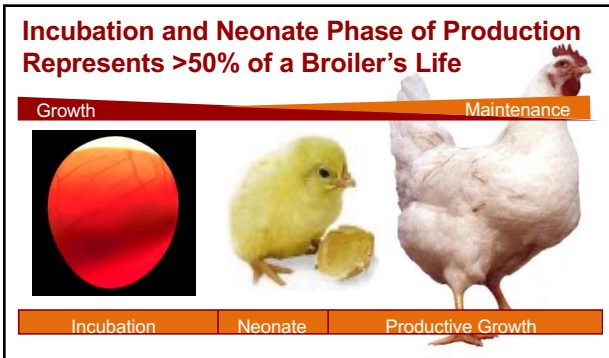
Incubation and Neonate Phase of Production Represents >50% of a Broiler's Life



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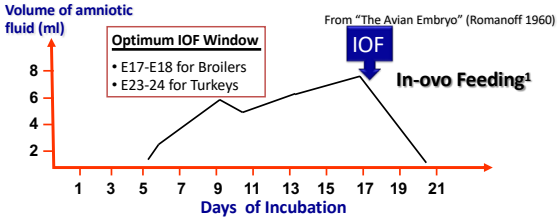
The First Meal Makes a Difference!



¹Uni and Ferket (2004; 2014). Patented in the USA and Other Countries

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In-OVO FEEDING

Nutrient Supplementation of Amnion

E17 for Broilers; E24 for Turkeys

Benefits:

- Increased glycogen reserves
- Improved chick quality
- Advanced gut development
- Improved skeletal health
- Increased body weight gain 2–5%
- Improved Feed conversion ~2%
- Increased muscle/meat yield
- Enhanced immune function

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Effect of In Ovo Feeding on Growth Performance of Ross 708 Broilers (2012)

Measurement	Control[1]	IOF[2]	P-Value
Body Weights	---------- grams -------		
Hatch Weight	41.1	41.7	0.0180
Placement Weight	39.9	40.6	0.0010
12 hr Shrinkage, %	2.9	1.2	0.0010
10 days of age	203	206	0.2878
42 days of age	2,636	2,725	0.0024
% C.V. at 42 days of age	10.11	8.05	0.0012
Feed Conversion Ratio	--- Adj. Feed:Gain ---		
0 – 42 days of age	1.632	1.578	0.0001

[1]0.1 ml Marek's Vaccine, injected in the amnion at 18 days of incubation.
[2]0.60 ml IOF solution + Marek's Vaccine, injected in the amnion at 18 d incubation

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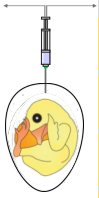
Summary of Compounds Delivered by In Ovo Feeding

Nutrient Supplements		Non- Nutrient Supplements	
Macro-molecules	• Enhanced intestinal nutrient uptake and digestion • Stimulation of myogenic cell proliferation; elevate breast muscle %	Immuno-stimulants	• Effects on heterophils and protection against *Salmonella* invasion; • Effect on macrophage and antibody response
Amino Acids	• Effects on chick BW • effects feed intake, FCR and immune response	Proteins (Anti-bodies)	• Effects on BW and muscle mass • Effects on antibiotic residue
Carbohydrates	• Trophic effects on SI • Increased goblet cell activity • Increased embryonic metabolism and BW	Hormones	• Effect on muscle content • Increased BW, skeletal growth, feed efficiencies, and adipose tissue development
Vitamins and Minerals	• Stimulation of mineral consumption from yolk • Increased bone ash content and stiffness	Prebiotics Probiotics Synbiotics	• Effects on *Salmonella* colonization • Effect on BW • Increased absorptive surface area in the SI



Uni and Ferket 2003-2008; Foye et al., 2007; Kornasio et al., 2008; Cheled-Shoval et al., 2011; Yair et al., 2015; Reviews by Peebles, 2018; Roto et al., 2016 ; Kadam 2013; Betes 2018; Celik and Ferket, 2023

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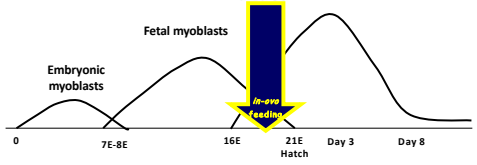
In ovo Feeding Timed to Boost 2nd and 3rd Wave of Satellite Cell Development



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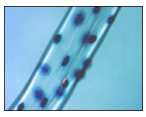
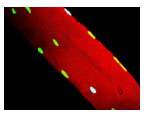
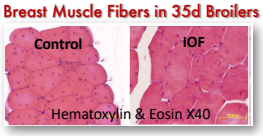
Skeletal Muscle Satellite Cells (Thymidine Incorporation - CPM)

Broiler Chicks	3 d of age	7 d of age
Non-injected	16,803	310
Commercial IOF	29,453	1,524
Δ	175%	492%





Breast Muscle Fibers in 35d Broilers



Kornasio et al. (2011) PSJ

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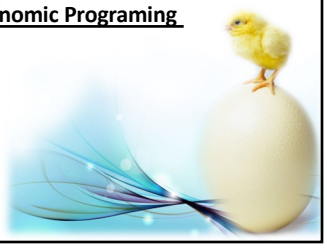
Nutritional Imprinting

Imprint for the desired trait when they are young

Potential Benefits of Nutrigenomic Programing

- Nutrient utilization
- Performance efficiency
- Disease resistance
- Meat yield and quality
- Reproductive efficiency
- Enteric ecosystem
- Behavior and stress tolerance



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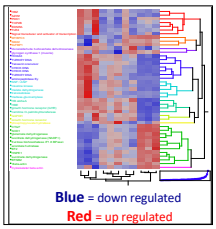
Genes Affected by IOF at 4d

35% of genes expressed differently over time by IOF

Epithelial growth	• EGFr • ILGF-BP1 • Thyroid receptors α1 & β1
Innate Immunity	• IL-8 • TLR2 • Fas-Ligand
CHO and Protein Metabolism	• Maltase-glucoamylase • Glycogen synthase kinase • Aminopeptidase 1
Muscle Development	• F-actin capping protein • Myosin light-chain 4 & 8



Bohorqez et al. (2009) *Oliveira et al. (2008)*

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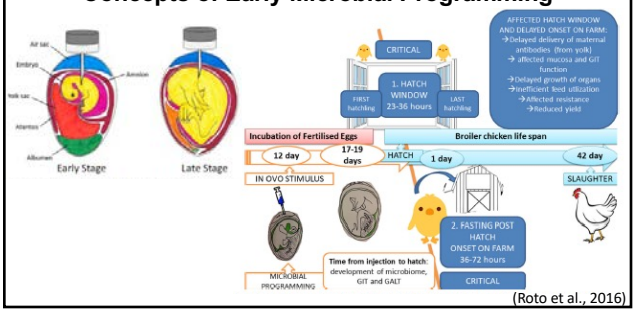
Concepts of Early Microbial Programming



(Roto et al., 2016)

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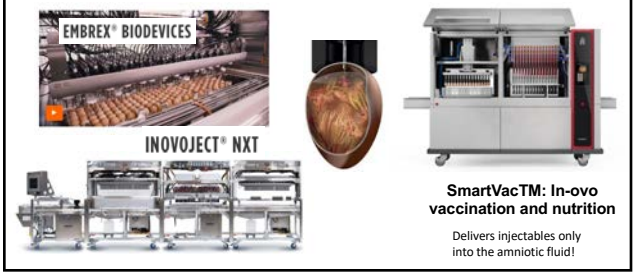
In Ovo Stimulation AND In Ovo Feeding Technology

Can be done by modified in ovo vaccination systems!



SmartVacTM: In-ovo vaccination and nutrition

Delivers injectables only into the amniotic fluid!

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New Hatching and Early Feeding Systems

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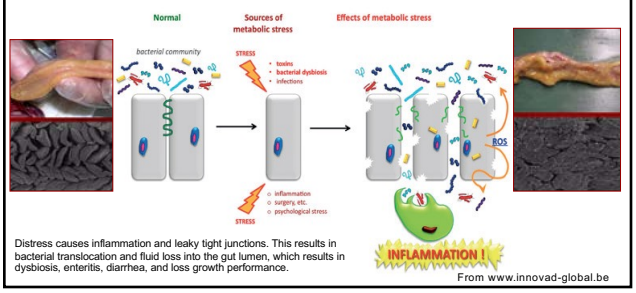
Enteric Distress and Inflammation



Distress causes inflammation and leaky tight junctions. This results in bacterial translocation and fluid loss into the gut lumen, which results in dysbiosis, enteritis, diarrhea, and loss growth performance.

From www.innovad-global.be

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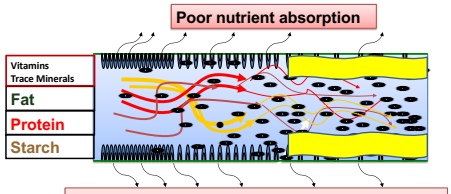
Poor Digestion; more substrate for hindgut dysbiosis!



(Ferket et al., 2008)

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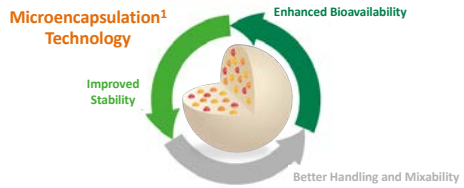
Innovation in Vitamin and Mineral Product Form Quality Minimizes Nutritional Formulation Risk



[1]Ferket et al. 2018, Patent CA3043176 A1 2018/05/16; 17 May 2018
Exclusively licensed to Jefo Nutrition, Inc. (http://jefo.ca)

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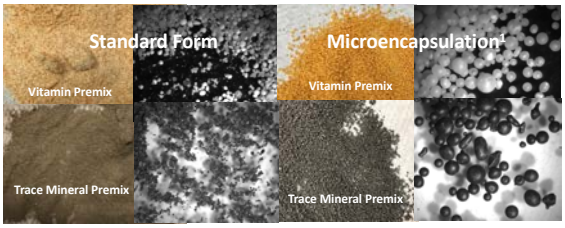
Feed Handling and Stability Characteristics *of Standard and* Microencapsulated[1] Vitamin and Trace Mineral Premixes



[1]Ferket et al. 2018, Patent CA3043176 A1 2018/05/16; 17 May 2018
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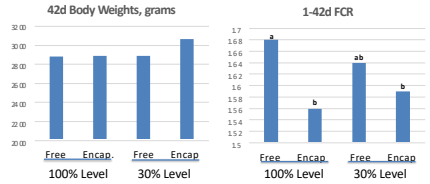
Effect of Premix Level and Microencapsulation[1] on 42-day Male Broiler Growth Performance



[1]Ferket et al. 2018, Patent CA3043176 A1 2018/05/16; 17 May 2018
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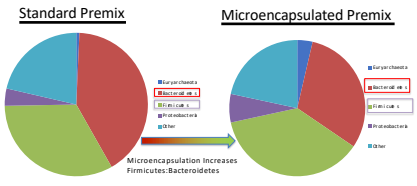
Effect of Standard and Microencapsulated[1] Premixes on Ceca Microbiome Phyla Distribution



[1]Ferket et al. 2018, Patent CA3043176 A1 2018/05/16; 17 May 2018
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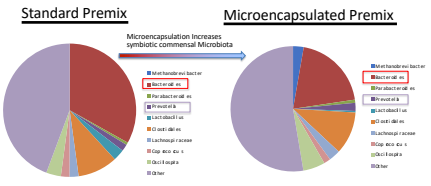
Effect of Standard and Microencapsulated[1] Premixes on Ceca Microbiome Genera Distribution



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Effect of Microencapsulated Vitamins and Trace Minerals on Broiler Breeder Performance

Treatment	Level and Form of Vitamins	Level and Form of Minerals
1	100% Free	300% Free
2	100% Encapsulated	300% Encapsulated
3	100% Free	100% Free
4	100% Encapsulated	100% Encapsulated

[1]100% level = Aviagen Recommendation for Ross 708 (2016).

- 108 Females Ross 708, 24 Males Ross HY; 12 litter floor pens with 9 Females and 2 Males
- Nest box with 6 nest for each pen
- 1 Plasson bell drinker/Pen; 1 Female feeder; 1 Male feeder hanged higher
- 16 Hours of light; Egg collection once a day beginning at 26 wk of age

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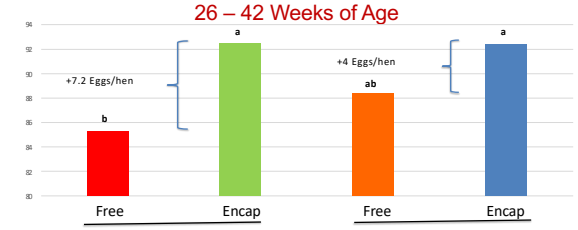
Effect of Vitamin and Mineral Encapsulation and Supplementation Level on Eggs/Hen

26 – 42 Weeks of Age



a,b P<.005

P=0.0052

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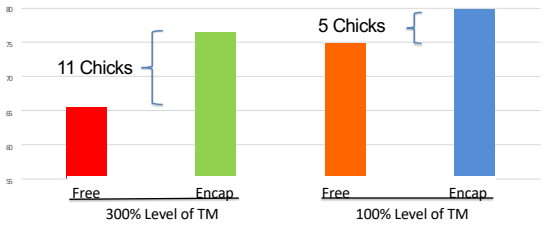
Effect of Vitamin and Mineral Encapsulation and Supplementation Level on Chicks/Hen

26 – 42 Weeks of Age



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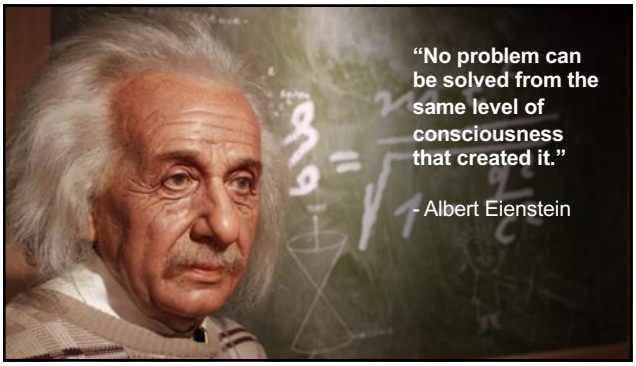

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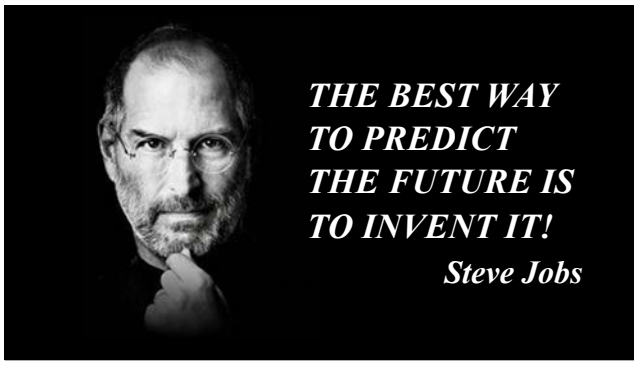

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Animal Health and Nutrition Consortium

Industry-supported Pre-Competitive Research Partnership with an Entrepreneurial Mindset

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Top research in food and companion animals

First access to the latest concepts and intellectual properties

Precompetitive exchanges with peer industry leaders

Food Animal Initiative
Establishing North Carolina as the World leader in food animal biosciences.

Substantive results that translate into greater profits and market share

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