Chapter One

The Early History of American Nutrition Research

From Quality to Quantity

On May 15, 1862, President Abraham Lincoln approved a bill to establish the United States Department of Agriculture. The USDA was born with $60,000 in six rooms in the basement of the Patent Office building.[1] Drawing from the European import of a scientific approach to agriculture, which relied largely on the nascent field of chemistry, the USDA's directive was to advance scientific research. The department was "laying the foundation for becoming a great science-producing agency of government" (Cochrane, 1993, p. 96). It was the expressed goal of the newfound department to: "Test by experiment the use of agricultural implements and the value of seeds, soils, manures, and animals; undertake the chemical investigation of soils, grains, fruits, vegetables, and manures, publishing the results."[2] From cotton to cattle to cucumbers, the USDA had an array of directions in which to take their scientific research.

In the years after the approval of this bill, federally funded scientists, in USDA-sanctioned labs, set to unearthing the chemical components of food, and the physiological processes of digestion. Chemists used the process of calorimetry to break food down into calories, fats, proteins, and carbohydrates. Techniques of dehydration, precipitation, and combustion reduced foods to their constituent molecular parts. These experiments, as well as experiments using the calorimeter to quantify human action, rendered the relationship between food and eater measurable. The emerging science of nutrition introduced the notion of the balanced human-food equation based on the zero-waste model of the combustion engine. In order for maximum efficiency in the human body, the input of food must equal the output of work. The USDA thought that understanding these two quantities, the calories in food and the calories used by metabolism, could improve the lives of Americans.

While chemical catabolism occurred in the laboratory, creating new knowledge about food, the laboratory lexicon served as the new language to discuss it. The terms of science were old, but their application to food was new. In these early experiments, a scientific language was mobilized to make food a quantifiable entity. A cool, creamy glass of milk became 150 calories and a measurable ratio of fat, proteins, and carbohydrates. The scientific and systematic analysis of foods by the USDA created both knowledge about food and a method for its communication. The scientific treatment of food, the categorization and charting of the constituent nutrients of everything edible, and the grading of food on its proportions of these quantifiable components mark an important moment in the development of American nutrition.

This chapter lays the historical groundwork for how a language of quantification became the preferred mode of communication in federal food policy, and it outlines the United States Department of Agriculture's early use of numbers, measures, and standards. Such a historical foundation demonstrates the coproduction of scientific knowledge and a numeric language of food. From the birth of the USDA in 1862, its implementation of science as the disciplinary framework of knowledge production determined the type of information the agency produced. By default, science provided the language with which to produce new knowledge about domestic agriculture. Because food fell under the aegis of the department, the government body's advice on food and "good" or "proper" eating (the former being under its jurisdiction and the latter implicated in the former) has never extended its discursive reach beyond the language of science, scientific methods, and the cornerstones of this discipline: numbers, measures, and quantitative comparison. The late 19th- and early 20th-century agriculture laboratories, through their research mandates, publications, and formation of a scientific community, gave birth to and encouraged the proliferation of a discourse of quantification.

Within this newfound science of food, new technologies were in place to produce knowledge and encourage the use of a discourse steeped in numbers and calculations. The chemical and calorimetric analysis of foods using the technologies that produced numeric data perpetuated a language of quantification and measures that allowed for, and encouraged, normalization, standardization, and objectification of qualitative judgments about taste. The language of numbers and standards allowed for the objective comparison of apples to oranges to steak to sugar. Therefore, I use this history to argue that early federal scientific and quantitative communication of food conflated the idea of *quality* with the idea of *quantity*. *How much* of something became the marker for *how good* it was. Thus, *quality* food was determined by *quantitative* terms.

Federal Agricultural Science: The Mandate of the USDA and the Hatch Act

In 1862, the same year Lincoln founded the U.S. Department of Agriculture, increased contact between American and European scientists created a growing interest in improving agricultural practices (Gates, 1965, p. 255). In his first annual report the commissioner of the USDA, appropriately named Isaac Newton, declared that

> It shall be the duty of the Board to watch the interests of agriculture as they are or may be affected by the legislation of the country; to make such reports, memorials and recommendations, as may advance the cause of agriculture, promote and diffuse agricultural knowledge . . . and to show the importance of science to agriculture. (Qtd. in True, 1937, p. 37)

These reports would become the gold standard for work at the USDA, and they are still, today, one of the central markers of the scientific ethos intrinsically tied to this branch of the government.

A chemist published the first scientific paper in the department. The paper was a report on the chemical analysis of grapes wherein American chemists concluded that domestic grapes were as good as any European grapes for making wine. Obviously, French vintners would find such a conclusion amusing and dead wrong. But by reducing grapes to their chemical constituents such an argument becomes possible. Reports and papers followed on sugar beets and the chemistry of sugar manufacturing, stone fruits, sweet potatoes, peanuts, edible fungi, tea and coffee substitutes, butter and edible oils, baking powders, and meat extracts. In 1869 a staff chemist called attention to the excessive adulteration of foodstuffs and the need to maintain and monitor the purity of these products by chemical means.[3] These early papers hinted at the extent to which the scientists at the USDA would be involved in federal policy and public communication. In *Science in the Federal Government*, American political historian Hunter Dupree (1957) states that these acts of 1862 "mark a genuine turning point for science in the government" (p. 149). Prior to 1862 scientific institutions lacked constitutional status, largely due to internal incoherence and conflict between institutions. With governmental support and structure, science and agriculture were given a political space in which to proliferate.

While the creation of the USDA marked the government's commitment to federal scientific research in agriculture, the Morrill Land Grant College Act, passed in the same year as the formation of the USDA, aided scientists who needed laboratory space to perform their experiments. The Land Grant College Act did not affiliate the laboratories with the federal government or the USDA, but the act endowed the individual states with public land to be sold, the profits of which were used as financial boosters to colleges of agriculture.[4] Within the agricultural colleges, the act's money created state experiment stations. These stations provided laboratory space and research facilities to those studying the scientific applications of agriculture. But the Land Grant College Act provided more than a physical space for scientists. Because chemistry and botany were the only mature disciplines assumed by the new stations, "agriculture" itself was not yet defined. The physical space of the laboratory was influential in establishing the field of agriculture, and the kind of work in which the scientists were to engage. The experiment stations encouraged the professional self-definition of agricultural *science*, and the Land Grant College Act abetted the creation of a new scientific discipline (Danbom, 1986).

At the Convention of the Association of American Agricultural Colleges and Experiment Stations, speaker M. H. Buckam posited that the Land Grant College Act had brought "the light of learning and the aid of science to bear upon those pursuits and callings which . . . would thus be lifted to the plane of the other professions and confer equal respectability upon their members."[5] Science had social value, and it imported structure and respect to agriculture. Experiment station scientists performed the agricultural experiments that the individual farmer (who lacked time, opportunity, and often a formal education) could not.[6] The transposition of experimental science upon agriculture elevated farming and made it a profession requiring special knowledge and skill. Instead of agricultural knowledge creation in the hands of the "hicks, yokels and ignorant bumpkins," whose approach to agriculture relied on intuition and experience, the newfound scientific and quantitative approach put agriculture into terms that were bound, concrete, well defined, comparable, and verifiable (Rosenberg, 1977, p. 403). This national effort to encourage a rational approach to agriculture served to redefine the terms of agriculture itself. The experiment station scientist was encouraged by what Charles Rosenberg calls "the ideological primacy of science and agriculture" to commit to a set of professional values that influenced American science at this time (1976, pp. 171–172). Encouraged by the institutions to stimulate economic development and interest in pure science, the experiment station scientists were empowered to establish the language of communication for this new marriage of the farm and hard facts.

The first experiment station in the United States was in Connecticut. This station was established by the efforts of Yale professor Samuel Johnson and his former student, Wilbur Olin Atwater. The two men were active promoters of agricultural research in the United States, and Johnson had served as the advisor to President Lincoln when the creation of the USDA was signed into law. Johnson and Atwater were largely responsible for the establishment of the experiment stations' scientific credo. In later years, the USDA credited Atwater with showing the experiment station to be "primarily and fundamentally a scientific institution" that "undoubtedly had a broad influence in the further development of such institutions in the United States" (True, 1937, p. 85). The Connecticut Experiment Station in Storrs, affiliated with Wesleyan University, specialized in chemical analyses of fertilizers and foods. Johnson and Atwater were both European-trained chemists who had worked in German agricultural chemistry laboratories that specialized in nutritional chemistry. Johnson's German mentor and pioneer of the nutritional sciences, Justus von Liebig, largely influenced the direction of his research, and the methods he used in the Connecticut experiment station. Americans and Europeans alike considered Liebig the founder of experimental agricultural and nutrition sciences. He trained scientists from all over the world in his lab in Giessen and specialized in eudiometric analyses of organic elements in foods.[7]

Liebig developed a distinctly quantitative approach to nutrition from his studies in inorganic chemistry, in which he used highly efficient and precise techniques of chemical analysis. In the 1830s he used those techniques to begin studying the chemical processes of living organisms. He first studied plants and the chemical constitution of soil, water, and air. This led him to the conclusion that the nutrient substances of plants were inorganic, rather than organic. From this insight he was able to invent artificial fertilizers. Therefore, Liebig's move into the chemical analysis of plants opened up new and important connections between chemistry and industry because he could promise greater productivity of food. He used this same emphasis on improved productivity in his work on animal chemistry. In 1842 he published *Animal Chemistry*, in which he claimed that "the only method which can lead to their [animals] final resolution, namely, the *quantitative* method, has been employed" (Liebig, 1842, p. xxii). Liebig's approach was to measure and analyze the foods taken in by the animal, and the products that were exhaled or excreted. On the basis of such analyses, he proposed a great deal of theoretical speculation about the chemical processes of the body. Thus animal and human nutrition depended on chemical changes that could be assessed by the calculation of the relation of inputs and outputs.[8] The point of this approach was to assess, quantitatively, the relationship between what was consumed as food and what was expended as work and heat in both the animal and human body. This concern with work and physical efficiency became a central preoccupation of early American nutrition research.

The Storrs experiment station research reflected Johnson's European training under Liebig. Starting around 1880, the American chemists used a modified Bertholet bomb calorimeter to begin determining the heats of combustion of a variety of foods. The Bertholet bomb calorimeter was considered to be the perfect technique for determining the heat and energy equivalents of carbon-containing compounds and built upon Atwater and Johnson's eudiometric nitrogen research under Leibig. The Connecticut research station began producing and publishing studies of the chemical composition of foods and became known as the station concerned with the nutrition of man and animals (True, 1937, p. 153).

Samuel Johnson and Wilber Atwater were highly prized consultants to the USDA due largely to their experiences in government-funded European experiment stations. The two men gave direction and advice to the government and became vocal promoters for the establishment of federally regulated and funded agricultural research. American scientists returning from European labs came back with technical knowledge and a new vision of how science ought to be pursued, and what contributions it could make to the American public (Ashby, 1959). In USDA publications, Atwater began writing in favor of adopting the European model of the scientific laboratory in domestic experiment stations.[9] From 1885 to 1887 Johnson and Atwater served as agricultural science advisors to Congress and made the push for support of federal appropriations for the experiment stations. After lengthy debate, President Grover Cleveland signed the Hatch Experiment Station Act on March 2, 1887. This act changed the financial structure of the experiment stations and formed an alliance between the USDA and the heretofore independent experiment stations. Prior to the passage of the Hatch Act, the Department of Agriculture found it difficult to coordinate and keep track of what was going on at each station. This new alliance (and allotment of funds) allowed the government to standardize and influence what the research scientists in each station should be doing and how they should be doing it.

The Hatch Act was a nationwide subsidization of research in agriculture by the federal government. After the act passed, the state experiment stations became the joint responsibility of both the federal and state governments, and the stations developed a formal relationship with the USDA. Each state received an annual federal grant of $15,000 to maintain their experiment station if they had one. In addition to the financial handout, the Hatch Act provided a structure and mandate that directed and defined the activities of the experiment stations and their scientists. The act stated that the goal of experiment stations was:

> To acquire and diffuse among the people of the United States, useful and practical information . . . and that it should be the object and duty of said experiment stations to conduct original researches [*sic*] or verify experiments on the physiology of plants and animals.[10]

Federally controlled experiment stations were enormously successful in Europe, and the European-trained American scientists felt that with more attention paid to agricultural science, the United States could surpass Europe in the advancement of agricultural science.[11] The Hatch Act was seen as the best way in which applications of science could "increase [agricultural] production at a decreased cost" and promote the precision of scientific methods that had come to define the USDA as the "foremost agency for the advancement of agricultural science" (True, 1937, p. 126).

Through the establishment of the USDA and the passage of the Morrill Land Grant College Act and the Hatch Act, the American government demonstrated its scientific directive. The promotion of science and the federal sanctions now circumscribing agriculture came to constitute the mission of the USDA. These acts also bestowed upon federal scientists the institutional values of a scientific ethos. The federal mandate of science enabled its normative structure to take root and thus demarcate patterns of knowledge production. These acts established the experiment stations as centers of knowledge production, and the experiment station scientists as knowledge producers. As Robert Merton (1974) notes, the institutional values of science that are "transmitted by precept and example and reinforced by sanctions . . . in varying degrees internalized by the scientist, thus fashioning his scientific conscience," became the foundation for agricultural knowledge production in America (p. 269). By adopting and encouraging science as epistemological bedrock, certain kinds of knowledge, kinds that could be, according to Merton, "empirically confirmed" and "logically consistent," were the prized products of the newly defined discipline of agriculture (p. 270). Agriculture, its practices, and its discourse became shaped by the professional standards of the scientist.

In 1888, the year following the passage of the Hatch Act, the government noted some "irregularities" in the use of the federal funds by some of the states. In order to abate inappropriate use of funds, the USDA created the Office of Experiment Stations, a federal sentinel for the activities of the stations. The government gave the Office of Experiment Stations, or OES, the power to regularly monitor and appraise the research projects financed by government money. The OES, entirely run by European-trained American scientists, sought a European model for the stations and their experiments: clearly delineated research that used verifiable scientific principles, uninfluenced by bureaucratic impulses or political interference. The stations were not to be purveyors of general information on agriculture; they were autonomous, science-serving institutions (Harding, 1947; Ferleger, 1990a).

To generate scientific spirit among the experiment station scientists and to provide a standard for written communication among them, the OES published the *Experiment Station Record.* An important source of information, the *ESR* was a collection of scientific papers from Hatch Act–established American agricultural experiment stations and abroad. The OES made it known that the *ESR* was not a forum for swapping farm practices or tricks of the farming trade. The *ESR* published scientific abstracts, experiment results, papers, and both domestic and foreign agricultural science news. Stations were heavily criticized by the OES if they merely presented well-known farm practices to popular audiences. Often times the experiment station scientists felt bound by their instructional duties at the land grant colleges and lectured or wrote at the undergraduate level instead of at the level of the chemist or agronomist. Furthermore, the stations were chastised for being mere "bureaus of information or education" and warned that resources that were depleted during these activities would not be recuperated. Any activities that experiment station scientists engaged in should not detract from their scientific inquiries. This mandate ensured that experiment station scientists, though they may not all write or communicate using scientific conventions, could read them in the *ESR*.

The Hatch Act also mandated that each experiment station or affiliated college report its research to the USDA and publish its experiments in quarterly experiment station bulletins (which contained only the research of the individual experiment station) and the national *Experiment Station Record.* In addition to keeping scientists abreast of national experiment station laboratory work, the *ESR* held the scientists accountable to particular standards of research and the appropriate communication of that research. Knowing that their research was going to be nationally circulated among fellow scientists ensured the upholding of, and attention to, scientific detail and the attendance to scientific language—acts of public communication could supposedly insure the precision and value of experiments.

The *Record* provided scientists with a disciplinary framework that could guide their style of communication. Experiment reports contained lists of apparatuses, methods of experimentation, and numeric data. In addition to developing a cohesive scientific standard for written discourse among the scientists, the USDA recommended that the experiment stations form regional or national associations or affiliate themselves with the Association of Official Agricultural Chemistry or Society for the Promotion of Agricultural Science. These associations provided scientists with behavioral guidelines for the profession, and helped shape the research initiatives of the scientists and provided ideas for "intelligent lines of inquiry" (True, 1937, pp. 119–120).

By acting as a clearinghouse for the laboratory experiment reports, and by encouraging association among scientists, the OES and the *Experiment Station Record* strengthened the USDA's commitment to the marriage of science and agriculture and perpetuated and inculcated the structures and language of science, the rigidity of experimentation and method, and the need for objective and quantifiable results. The *ESR* represented a palpable instantiation of the attitude of the new science of agriculture. By encouraging the scientific form and style of agricultural knowledge, the *ESR* restricted access to new agricultural information to those who could speak the language of science. According to Scott Montgomery (1996), "such inaccessibility alone has the power to intimidate" and allows for the occlusion of lay language, and by extension, lay knowledge (pp. 7–8). This application of the language of science to the ordinary farming routine, served to shift the persona of the agricultural expert from the farmer, who was scientifically illiterate, to the USDA chemists, botanists, and veterinarians. The process of the nomination of practices by science, practices that were once accessible to the laity, rendered them scientific phenomena, to be explored only by those who could manage this new language.

When the Office of Experiment Stations came into existence, Wilbur Atwater became its director. While the immediate function of the OES was to regulate and coordinate experiment station work, it also sought to point research in what it deemed to be scientifically fruitful and socially useful directions. The Hatch Act clause calling for the diffusion of "useful and practical information" was subject to various interpretations. The USDA's commitment to science did not define public lectures to farmers as useful and practical. The Office of Experiment Stations acted as a scientific watchdog that ensured that the experiment station expenditures were made in accordance with the spirit of the Hatch Act. Atwater was encouraged to "secure, as far as practicable, uniformity of methods and results in the word of [experiment] stations and to furnish forms, as far as practicable, for the tabulation of results, of investigations or experiments."[12]

The nomination of Atwater to the position of OES director was central to the ideological shift that was taking place in the USDA in the late 19th century. While almanac-type knowledge was quaint and perhaps useful to some, Atwater insisted that agricultural experiment stations needed more scientific agriculture and laboratory research. "Abstract" research that specialized in verifiable scientific particulars, was preferred to the approach of the holistic farming "system."[13] The designation of the "professional" scientist at the helm of agricultural knowledge production fit neatly into the zeitgeist of the American population at that time, who equated moral efficiency and social order with professionalization and bureaucratization (Haskell, 2000; Wiebe, 1967). The rhetorical force of the formally educated scientist easily displaced the simple and provincial farmer as the voice of agricultural authority (Haskell, 1984, pp. 28–83).

In *American Science in the Age of Jackson*, George Daniels (1968) writes that the abstraction of a "body of knowledge from the public domain is a necessary first step in creating a place for a society of experts. . . . It is incumbent upon the profession to demonstrate that it is in the interest of society at large to support a special group in the cultivation of esoteric knowledge" (p. 41). Because the USDA supported their research, the experiment station scientist was supported by the "public" to produce knowledge. As the government used science as new rhetorical muscle and claimed that it was to be performed in a certain way, by accredited people, in particular places, to produce "special knowledge," other discourses of agriculture and, by extension, food, became of fringe value to the federal government. At the USDA, the shift from lay knowledge to the socially influential professional knowledge augmented and perpetuated the institution's default manner of communication. Science was the mother tongue of federal agriculture and scientists were the native speakers. This fluency afforded the federal experiment station scientist the social authority to advance the application of this style of communication to all agricultural matters from fertilizers to butter adulteration to the fecundity of Guernsey cows.

Wilbur Olin Atwater, "der Vater of American Nutrition"

The director of the Office of Experiment Stations, Wilbur Atwater, was the chemist and principal scientist at the Connecticut Experiment Station at Wesleyan University. Atwater had received his PhD in 1869 from Yale University under Samuel Johnson, and then completed a postdoctoral course of study in Europe at the universities of Leipzig and Berlin. There, Atwater saw the workings of the German experiment station, which provided him with an archetype for nascent American agricultural science. Atwater's European experiences in the laboratories of German chemists and physiologists further focused his academic interests on the interactions and applications of agriculture and human nutrition. Importing the European model of nutrition research and the experiment station was vital to the construction of the discourse and knowledge of the science of nutrition as it emerged in America. Atwater's position at the OES allowed him to push the agricultural experiment station research toward a more scientific and experiment based approach. While assuming the position of director of experiment stations, Atwater maintained his post as the director of the Connecticut Experiment Station at Wesleyan to pursue his own research interests. Atwater was an outspoken advocate for the federally funded research lab and after the passage of the Hatch Act and his appointment as the office director, many of the stations feared that Atwater's position at the office might influence the allocation of any additional research funds. Atwater resigned as director of the office in 1891 to pursue his research at the Connecticut Experiment Station. While Atwater's resignation removed him from appearing to directly influence congressional appropriation of funds for specific agricultural research projects, he received the first appropriation in 1894, allocated to his laboratory for research on human nutrition.

Atwater's doctoral dissertation, "The Proximate Composition of Several Types of American Maize," represented the first series of food analyses by modern methods in the United States. At Wesleyan, the U.S. commissioner of fisheries funded Atwater to analyze the different species of fish eaten in the United States, and Atwater used the method of proximate analysis to do so. Proximate analysis entailed determining the crude protein, fat and carbohydrate ratios of foodstuffs. While the method served the purpose of producing quantitative determinations of food components, the imprecision of the technique frustrated Atwater. Because the analysis had to be performed in the open air, impurities, residual moisture, and loss of extractable materials made it difficult to obtain reproducible results (Atwater, 1878).

In 1882–1883, Atwater received a federal grant to study whether humans could digest fish as well as they could meat, and he headed to Germany to begin the study. At the University of Munich, he worked in the laboratory of Carl von Voit, protégé of Justus von Liebig. Voit, a leading nutritional chemist, was fascinated with human metabolism and the physical and chemical principles of human intake and output. With his cadre of chemists, Voit explored the idea that proteins, fats, and carbohydrates all had different effects on the body because they stimulated the body's metabolic processes at different rates. Voit concluded that the mass and capacity of human cells determine the total metabolism. The human "machine" Voit found, worked best when it had sufficient calories to fuel the engine (in the form of fats and carbohydrates) and sufficient protein to restore and retain muscular tissue. The ideas of Voit and his colleague Max Rubner facilitated the application of reductionist, determinist, and positivist ideas to the interaction between humans and their food. A central issue in 19th-century German science was the determination of the chemical composition of food, and the best foods to eat in order to maximize human output (Cravens, 1996).[14] Voit's lab gave Atwater his first taste of the European procedures for studying human nutrition, and the attempts that the Munich group were making to put social and economic values on foods based on their contributions of protein and energy to the human body (Carpenter, 1986).

While Voit's studies were inconclusive, and later bettered by Rubner, his interest in *stoffwechsel*, or the chemical theory of metabolic substances, was vital to the then-popular concept of the body as a de-animated machine. Voit's theory of the metabolization of food treated the body as a Helmholtzian motor, whose non-energetic needs could be ignored (Rabinbach, 1990). This model of the human motor allowed for the concurrent birth of a discourse of quantification of foodstuffs, as well as the quantification of human activity. While the *stoffwechsel* framework was too rudimentary to develop a complete theory of human motor-food interaction, Voit's casting of the Helmholtz-human brought together and solidified the concept of enumerated food and quantifiable human activity. If Voit could accurately count food, and food fueled humans, then it would not be long before technological innovation could allow for the determination of the waste-free balance between human food intake and physical output.

Voit's goal of determining the human *kraftwechsel*, "a mathematically reliable system of equivalence between the amount of potential energy ingested in the form of nutriments and the amount of energy produced" (Rabinbach, 1990, p. 126) remained out of his reach until the development of the room calorimeter. But it was in Voit's lab that Atwater first worked with a government-funded human respiration calorimeter. This precursor to the room calorimeter was the fundamental tool in testing the laws of human energetics, the application of the first law of thermodynamics to the human body, and in creating quantitative distinctions between foods and their interaction in the human body. Food taken into the body was transformed through digestion into a set of discrete metabolites that could be extrapolated through the human output of gas. Calorimetry made Atwater's technique of proximate analysis seem simple and imprecise. But the European technology of calorimetry furnished Atwater with an enumerated discourse to apply to food: a language of caloric quantities. Atwater's experience with the German calorimeter gave insight into the future of technologies of nutritional science, as well as a rhetoric in which to express the results of the technology, which fit into the already established framework of scientific communication encouraged by the USDA.

The calorimeter was a cornerstone technology for the application of science to human food, to the organization of new knowledge about food, and to the integration of numeric language for communication about food. In other words, the creation of the American notion of nutrition, or the science of food, relied on the federal government's embrace of the scientific method to further agriculture, as well as the import of scientific technologies and ideas about food and the human body. The technology of the calorimeter availed a language of numbers to the discursive community of scientists already in place at the USDA, and acted to set the agenda for nutrition research to follow. A technology of quantification like the calorimeter was "simultaneously a means of planning and of prediction" (Porter, 1995, p. 43). This newfound ability to measure food forged a numeric relationship between food and human activity and provided a set of scientifically appropriate terms to define that relationship. Thus, calorimetric measurements were not demonstrating a theory, but they were manifestations of a technology that could be used in future to manage human activity and structure and give meaning to scientific practice.

Human Calorimetry: The Technology of Nutrition

In late 1886, just prior to the passage of the Hatch Act, Atwater returned to Germany, this time to the laboratory of Max Rubner. Rubner, a laboratory colleague of Atwater's from Voit's lab, had modified the Voit calorimeter and began to study the heat energy equivalence of foodstuffs. Rubner had established his own laboratory and began investigating the human body in a new way with a new calorimetric tool: the room calorimeter. Rubner's interest was in the science of energetics. He believed that calories were the human fuel, and he conceived the body as a combustion engine. This parallel allowed Rubner to extend the first law of thermodynamics, the law of conservation of energy, to people. The room calorimeter fit Rubner's concept of the closed system body/machine, in which he could ensure that the total energy of the system remained constant. Rubner had people enter the room calorimeter and perform a variety of tasks for which he measured the output of respiration gases. With this apparatus, Rubner could determine more than just the number of calories in a food, the limitation of bomb calorimetry. Now he could determine how many calories of *human* energy foods yielded. Rubner discovered that when fueled by fats, the human body gleaned twice as much caloric energy as when fueled by sugars or proteins.

The room calorimeter became the ultimate arbiter of the quantification of human activity and established a numeric relationship between food intake and physical output. It could measure the calories going into the human, and the calories going out for any given (albeit room-restricted) activity. Together with determining how much energy the human machine expended, Rubner collected caloric data and chemical analyses of commonly consumed foods. The data of energy expenditure, along with the data of energy available in food, gave birth to a simple human mathematical equation.[15] Calorimetry could determine how much you should put into your body, based on how much you put out.

Human calorimetry impressed Atwater. In it he saw a leveling, rational, and impartial approach to food with myriad applications to ameliorate American society. The USDA had experimented with food, and Atwater himself was very fond of determining nutrient ratios of foods through combustion, but nutritional experimentation on the interaction of food and humans was uncharted waters. The deficiency of domestic nutritional technology, one that had so much scientific, social, and economic potential, frustrated Atwater, and he became more vocal and insistent that it was in America's best interest to perform calorimetric analyses of American food in conjunction with tests of human digestibility and fuel value. Atwater became a vocal and prolific advocate of the benefits of the application of science to food, and he began to write about food, the American diet, and the importance of good nutrition in USDA publications as well as in the public press.[15] In 1887 he wrote a series of articles entitled "The Chemistry of Food and Nutrition" for *Century Magazine*, a magazine that circulated widely among the middle-class public. In this publication, Atwater outlined America's problems with its diet: overconsumption of sweets, wasteful spending on expensive cuts of meat, and too little attention to the diet in general. He called for the public to better themselves through education in the science of nutrition:

> Among those who desire to economize there is great pecuniary loss from the selection of materials in which the nutrients are really, though not apparently, dearer than need be. . . . Our task is to learn how our food builds up our bodies, repairs their wastes, yields heat and energy, and how we may select and use our food-materials to the best advantage of health and purse. (Atwater, 1887b, pp. 59–60)

Atwater encouraged education in nutritional science but apologized to the readers of *Century Magazine* for his abstract scientific explanations: "[I should] make these articles not too abstrusely scientific and avoid the tone and language of the college lecture-room as [they] are unsuited to the pages of a magazine. But I must crave a little latitude; the results of scientific research cannot be explained without some tedious technicalities and dry details" (p. 60). Thus the article proceeded to outline, in detail, the process of bomb calorimetry (including apparatus diagrams), the importance of the chemical analyses of foods' fats, protein and carbohydrate contents (including a chart of the percentages of the contents for 70 foods), and the chemical and mineral composition of the human body. At several points, Atwater waxes about the superiority of the American worker to the European, the superiority of the domestic soil in producing nutritionally rich foods, and the productivity of the American workforce. Despite these advantages, Atwater was embittered by the fact that America still lacked a human calorimeter:

> In the German laboratories, particularly, one finds not only the needed apparatus, but what is no less important, trained assistants and servants. [Why must we] seek the fundamental data of our [food] studies in the learned and profound research of foreign universities? (p. 73)

Atwater's push for the passage of the Hatch Act was spurred largely by his desire for an American calorimeter in his own Wesleyan experiment station.

His Connecticut laboratory was a successful institution for nutritional agricultural research, and the Hatch Act allowed Atwater to pursue his goal of emulating the European laboratory experience, where federal funds were availed to perform large-scale scientific work. Determining the chemical composition of foods was important, but it was at the level of human interaction with food via calorimetry that nutrition work represented practical social value. Atwater saw the calorimeter as a social liberator: Americans who understood the science of nutrition could be healthier, save money, and live happier lives. If Americans understood food in terms of quantities: calories, percentages, and rations, they could determine their daily nutritional needs and eat accordingly. With enough scientific research into the workings of food and its interaction with the human body, nutrition could save the health and wealth of American citizens.

With Atwater as the numerate emissary of the calorie, the push began to fund wide-scale research into American nutrition and a domestic calorimeter. The USDA could easily justify an apparatus whose data could ameliorate American society. In 1893 an *Office of Experiment Stations Bulletin* printed an article entitled "Suggestions for the Establishment of Food Laboratories in Connection with the Agricultural Experiment Stations of the United States," wherein the authors made the plea for an allotment of federal money that was "a small additional appropriation in order to complete the service and to round out the whole science of nutrition by including the nutrition of mankind as a final object of the whole work" (Atwater, 1893). Because nutrition was such a worthwhile course of study, and because it had far-reaching benefits, this money was to be separate from, and in addition to, the Hatch Act funds.

In the first yearbook of the USDA in 1894, Atwater authored the article "Food and Diet." This article contained charts, classifications, and lists of food. In this article, he wrote about food's relative nutritive value to the body, and economic value to the family, while emphasizing the importance of knowledge of nutrition, and his own dietary research:

> With the progress of human knowledge and human experience we are at last coming to see that the human body needs the closest care . . . and that among the things essential to health and wealth, to right thinking and right living, is our diet. (p. 357)

Atwater concludes with a plea for support for more research:

> [W]hat is now most needed is research. Of the fundamental laws of nutrition we know as yet too little. Of the actual practice of people and their food economy, our knowledge is equally deficient. More thorough study of the research of man is very much needed. (p. 359)

For the fiscal year of 1895, Congress made an appropriation of $10,000 for investigations on the nutritive value of human foods, with "a view to determining ways in which the dietaries [*sic*] of our people might be made more wholesome and more economical" (p. 387).[17] This project was carried on in conjunction with the state colleges and experiment stations with Atwater as the special agent in charge of the investigations.

Atwater used a portion of the government money allotted to human nutrition research to complete, in 1897, the first U.S. human respiration calorimeter based largely on the calorimeter design of Voit and Rubner. With the help of Wesleyan physicist E. B. Rosa, Atwater perfected a respiration calorimeter that produced results of enviable accuracy. The calorimeter was a large copper-lined wooden box about 170 cubic feet, large enough to accommodate a folding bed or table, or whatever athletic apparatus the experiment required. What was most amazing about the calorimeter, aside from the fact that it worked, was that the subjects appeared to remain reasonably well and comfortable during their calorimetric incarceration that lasted, on average, four or five nights. Along with resting and active metabolic rates, Atwater tested for brain energy expenditure by having college students take their examinations in the calorimeter.

This newfound technology revealed precise measurements about human energy expenditure. By monitoring the change in temperature in the room during the human subject's various activities, the calorimeter determined the quantities of nutrients and energy that the human subject metabolized during different physical activities. It established the relationship between expended energy and metabolized energy, as well as the digestion and assimilation of foods. The Atwater-Rosa calorimeter could recover 99.8% of the carbon dioxide expelled by the subject during the experiment and 99.9% of the heat produced by the human subject, as well as the substrates they metabolized. The system allowed for the measure of the balance between food intake and energy output and the quantification of the dynamics of human digestion. The Atwater-Rosa calorimeter gave the calorie human implications. In order to determine human metabolism calculations, Atwater used his new technology in conjunction with a bomb calorimeter. The bomb calorimeter allowed Atwater to burn foods to determine their energy values as well as burning the excreted products of the room calorimeter's human subject. Used together, both apparatuses could measure the body's energy expenditure as the difference between the food input and human "output" (Wiggen, 1993). The room calorimeter was capable of amazingly precise measurements of human metabolism. It could record a change in room temperature if the human subject so much as wound her watch.

Prior to the merge of the data of the bomb and respiration calorimeters, food's numeric information was external to the food itself. A food's quantities dealt strictly with extrinsic amounts, numbers that could be determined through gross weights and measures. The quantities of fats, protein, and sugars in a foodstuff when they were burned and weighed in a laboratory oven were important information. But by studying the digestibility and metabolization of foods, Atwater determined that in the human body fat yields 9 calories of energy per gram, and carbohydrates and proteins each 4 calories per gram. These Atwater units of metabolizable energy of foods based on the chemical composition were the linchpins in the study of American nutrition.[18]

Wilbur Atwater's process of experimentation and innovation to perpetuate the "calorification" of food could be compared with Robert

Millikan's determination of the charge on the electron. As outlined by Ian Hacking (1983), experiments that establish *constants*, or numeric values that change in no appreciable way over time, confer epistemic clout to those who pioneer the experiment (p. 236). In the case of Atwater and his determination of the Atwater units, his innovation of the extraordinarily accurate calorimeter enshrined the quantitative model of food and eating, because there were always new numbers and knowledge to produce, and no challenge to their verity. The numeric regularity of Atwater's work established these ratios, as Hacking puts it, as constants that "transfer mathematical use to the description of the world." The surety of the constants, the "positivist regularities," is "the intended harvest of science" (pp. 61–63). Just as the calorimeter became the terra firma technology for producing scientific and numeric knowledge about food, the establishment of the Atwater units fortified the foundation upon which nutrition could become *the* framework for understanding food, and numbers its qualitative adjectives. Hacking (1990) writes: "The numbers are called fundamental because they occur as parameters in the fundamental laws of nature. Such a picture is implicitly hierarchical. First come the laws, then the constants that fix their parameters, and then a set of boundary conditions" (p. 56). And so, the calorimeter became the instrument for knowledge production, and Atwater the namesake to the numeric knowledge the instrument produced. The Atwater units then, became the language of the calorimeter.

For every food that the calorimeter burned, the instrument spoke to the scientist through its heat readings and ash analysis. The idea was that the calorimeter could communicate information about things like motion or protein content and establish it as natural fact. In *Instruments and the Imagination*, Hankins and Silverman (1995) make a similar point. They argue that instruments, such as the calorimeter, are "things whose purpose it is to help us analyze and reason about other things. They are things that we construct to represent and interpret nature" (p. 9). Through facilitating analysis and reason, and by communicating and representing knowledge through quantitative readings, the calorimeter produced words imbued with scientific meaning:

> Words were more than arbitrary symbols for things; they contained hidden signification, so that through one word one could learn about the thing. It was a kind of secret language that signified more than the images and words taken by themselves could mean. It was also secret in the sense that only those learned individuals who had been initiated into the meaning of those images and words could understand it. (p. 8)

The calorimeter was a fundamental tool in shaping and organizing a discourse of quantification and the science of nutrition. Because "reading" the calorimeter required one to speak the "secret language," the scientist became the interpreter between the calorimeter and the ideas it produced. As with many scientific instruments, the calorimeter "determined what is possible, and what is possible determines to a large extent, what can be thought" (p. 5).

Through his research with the two calorimeters, Atwater determined how many calories foods yielded in the human body. Once a term used exclusively in the laboratory of physical chemists and physicists, with its application to human nutrition, *calorie* had now taken on a new meaning. Human calorimetry experiments transformed the calorie from a unit of physical science, to a unit of human fodder, and finally, through Atwater's application, a determinant of quality.[19] The calorie made food something outside of just eating and the sensation of taste. Food became something to calculate, measure, and empirically "know." The application of the once solely scientific calorie to the human diet represents a pivotal moment in the establishment of an American epistemology of food and eating. When federal agricultural science adopted the structures and means of empirical research, the calorie became an integral part of the lexicon of human nourishment.

Normalizing the Eater and Rationalizing Quality

In 1896, Atwater published "The Chemical Composition of American Food Materials" in an *Office of Experiment Stations Bulletin*. This was the first compendium of his calorimetric analyses and contained the chemical breakdown of no less than 2,600 food items. The compendium charted the fat, carbohydrate, protein and ash content, as well as the caloric value per pound of food for everything from the spinal column of a sturgeon to canned Russian lamprey to vanilla wafers and whortleberries (Atwater, 1896). During the 15-year period between 1895 and 1910, some 350 studies were conducted in federal experiment stations under Atwater's direction. All told, Atwater used the calorimeter to analyze almost 8,000 foodstuffs, publishing the data in various USDA yearbooks and bulletins. Atwater's early dietary studies were the precursor to "official" federal food guides. He was clear that his publications were meant to be a reference for federal dietary standards and he had no reservations about rating the quality of foods based on the proportion of their nutrients:

> The information gathered from a study of the composition and nutritive value of foods may be turned to practical account by using it in planning diets for different individuals. . . . By comparing the results of many such investigations it is possible to learn about *how much* of each of the nutrients of common foods is needed by persons of different occupations and habits of life. (Atwater, 1902, p. 32, italics mine)

This statement nicely summarizes the purpose of the next hundred years of nutrition guidance published by the USDA.

Atwater also believed that the scientific analysis of foods had important economic ramifications. In other words, he believed that nutritional ignorance was costly. Hard-working citizens wasted money by selecting decadent and expensive foods that had no more nutritional value than many cheaper ones. With some understanding of food science, caloric composition and good nutrition, Americans could easily spend much less money on the same measured amounts of raw fats, proteins and carbohydrates. Atwater conscientiously defined "cheap food," "healthful food," and "economical food" and stated that the best foods were the ones that yielded the most nutrients for the least money. Distinguishing between good food and bad food then, required an understanding of the scientific composition of various foods, the nutrients they furnish to the human body, and it required calculating a cost/nutrient ratio for each. Economical foods were cheap, healthful, and the most desirable. By conceptualizing the American eater as a rational actor, Atwater justified his message, and its objective criteria for understanding quality. His food guidance assumed that Americans would want to follow his guidelines, would want better nutritional health, and would want to "turn it to practical account." His construction of eaters and his attempts to sway the eating patterns of this fictional population based on scientific reason demonstrate how a discourse of quantification was an ideal language for such a cultural policy.

With such a malleable concept as Atwater's fictional eater, making scientifically or numerically rational arguments seemed commonsensical:

> Ten cents spent for beef sirloin at 20 cents a pound buys 0.5 pounds of meat, which contains 0.08 pound of protein, 0.08 pound of fat, and 515 calories of energy, actually available to the body, while the same amount spent for oysters at 35 cents a quart would buy little over half a pound of oysters, containing 0.03 pound of protein, 0.01 pound of fat, 0.02 pound of carbohydrates, and 125 calories of energy; or if spent for cabbage, at 2¼ cents a pound, it would buy