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MODELING THE TRANSPORT OF *SALMONELLA* INTO WHOLE-MUSCLE MEAT PRODUCTS DURING MARINATION

By

Julie A. Rochowiak

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ABSTRACT

MODELING THE TRANSPORT OF *SALMONELLA* INTO WHOLE-MUSCLE MEAT PRODUCTS DURING MARINATION

By

Julie A. Rochowiak

Salmonella is a harmful bacterium that can cause serious illness if contaminated meat is not properly processed. Recent research has shown that the assumption that the interior of intact whole-muscle meat products is sterile is not necessarily true for marinated products exposed to pathogens. Therefore, the objectives of this project were to: (1) develop a mechanistic mathematical model to describe the transport of *Salmonella* into intact whole-muscle meat products during marination, (2) estimate model parameters from laboratory trials, and (3) validate the model using independent data. The proposed model represents one-dimensional transport of *Salmonella* into whole-muscle meat products, assuming capillary diffusion of marinade and capsule-like transport of the *Salmonella* cells along with the marinade. The model solution was stable and yielded reasonable relationships between input and output variables (i.e., moisture uptake and *Salmonella* migration). In experimental trials, the total mass uptake was very low, $< 1\%$, but significant numbers of *Salmonella* entered the product (counts $> 10^1$ at 4.5 cm from the surface in contact with marinade). However, the model did not predict the distribution of *Salmonella* in whole-muscle meat products during marination with sufficient accuracy to support the hypothesis regarding the underlying mechanism.

This thesis is dedicated to my parents for the endless love and support that they have given me.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

KEY TO SYMBOLS

Lower-case Letters

d_f	effective length of flagella, measured from centerline of the cell (m)
d_s	diameter of *Salmonella* (m)
g	gravitational force ($m\cdot s^{-2}$)
h	water potential (m)
k	capsule to pipe diameter ratio, d/D_p
n	empirical parameter
n^v	*Darcy's* velocity ($m^3\cdot s^{-1}\cdot m^{-2}$)
$r_{eff,\,0}$	initial effective gap radius (m)
$r_{eff,\,t}$	effective gap radius at time t (m)
r_i	radius of pores in the i^{th} pore size class (m)
s	distance along flow (m)
t	time (s)

Upper-case Letters

A	total cross-sectional area (m^2)
A_{DM}	percent area of dry matter
$A_{gap,\,0}$	initial percent area of the gap
$A_{gap,\,t}$	percent area of the gap at time t
$A_{muscle,0}$	initial percent area of muscle
B	empirical parameter
$C_{db,\,0}$	initial dry basis moisture concentration (decimal)
$C_{db,\,t}$	dry basis moisture concentration at time t (decimal)
C_s	*Salmonella* concentration of the marinade (cells/ml)
$C_{wb,\,0}$	initial wet basis moisture concentration (decimal)
$C_{wb,\,t}$	wet basis moisture concentration at time t (decimal)
D	capillary diffusivity ($m^2\cdot s^{-1}$)
D_p	pipe diameter (m)
K	capillary conductivity (m/s)
L_s	length of individual *Salmonella* cell (m)
N	number of *Salmonella* cells entering the meat ($cells\cdot cm^{-3}$)
Q_i	volumetric flow rate per pore ($m^3\cdot s^{-1}$)
S	*Salmonella* relative density
V_{av}	average water velocity ($m\cdot s^{-1}$)
V'_{av}	hypothetical average marinade velocity ($m\cdot s^{-1}$)
V_c	capsule velocity ($m\cdot s^{-1}$)
V_o	threshold velocity ($m\cdot s^{-1}$)
X_t	location of *Salmonella* at time t
X_{t+1}	location of *Salmonella* at the previous time step

Greek Letters

$\Delta\beta_i$	volume fraction of pores with radius r_i
ΔC_{db}	change in dry basis moisture concentration
Δt	time step (s)
Δx	layer thickness (m)
$\rho_{marinade}$	density of marinade ($kg \cdot m^{-3}$)
ρ_{meat}	density of meat ($kg \cdot m^{-3}$)
τ	tortuosity of the meat
μ	marinade viscosity ($N \cdot s \cdot m^{-2}$)
ν	marinade velocity ($m \cdot s^{-1}$)
ω_i	number of pores in the i^{th} pore size class
γ	marinade surface tension ($N \cdot m^{-1}$)
λ	time distance ratio
ψ	capillary potential ($N \cdot m^{-2}$)

1. INTRODUCTION

Salmonella, a group of bacteria found in the intestinal tract of humans and other animals, can contaminate the outside of meat and poultry products through contact with feces or other possible sources of contamination. *Salmonella* is the second leading bacterial cause of food-borne illness in the U.S., after *Campylobacter*, and is responsible for an estimated 1.4 million cases of salmonellosis annually in the United States, resulting in more than 500 fatalities (CDC, 2005).

Salmonella is the target organism in the United States Department of Agriculture (USDA) Food Safety Inspection Service (FSIS) lethality performance standards for ready-to-eat meat and poultry products (FSIS, 1999). Ready-to-eat products have been increasing in popularity, and marination is one means that is used to increase product flavor, quality, and value. Value-added processing, such as vacuum tumbling, is used to improve marinade uptake in whole-muscle meat products and can result in an increased number of *Salmonella* being transferred to the interior of the meat if the exterior of the meat or the marinade is contaminated (Warsow, 2003). Thus, marinated whole-muscle meat products might be at risk for *Salmonella* contamination both in the interior and on the exterior surfaces.

Food processors producing marinated whole-muscle meat products are operating under the common assumption that the interiors of intact undamaged whole-muscle products are pathogen free (Elmossalami and Wasef, 1971). This belief is also reflected in federal regulations. Prior to 2005, FSIS distinguished between intact beef cuts (e.g., steaks and roasts) and non-intact cuts when establishing policies regarding *E. coli*

O157:H7 contamination (FSIS, 2002). An intact piece of beef is defined as "a cut of whole muscle that has not been injected, mechanically tenderized, or reconstructed" (FSIS, 1999). The FSIS justified this distinction by stating, "… the interior of intact products remains essentially protected from pathogens migrating below the exterior. Consequently, customary cooking of intact products will destroy any *E. coli* O157:H7" (FSIS, 2002). However, due to growing concern regarding the sterility of marinated whole-muscle meat products, FSIS issued a notice requiring all whole-muscle meat products "injected with marinade" to be treated as mechanically tenderized product (FSIS, 2005). Even though this notice states products "injected with marinade", many inspectors are applying this rule to all marinated products (Booren, 2006). Recommendations of using known intervention techniques in these products is prudent.

Also, recent research at Michigan State University has shown that the assumption of interior sterility may not be accurate (Warsow, 2003; Velasquez, 2006). These studies indicate that pathogens can indeed migrate into the interior of intact products, particularly if the product has been vacuum tumbled (Warsow, 2003). This interior contamination can be especially dangerous, because other tests have also shown that pathogens found inside whole-muscle products have a higher thermal resistance than those in ground products (Orta Ramirez et al., 2005; Tuntivanich et al., 2005; Velasquez et al., 2005; Velasquez, 2006). Thus, current cooking models may be ineffective at accurately predicting the time and temperature required to ensure adequate thermal processing.

The limited knowledge and tools currently available makes it difficult for companies to perform reliable lethality predictions and process validations for whole-muscle products. No current model exists that predicts how pathogens can migrate into whole muscle meat products. A model would allow processors to understand better how far and fast *Salmonella* can contaminate the interior of whole-muscle meat products. Thus, it is important to develop a model that the industry can use to verify process effectiveness and ensure the microbial safety of whole-muscle products.

The type of model influences the range and usefulness of the model. Empirical models, based entirely on experimental data, can give a very good representation of the process they represent. However, if any of the parameters in the process change, then the original empirical model cannot be presumed valid. Models based solely on theoretical principles provide a much broader range of use, but it can be difficult to describe complex materials and processes completely in theoretical terms. Therefore, the proposed model in this study was based on mechanistic principles, such as capillary flow, rather than solely statistical results, with the hope of giving it a broader range of applicability than an empirical model.

The objective of this project was to develop a mechanistic mathematical model to describe the transport of *Salmonella* into intact whole-muscle meat products during marination, estimate model parameters from laboratory trials, and validate the model using independent data.

2. LITERATURE REVIEW

2.1 Overview

This literature review is divided into nine sections that describe risks associated with *Salmonella*, the type of product at risk, the problem with bacterial transport into whole-muscle, and different types of models that could be used to represent this process. Section 2.2 describes S*almonella* and the illness that it can cause to show why it is important to ensure that *Salmonella* is not found in cooked whole-muscle meat products. Sections 2.3 and 2.4 describe the processes of marination and vacuum tumbling to show how *Salmonella* may be transported into meat during processing. Section 2.5 describes surface penetration and bacterial transport of *Salmonella* and marinade into whole-muscle meat products. The remaining sections, 2.6 through 2.9, describe various models based on flow through a porous medium, capillary flow, pipe flow, and capsule flow.

2.2 *Salmonella*

2.2.1 Description

Salmonella are enterobacteriaceae of the genus *Salmonella*. *Salmonella* are Gram-negative, non-sporeforming, rod shaped bacilli found in the intestinal tract of animals. The bacilli are straight rods that are approximately 0.5 μm wide and 2 μm long (Adams and Moss, 2000). They exist as a single, in pairs, or in short chains, and move by means of 1-5 uniformly distributed flagella. These flagella assist in the invasion of human cells (CDC, 2005).

Salmonella is a facultatively anaerobic bacterium; it can survive and grow under conditions of reduced oxygen (Adams and Moss, 2000). *Salmonella* can survive and grow in temperature between 5 and 47 °C, with an optimum temperature for growth of 37 °C (Adams and Moss, 2000). The minimum water activity for growth of *Salmonella* is 0.93, but it can survive in foods with much lower water activities (Adams and Moss, 2000). The minimum pH for *Salmonella* growth is ~4.5 , with an optimum of 6.5 to 7.5 (Doyle et al., 1997). *Salmonella* is heat sensitive and can be killed through adequate pasteurization or cooking processes; therefore, it is critical that food processors know about *Salmonella* and the treatment required to eliminate it from contaminated foods.

2.2.2 Salmonellosis

Salmonellosis is the disease caused by ingesting *Salmonella*. Two thousand of the 2,500 *Salmonella* serotypes identified cause illness in humans (CDC, 2005). The serotypes *S*. Enteritidis and *S*. Typhimurium are responsible for half of all reported cases of salmonellosis (CDC, 2005). Because *Salmonella* is found in the intestinal tract of animals, the most common sources for contaminated food include meat, milk, poultry, and eggs. These contaminated foods cause illness in humans when they are consumed without proper cooking or if the food is cross-contaminated without further cooking (CDC, 2005). The typical infectious dose is as low as 1 to 10 cells, but varies depending on food source, susceptibility of individual, and the virulence of the serotype (Doyle et al., 1997). Symptoms of salmonellosis include fever, abdominal cramps, and diarrhea (sometimes bloody), which usually appear 12-72 h after infection (CDC, 2005). Everyone exposed to *Salmonella* is at risk of contracting salmonellosis; however, these symptoms are more severe in the elderly, young, and immune compromised (CDC, 2005).

2.3 Marination

Marination is a process in which a solution is added to meat products, in order to improve water-holding capacity and thereby increase the juiciness, tenderness, and weight of the meat. A typical marinade is composed of water, salt, and phosphate. The effects of salt and phosphate vary depending on how much is added to the meat. High levels of salt (10-15%) lower the water activity in the meat and act as a preservative to reduce the risk of microbial growth (Barbut, 2002). Low levels of salt have the reverse effect and increase the water holding capacity of meat (Barbut, 2002). High levels of phosphate can result in a decrease in the rate and depth of penetration compared to lower percentages (Xiong and Kupski, 1999a). The rate of phosphate transport into meat also depends on the type of phosphate, with larger phosphates diffusing more slowly than smaller phosphate molecules (Xiong and Kupski, 1999a). The combination of low levels of salt and phosphates creates a synergistic effect and results in decreased cooking loss and thereby greater yield than adding salt or phosphate alone (Froning and Sackett, 1985; Sheard and Tali, 2004). However, combining higher levels of salt (8%) and phosphate eliminates the benefits of phosphate (Xiong and Kupski, 1999a; Xiong and Kupski, 1999b).

During marination, there is an initial outward flow of water and soluble proteins from the muscle to the marinade, due to the lower osmotic pressure of the marinade (Lawrie, 1985). However, as the salt diffuses into the meat and binds with the proteins, the osmotic pressure of the meat becomes less than that of the marinade, and the marinade begins to flow into the meat (Lawrie, 1985; Xiong and Kupski, 1999). The rate of diffusion depends on the strength of the marinade and the microstructure of the muscle tissue (Lawrie, 1985).

It is clear that adding salt and phosphate can improve marinade uptake; however, no references were found that described the fundamental mechanism responsible for transporting plain water into whole-muscle meat products.

2.4 Effects of Vacuum and Tumbling

Vacuum and tumbling are methods used by processors of marinated whole-muscle meat products to improve marinade uptake. Tumbling occurs in a rotating drum equipped with different ribbon designs on the sides (Barbut, 2002). Most commercial tumblers have vacuum capabilities, which help remove air bubbles from the exudates and assist in protein extraction (Barbut, 2002). The purpose of tumbling is to improve marinade distribution and protein extraction from whole and chunked muscle products (Barbut, 2002). The meat is subjected to a certain degree of agitation that assists in distributing the salt and myofibrillar proteins. Marinade absorption during tumbling is time dependent, because the marinade must overcome physical barriers in muscle in order to diffuse into muscle fibers and myofibril matrices (Xiong and Kupski, 1999). The effects of vacuum and tumbling were not considered in the current model, but if they were included, they would likely increase the rate of *Salmonella* uptake in the meat.

2.5 Surface Penetration and Bacteria Transport into Whole-Muscle

Researchers have studied the effects of tenderization and marination treatments in which the surface of the whole muscle is penetrated by a needle, blade, or other mechanical device (Boyd et al., 1978; Johnston, 1978; Raccach and Henrickson, 1979). Boyd et al (1978) tested the sensory characteristics and microbial counts of mechanically tenderized beef and found that bacterial concentrations were higher in samples that had been tenderized four times compared to those tenderized once or twice or the untenderized control. Johnston (1978) summarized various aspects of a petition by the Community Nutrition Institute concerning the mechanical tenderization and packing of meat. The petition claimed that mechanical tenderization increases the microbial counts in meat by forcing bacteria, including *Salmonella*, into the interior of meat. Johnston (1979) also gave examples of outbreaks that occurred because of severe undercooking of meat that had surface *Salmonella* injected into the interior of the meat. Raccach and Henrickson (1979) showed that *Salmonella* and other bacteria can contaminate the interior of beef rounds and ribeyes during mechanical tenderization, but can be greatly reduced through proper sanitation of equipment. This research has shown that pathogens can migrate to the center of whole-muscle meat products if the surface of the meat is broken (Boyd et al., 1978; Johnston, 1979; Raccach and Henrickson, 1979).

A few previous studies have measured the effects of various bacteria and meat characteristics during unidirectional migration of bacteria into surface-inoculated whole muscle meat under atmospheric conditions (Gill and Penney, 1977; Gill and Penney, 1982; Gupta et al., 1983; Maxcy, 1981; Sikes and Maxcy, 1980; Thomas et al., 1987).

These studies have shown that the transport of pathogens into meat is affected by proteolytic activity, bacteria motility, water availability, and fiber orientation.

The proteolytic ability of bacteria, (the ability to break down protein molecules), has been shown to increase the depth of bacterial penetration (Gill and Penney, 1977; Gill and Penney, 1982; Gupta et al., 1983; Thomas et al., 1987). Proteolysis is presumed to speed the process of penetration by breaking down the connective tissue between muscle fibers (Gill and Penney, 1977; Thomas et al., 1987).

There have been some conflicting studies as to the effect of bacteria motility. Gill and Penny (1977) concluded that both motile and non-motile proteolytic bacteria could penetrate the surface of the meat. However, Thomas et al. (1987) found that motile bacterial strains were able to penetrate whole-muscle while non-motile strains remained on the muscle surface, regardless of the bacteria's ability to produce proteolytic enzymes.

The water-holding capacity of meat proteins also appears to have a significant effect on bacterial penetration into meat (Maxcy, 1981; Sikes and Maxcy, 1980; Thomas et al., 1987). Some researchers showed that freezing and thawing meat can lead to increased bacterial penetration (Maxcy, 1981; Sikes and Maxcy, 1980). They suggested that the loss of water molecules during freezing and thawing and the collapsed state of the muscle proteins result in the creation of larger pores for bacteria to move through (Maxcy, 1981; Sikes and Maxcy, 1980). Thomas et al. (1987) showed that high water contents increased the rates of penetration, presumably by increasing the inter-fiber distance in muscle and thereby decreasing the resistance to microbial movement within the tissue.

The rate of bacterial invasion into intact whole-muscle pork was greater in samples where the inoculum pathway was parallel to the fiber orientation than in samples with the inoculum perpendicular to the fiber orientation (Maxcy, 1981; Sikes and Maxcy, 1980).

Recent unidirectional marination trials with whole-muscle turkey breasts at Michigan State University indicated that *Salmonella* counts decreased with distance below the contaminated surface, increased with application of a vacuum, and increased with time (Warsow, 2003). Warsow's *Salmonella* log counts from unidirectional marination tests were used to estimate parameters for the proposed model in this study; his procedure and results are given in sections 3.10.1 and 4.10, respectively. Multidirectional tests were also conducted with whole-muscle pork and turkey exposed to *Salmonella*-inoculated marinade, which entered the product from all directions. These experiments resulted in the same general conclusions as the unidirectional tests (Tuntivanich et al., 2006; Velasquez, 2006; Warsow, 2003).

If *Salmonella* enters a whole-muscle product, thermal inactivation tests have shown that *Salmonella* exhibits greater heat resistance than in ground products (Orta-Ramirez et al., 2005; Tuntivanich et al., 2005; Velasquez et al., 2005; Velasquez, 2006). Those studies involved immersing core samples of irradiated whole-muscle meat in *Salmonella*-inoculated marinade for 20 min. The percent uptake was determined for the whole-muscle samples, so that the same amount of inoculated marinade could be mixed into the ground samples. There was no difference between the initial log counts of the whole and ground muscle samples. However, the thermal inactivation rate constants in ground muscle were double those in whole muscle at a given temperature. The composition, bacterial load, and thermal history were identical among sample types; therefore, the difference in *Salmonella* thermal resistance was attributed to the different physical state of meat components in the sample. Thus, it was concluded that the ground meat thermal inactivation studies used to set performance standards for meat and poultry products may be insufficient for whole-muscle products (Orta-Ramirez et al., 2005; Tuntivanich et al., 2005; Velasquez et al., 2005; Velasquez, 2006).

2.6 Flow through a Fibrous Porous Medium

2.6.1 Fluid Flow

The process of marinade absorption into meat can be viewed as the flow of a liquid through a fibrous material. Several researchers have modeled various aspects of liquid flow through a fibrous medium (Davis and James, 1996; Dhotkar et al., 1999; Kolodziej et al., 1998; Papathanasiou, 2001). Most of these studies focused on modeling matrix properties, such as permeability (Davis and James, 1996; Kolodziej et al., 1998; Papathanasiou, 2001). Dhotkar et al. (1999) developed friction, pressure, and total drag coefficient equations for non-Newtonian fluid flow through a fibrous medium. None of these articles gives any details as to the driving force responsible for the movement of fluid.

Zhong et al. in 2005 examined gravity driven flow of a fluid through a very porous fibrous medium. However, all the liquid can pass all the way through very porous media (meaning no capillary potential); therefore, this case would not accurately represent mass transfer through muscle tissue.

2.6.2 Particle Flow

Nilsson and Stenstrom (1994) investigated capillary gas diffusion of water vapor molecules through sheets of a fibrous porous medium. Multiple researchers have modeled the deposition of aerosol particles on fiber filters (Kirsh, 2004; Lebedev et al., 2002). However, these models are based on gas flow and very small particles; therefore, they do not provide the best representation of the current application.

The rate of particle migration through granular filters also has been modeled under varying hydraulic loads (Indraratna and Vafai, 1997; Locke et al., 2001). Mauret and Renaud (1996) compared capillary and particulate representation of the drag force on a cylinder in a fiber bed. Li and Park (2000) modeled the flow of colloidal particles in a liquid through fibrous and granular material by convection and Brownian diffusion. The particles described in that paper were small colloidal particles that were usually a few orders of magnitude smaller than the filter. Koska et al. (1996) modeled osmotically driven flow of particles through a hollow fiber bioreactor. A hollow fiber bioreactor resembles a tissue-capillary system; however, the equations developed rely heavily on the specific dimensions of the bioreactor, which are unknown for the current application.

A common problem with all of the articles on particle flow through a fibrous medium is that the particles are very small compared to the size of the pore space. In contrast, *Salmonella* particles are relatively large, on the same order of magnitude as the intercellular pore space in whole-muscle meat products. These models all represent a similar concept of the flow of particles through a fibrous medium; however, none of them combined the type of fluid, size of particle, and driving force needed for the present application.

2.7 Capillary Flow Models

Capillary flow was assumed to be the major driving force responsible for drawing bacteria and marinade into whole-muscle products. There are limited models that describe capillary driven flow through a fibrous or porous medium. However, other models based on capillary flow exist that do not involve movement through a fibrous material.

Fink and Muller (2000) compared the penetration depth of different viscous liquids in silicone rubber. The liquids used in the experiments were viscous solutions containing the corrosive alkali lithium hydroxide (LiOH) and therefore do not provide a good representation of the marinade used in the current model.

Some published models have described the flow of red blood cells in capillary networks (Bruinsma, 1996; Schmid-Schonbein et al., 1980). Bruinsma (1996) focused on the rheology and shape transition of red blood cells under capillary flow, showing how particles move through a complex capillary; however, they did not model the velocity or concentration of the particles. Schmid-Schonbein et al. (1980) modeled the distribution of red blood cells in capillaries; however, their model is complex and does not yield a set of equations that can easily be applied to a different situation.

2.8 Pipe Flow

Capillaries in general can be described as very small tubes; therefore, a very simplified model could describe *Salmonella* movement in meat as particle flow through bundles of tiny capillary tubes. Jean and Peddieson (2001) modeled the velocity, volume fraction distribution, and particle segregation patterns due to buoyancy of particulate suspensions in vertical pipes. Unfortunately, this was for the steady-state flow of very small particles. Other researchers have studied the flow of food particles through a vertical pipe as it relates to aseptic processing (Lareo and Fryer, 1998; McCarthy et al., 1997; Sastry and Zuritz, 1987). However, these were all for liquid particle mixtures where the particle diameter was significantly smaller than the diameter of the pipe. Sastry and Zuritz (1987) classified the various types of solid-liquid flow in a pipe as homogeneous flow, heterogeneous flow, intermediate flow, saltation flow, and capsule flow (Figure 2.1).

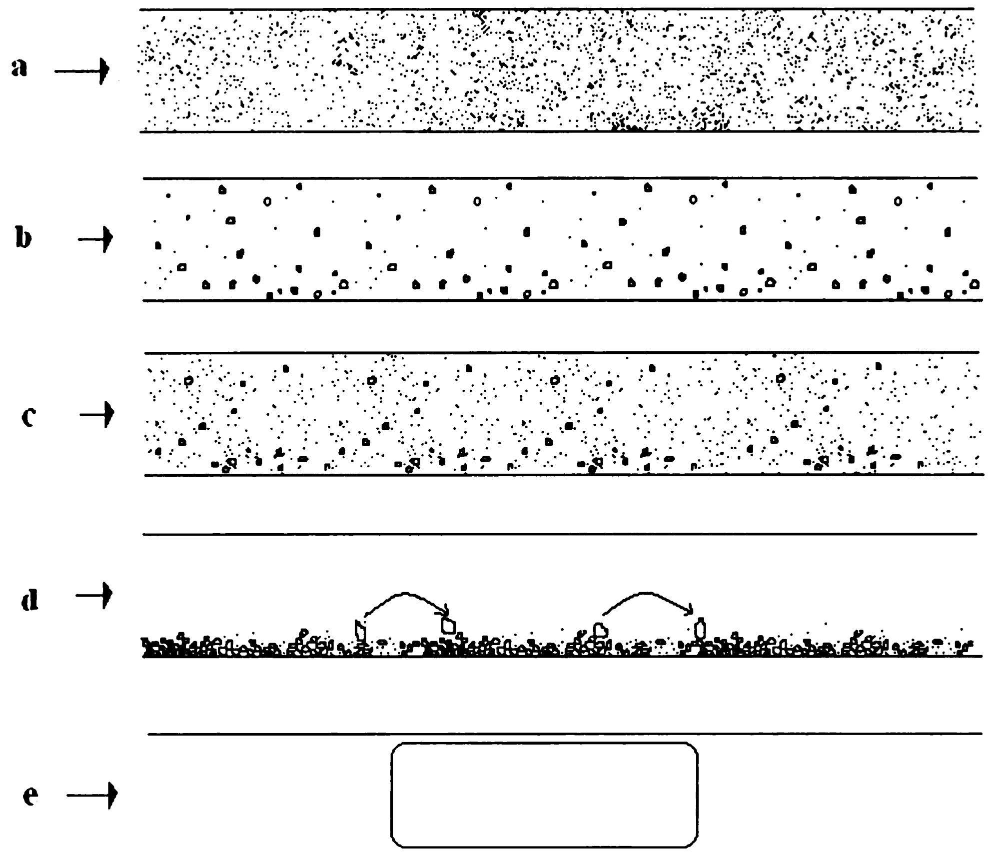

Figure 2.1: Types of solid-liquid flow: (a) homogeneous flow, (b) heterogeneous flow, (c) intermediate flow, (d) saltation flow, and (e) capsule flow. This figure was replicated from Sastry and Zuritz's (1987) figure 3.

Capsule flow involves the movement of an object through a pipe of roughly the same internal diameter. Therefore, this form of flow may be a reasonable model for the movement of *Salmonella* through muscle tissue.

2.9 Capsule Flow Models

Capsule flow has been studied the most as it relates to capsule pipelining. Pipelining is a method of transporting material by enclosing it in a capsule and then moving it through a pipe via the flow of fluid, usually water or air. In the 1960's and 1970's, the Research Council of Alberta (ARC) conducted theoretical and experimental research on capsule pipelining and published a series of 18 articles on their findings; however, only three of these articles included information on the velocity of a cylindrical capsule moving though a pipe (Charles, 1963; Ellis, 1964; Hodgson and Charles, 1963).

The first paper in the series illustrated the various flow patterns of oil capsules moving in a horizontal pipe under low and high water velocities. Testing showed that the velocities of the oil drops exceeded the overall velocities, because the oil drops are located in the section of pipe where the linear velocity is significantly greater than the average velocity of the overall pipe flow (Hodgson and Charles, 1963). Unfortunately, they did not quantify or model the velocity of the capsules.

Charles (1963) predicted the steady-state capsule velocity for a long cylindrical capsule moving through the center of a horizontal pipe under laminar and turbulent flow conditions. The proposed equation for capsule velocity under steady state laminar flow was:

$$V_c = 2V'_{av}\left(1-k^2\right) \qquad [2.1]$$

where:

V'_{av} = hypothetical average velocity (m/s)

k = capsule to pipe diameter ratio, d/D

This equation could be used for the current application; however, an equation representing flow in a vertical pipe, rather than a horizontal pipe, was used instead.

Ellis (1964) compared Charles' theoretical model to experimental velocity measurements for cylindrical and spherical capsules in a horizontal pipeline. The flow of single capsules of different sizes, shapes, and densities was tested in various liquids to determine the effects of length and end shape of the cylindrical capsules. Dimensional analysis showed that the velocity ratio was a function of four independent variables: average water velocity, diameter ratio, capsule length/ diameter ratio, and capsule end shape.

Latto and Chow (1982) modeled the steady-state velocity of a cylindrical capsule in a vertical pipe. Experiments were conducted using a 7.6 cm inside diameter vertical steel pipe and aluminum and nylon cylindrical capsules of 0.49, 0.65, and 0.82 diameter ratio. The velocity of the water ranged from 0.3 to 5.5 m/s. They developed a semi-empirical equation for capsule velocity by first plotting the experimental results for capsule velocity against the average water velocity in a test section minus the suspension (threshold) velocity. The equation of best fit for the data was:

$$V_c = \left[\left(\frac{L}{d}\right)\cdot k\right]^{0.128}\left(V_{av} - V_o\right) \qquad [2.2]$$

where:

V_c = capsule velocity

k = capsule to pipe diameter ratio, d/D

L = capsule length (m)

d = capsule diameter (m)

V_{av} = average water velocity ($m \cdot s^{-1}$)

V_o = threshold velocity ($m \cdot s^{-1}$)

An equation for threshold velocity was determined using dimensional analysis.

$$V_o = \sqrt{2gD(S-1)}\left(1-k^2\right)\left(\frac{L}{d}\right)^{0.371} \qquad [2.3]$$

where:

g = acceleration due to gravity (9.806 m·s^{-2})

D = pipe diameter (m)

S = capsule reality density

Substituting equation 2.3 into equation 2.2 yielded the semi-empirical equation for capsule velocity through a vertical pipe.

$$V_c = \left(\frac{1}{k^{0.128}}\right)\left[\left(\frac{L}{d}\right)^{0.128} V_{av} - \sqrt{2gD(S-1)\left(\frac{L}{d}\right)\left(1-k^2\right)}\right] \qquad [2.4]$$

Because this equation is for a small particle to pipe ratio in a vertical pipe, it offers a reasonable representation of the transport of *Salmonella* through the meat. Therefore, this equation is used in section 3.6 to calculate the velocity of a *Salmonella* bacterium moving through meat.

2.10 Summary

- *Salmonella* is a harmful bacterium that can cause serious illness if contaminated meat is not properly processed (CDC, 2005).
- Capillary diffusion was assumed to be the driving force transporting marinade into whole-muscle meat products.

- Research has shown that pathogens can migrate to the center of the meat if the surface of the meat had been damaged by blades, needles, or known process techniques (Boyd et al., 1978; Johnston, 1979; Raccach and Henrickson, 1979).
- Unidirectional (Warsow, 2003) and multidirectional (Velasquez, 2006; Warsow, 2003) marination trials at Michigan State University indicated that *Salmonella* can contaminate the interior of whole-muscle meat products regardless of whether the outside had been damaged by blades, needles, or known process techniques.
- Thermal inactivation tests showed that *Salmonella* exhibits greater heat resistance in whole-muscle as compared to ground products (Orta-Ramirez et al., 2005; Tuntivanich et al., 2005; Velasquez et al., 2005; Velasquez, 2006)
- The equation by Latto and Chow (1982) for capsule flow through a vertical pipe represents a reasonable model for the velocity of *Salmonella* as it moves through or into a whole-muscle product.

3. METHODS AND MATERIALS

3.1 Overview

The model proposed in this study represents one-dimensional transport of *Salmonella* into whole-muscle meat products, assuming capillary diffusion of marinade through small uniform tubes, and capsule-like transport of the *Salmonella* cells along with the marinade.

The transport of *Salmonella* into whole-muscle meat during marination is a complex process; therefore, in developing s simplified one-dimensional model, a number of assumptions were needed. These assumptions were:

1. Capillary diffusion is the only driving force transporting marinade into the meat (Gravitational force was calculated to be ~ 1.2 % of capillary force for this case.).
2. The meat is composed of a bundle of capillaries that are uniform cylindrical tubes of the same size (Figure 3.1).
3. All of the marinade transported into the meat is immediately absorbed into the cells of the meat, causing them to expand, thereby reducing intercellular space.
4. When the intercellular space decreases below the size of a *Salmonella* cell, the migration of *Salmonella* within the meat stops.
5. The physical properties of the marinade are equal to those of water.
6. The density of *Salmonella* is equal to the density of water.
7. All *Salmonella* are non-motile inert capsules of the same size.
8. There are no physicochemical effects from salts and phosphates in the marinade.

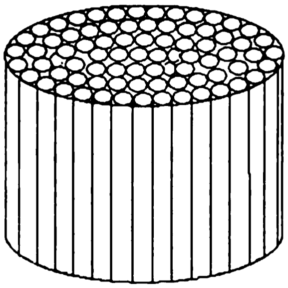

Figure 3.1: Conceptual image for the structure of meat as a bundle of small capillary tubes.

The overall solution consisted of eight steps, which sequentially estimated and/or solved for the following:

1. Physical and transport properties
2. Moisture concentration
3. Effective gap radius
4. *Darcy's* velocity
5. True marinade velocity
6. *Salmonella* velocity
7. *Salmonella* location profile
8. *Salmonella* concentration profile

Figure 3.2 contains a flow chart that describes the steps and conceptual framework of the model. The model was implemented completely in Microsoft Excel (Excel 2003, Microsoft Corp., Richmond, WA), using several user-defined functions and Palisade's RISKOptimizer (RISKOptimizer trial version, Palisade Corp., Ithica, NY). Once the model was formulated, two experimental data sets (*Salmonella* concentration profiles) were used to estimate two model parameters and to validate the solution.

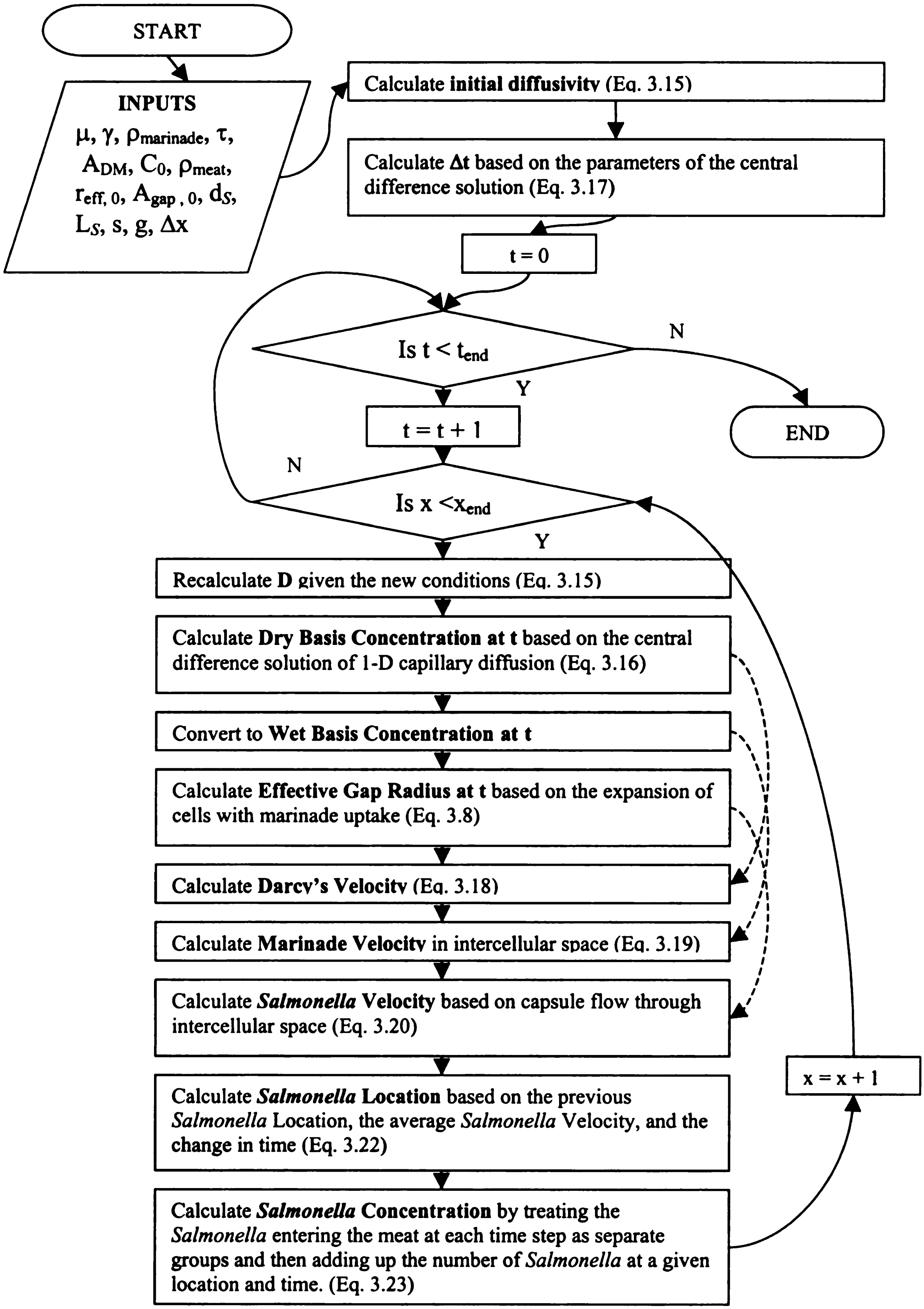
START
INPUTS
μ, γ, ρmarinade, τ, ADM, C0, ρmeat, reff, 0, Agap, 0, dS, LS, s, g, Δx
Calculate initial diffusivity (Eq. 3.15)
Calculate Δt based on the parameters of the central difference solution (Eq. 3.17)
t = 0
Is t < tend
N
Y
END
t = t + 1
N
Is x <xend
Y
Recalculate D given the new conditions (Eq. 3.15)
Calculate Dry Basis Concentration at t based on the central difference solution of 1-D capillary diffusion (Eq. 3.16)
Convert to Wet Basis Concentration at t
Calculate Effective Gap Radius at t based on the expansion of cells with marinade uptake (Eq. 3.8)
Calculate Darcy's Velocity (Eq. 3.18)
Calculate Marinade Velocity in intercellular space (Eq. 3.19)
Calculate Salmonella Velocity based on capsule flow through intercellular space (Eq. 3.20)
x = x + 1
Calculate Salmonella Location based on the previous Salmonella Location, the average Salmonella Velocity, and the change in time (Eq. 3.22)
Calculate Salmonella Concentration by treating the Salmonella entering the meat at each time step as separate groups and then adding up the number of Salmonella at a given location and time. (Eq. 3.23)

Figure 3.2: Steps and conceptual framework of the marination/migration model.

3.2 Physical and Transport Properties

Darcy's Law describes the overall flow of a liquid through a porous medium:

$$n^{v} = K\frac{\partial h}{\partial s} \qquad [3.1]$$

where:

n^{v} = volumetric flux or *Darcy's* velocity ($m^3 \cdot s^{-1} \cdot m^{-2}$)

K = hydraulic conductivity ($m \cdot s^{-1}$)

h = water potential (m)

s = distance along flow (m)

Written this way, *Darcy's* Law is a generic equation for liquid flow through any type of porous material. Therefore, equation 3.1 was modified to better represent capillary flow through a bundle of small tubes. This was done in part by using the following equation for volumetric flow rate of Poiseuille's flow through a tube of uniform radius (Datta, 2002):

$$Q_i = -\left(\frac{\pi \cdot r_i^4 \cdot \rho \cdot g}{8 \cdot \mu}\right)\left(\frac{\partial h}{\partial s}\right) \qquad [3.2]$$

where:

Q_i = volumetric flow rate per pore ($m^3 \cdot s^{-1}$)

r_i = radius of the tube (m)

ρ = density of ($kg \cdot m^{-1}$)

g = acceleration due to gravity ($9.806\ m \cdot s^{-2}$)

μ = viscosity of the fluid ($N \cdot s \cdot m^{-2}$)

The Poiseuille's flow equation is for a single straight pipe; therefore, equation 3.2 was altered to take into account a distribution of pore sizes (Datta, 2002), such that:

$$\Delta\beta_i = \frac{\omega_i \cdot \pi \cdot r_i^2}{A} \qquad [3.3]$$

where:

$\Delta\beta_i$ = volume fraction of pores with radius r_i

ω_i = number of pores in the i^{th} pore size class

r_i = radius of pores in the i^{th} pore size class (m)

A = total cross-sectional area (m^2)

In addition, a tortuosity factor (τ) was introduced to account for a non-straight travel path of the fluid; τ is the ratio of the roundabout path along the pore to the straight flow path (Datta, 2002). Therefore, the volumetric flux, or Darcy's velocity was represented by:

$$n^v = \frac{\rho \cdot g}{8 \cdot \mu \cdot \tau} \sum_i \Delta\beta_i r_i^2 \left(\frac{\partial h}{\partial s}\right) \qquad [3.4]$$

Given the stated assumption of uniform pore size, $\sum_i \Delta\beta_i r_i^2$ simplifies to $r_{eff,t}^2$, so that:

$$n^v = \frac{\rho \cdot g}{8 \cdot \mu \cdot \tau} \cdot r_{eff,t}^2 \cdot \left(\frac{\partial h}{\partial s}\right) \qquad [3.5]$$

Pressure is related to head as P = ρgh; therefore, terms in equation 3.4 can be combined to produce the following equation:

$$n^{v} = \left(\frac{r_{eff,t}^{2}}{8 \cdot \mu \cdot \tau} \right) \left(\frac{\partial P}{\partial s} \right) \quad [3.6]$$

Thus, the conductivity of the meat is represented by the following equation:

$$K = \left(\frac{r^{2}{}_{eff,t}}{8 \mu \tau} \right) \quad [3.7]$$

where:

μ = marinade viscosity ($N \cdot s \cdot m^{-2}$)

τ = tortuosity of the meat

$r_{eff,\,t}$ = effective radius of the pore space at time t, representing the intercellular gap (m)

The effective gap radius of the pore space at time t was calculated based on the assumption that the effective gap radius is proportional to the area of the gap.

$$r_{eff,t} = \frac{\left(r_{eff,0} \right) \left(A_{gap,t} \right)}{A_{gap,0}} \quad [3.8]$$

where:

$r_{eff,0}$ = initial effective gap radius (m)

$A_{gap,0}$ = initial percent area of the gap

$A_{gap,t}$ = percent area of the gap at time t

The initial r_{eff} value was approximated from Figure 3.3 by measuring the area between cells (i.e., the thickness of the gap) at various locations. The measured thicknesses were averaged and divided by two to get an initial value for the effective gap radius.

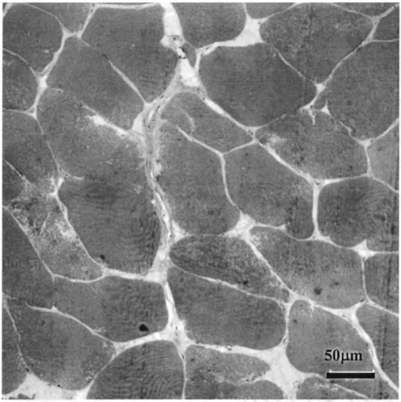

Figure 3.3: Micrograph of non-marinated irradiated turkey breast (Photo courtesy of V. Tuntivanich, Michigan State University).

The initial percent area of the gap ($A_{gap,0}$) was estimated using MATLAB's Image Processing Toolbox (MatLab Image Processing Toolbox, The Mathworks, Natick, MA). A thresholding value was used to determine the cutoff point between light and dark pixels. The meat's pore space was represented by white pixels (pixels with a value below the threshold), while the meat's cellular space was represented by the pixels above the threshold value (Figure 3.4). An optimum thresholding value (145) was automatically calculated in MATLAB using the Otsu method for thesholding. The number of white pixels was divided by the total number of pixels in the image to yield the percentage of pore space.

Figure 3.4: MATLAB's threshold image of Figure 3.3.

The percentage of pore space decreases as the moisture content of the meat increases and was calculated using:

$$A_{gap,t} = 1 - \left(\frac{A_{DM}}{1 - C_{wb,t}} \right) \qquad [3.9]$$

where:

A_{DM} = percent area of dry matter in a piece of meat

$C_{wb,t}$ = wet basis moisture concentration at time t

The percent area of dry matter in the meat was calculated from the initial wet basis moisture concentration and the initial percent area of the gap. The amount of dry matter in meat does not change with marinade uptake and, therefore, does not have to be recalculated at each time step.

$$A_{DM} = \left(1 - C_{wb0}\right)\left(1 - A_{gap_0}\right) \quad [3.10]$$

where:

$C_{wb,0}$ = initial wet basis moisture concentration

$A_{gap,0}$ = initial percent area of the gap

The capillary-based *Darcy's* flow equation 3.6 was converted to a capillary diffusion based flow using the definition of capillary diffusivity (Chow et al., 1988):

$$D = K\left(\frac{d\Psi}{dC_{db}}\right) \quad [3.11]$$

where:

K = capillary conductivity of meat ($m \cdot s^{-1}$)

Ψ = capillary potential ($N \cdot m^{-2}$)

C_{db} = dry basis moisture concentration

The capillary conductivity used in this equation was calculated using equation 3.7. Capillary potential was expressed as (Datta, 2002):

$$\Psi = \frac{2 \cdot \gamma}{r_{eff,t}} \quad [3.12]$$

where:

γ = surface tension of the liquid ($N \cdot m^{-1}$)

$r_{eff,t}$ = effective gap radius at time t (m)

Based on this equation, $\left(\frac{\partial \Psi}{\partial C_{db}} \right)$ from equation 3.11 can be rewritten as follows:

$$\left(\frac{\partial \Psi}{\partial C_{db}} \right) = \frac{\partial \left(\frac{2\gamma}{r_{eff,t}} \right)}{\partial C_{db}} \quad [3.13]$$

The derivative of capillary pressure with respect to dry basis moisture content was solved using the chain rule. The complete derivation is included in Appendix 7.1, yielding:

$$\frac{\partial \left(\frac{2\gamma}{r_{eff}} \right)}{\partial (MC)} = \frac{2 \cdot \gamma \cdot A_{gap,0} \cdot A_{DM}}{r_{eff,0} \left(MC,t - \left(1 - A_{DM} \right) \right)^2} \quad [3.14]$$

Substituting this equation and equation 3.7 into equation 3.11 results in the completed equation for the diffusivity of the meat at any given time step:

$$D = \left(\frac{r_{eff,t}^{\ 2}}{8 \cdot \mu \cdot \tau} \right) \left(\frac{2 \cdot \gamma \cdot A_{gap,0} \cdot A_{DM}}{r_{eff,0} \left(MC_t - \left(1 - A_{DM} \right) \right)^2} \right) \quad [3.15]$$

3.3 Moisture Concentration

Given D, the central difference solution for 1-D unsteady-state diffusion (Merva, 1995) can be applied as follows:

$$C_{(i,t+1)} = \lambda \cdot C_{(i-1,t)} + (1 - 2 \cdot \lambda) C_{(i,t)} + \lambda \cdot C_{(i+1,t)} \qquad [3.16]$$

where lambda (λ) is the following time and distance ratio:

$$\lambda = \frac{D \Delta t}{\Delta x^2} \qquad [3.17]$$

and:

Δt = time step (s)

Δx = solution layer thickness (m)

For solution stability, the time step and layer thickness were selected based on the rule that (Merva, 1995):

$$0 < \lambda = \frac{D \Delta t}{\Delta x^2} \leq 0.5$$

Following this rule, equation 3.17 was used to calculate Δt from the initial diffusivity and a reasonable guess for Δx, and setting the equation equal to 0.5. The value of Δx was adjusted until a reasonable time step value was found.

Diffusivity of the meat decreases as the moisture concentration of the meat increases, because, as marinade diffuses into the muscle, the cells swell, and the percent area of the gap decreases along with the effective gap radius of the pores. The effective gap radius used in equation 3.15 is the effective gap radius at the previous time step.

Because λ is not a fixed value, it must be recalculated at every time step. In order to do this, a user function was created (see appendix A.2). This user function calculates a new λ for each position at each time step and enters it into equation 3.16, returning the dry basis moisture concentration for the given location and time.

The solution for the moisture concentration profile had the following boundary conditions:

1. At the initial time step (t = 0), moisture concentration at all locations was set to the initial moisture concentration of the meat (C_0).
2. At every other time step (t > 0) the moisture concentration in the first layer C(x = 0) was set to a saturation value consistent with the results of the moisture concentration tests described in section 3.11.1.

3.4 Effective Gap Radius

The effective gap radius was calculated using equations 3.8 and 3.9.

3.5 Darcy's Velocity

Darcy's velocity of the marinade is the volumetric flow rate of the marinade, relative to the cross-sectional area of the meat. *Darcy's* velocity of the marinade was calculated using Fick's Law (Datta, 2002):

$$n^{v} = -D \cdot \left(\frac{\Delta C_{db}}{\Delta x} \right) \quad [3.18]$$

where:

n^{v} = *Darcy's* velocity of the marinade ($m^3 \cdot s^{-1} \cdot m^{-2}$)

D = capillary diffusivity ($m^2 \cdot s^{-1}$)

ΔC_{db} = change in dry basis moisture concentration

Δx = layer thickness (m)

3.6 Marinade Velocity

Darcy's velocity does not reflect the true average velocity of the marinade within the pores, because the cross-sectional area of the pores (i.e., area available for flow) is smaller than the total cross-sectional area of the entire piece of meat. Thus, the true marinade velocity as it is drawn into the meat can be estimated by dividing *Darcy's* velocity by the porosity of the meat. In this case, porosity is defined as the fraction of cross-sectional area that is intercellular space.

$$v_{marinade,t,x} = \left(\frac{n^{v}_{x,t}}{1 - \frac{A_{DM}}{1 - C_{wb,t}}} \right) \quad [3.19]$$

where:

$n^{v}_{x,t}$ = *Darcy's* velocity at the given location and time ($m^3 \cdot s^{-1} \cdot m^{-2}$)

A_{DM} = percent area of dry matter

$C_{wb,t}$ = wet basis moisture concentration at time t

3.7 *Salmonella* Velocity

Velocity of a single *Salmonella* bacterium was calculated using Latto and Chow's (1982) equation for a cylindrical capsule in water moving through a vertical pipe:

$$V_c = \left(\frac{1}{k^{0.128}}\right)\left[\left(\frac{L}{d}\right)^{0.128} V_{av} - \sqrt{2gD(S-1)\left(\frac{L}{d}\right)\left(1-k^2\right)}\right] \quad [3.20]$$

where:

V_c = capsule velocity ($m \cdot s^{-1}$)

k = capsule to pipe diameter ratio, d/D

L = capsule length (m)

d = capsule diameter (m)

V_{av} = average water velocity ($m \cdot s^{-1}$)

V_o = threshold velocity ($m \cdot s^{-1}$)

g = acceleration due to gravity (9.806 $m \cdot s^{-2}$)

D = pipe diameter (m)

S = capsule relative density

However, equation 3.20 is for a smooth cylindrical capsule flowing through a larger smooth pipe; therefore, the capsule never slows down or stops because of reducing pipe diameter. A new term ($d_f/r_{eff,\,t}$) and two model parameters were added to equation 3.20 to take into account the flagella that could cause the *Salmonella* to slow down and stop in a manner that would occur with an idealized, smooth capsule, so that equation 3.20 was modified to become:

$$V_c = B \cdot \left(\frac{1}{k^{0.128}}\right)\left[\left(\frac{L}{d}\right)^{0.128} V_{av} - \sqrt{2gD(S-1)\left(\frac{L}{d}\right)\left(1-k^2\right)}\right]\left(\frac{2 \cdot r_{eff,t}}{d_f}\right)^n \quad [3.21]$$

where:

B = empirical parameter

d_f = effective length of flagella, measured from centerline of the cell (m)

$r_{eff,t}$ = effective gap radius at time t (m)

n = empirical parameter

The number of flagella was not incorporated into this term, except to assume that flagella were uniformly distributed around the cell. A schematic of a *Salmonella* cell in a vertical pipe is shown in Figure 3.5.

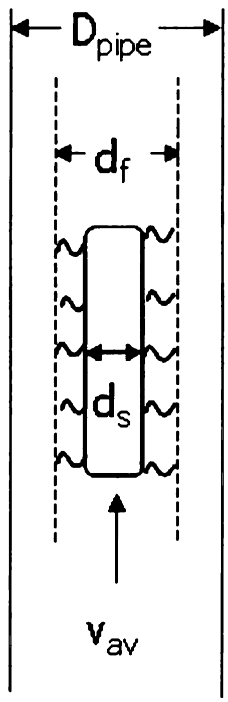

Figure 3.5: Schematic of *Salmonella* in a vertical pipe.

The current model assumes a capsule (*Salmonella*) relative density of one; therefore, part of equation 3.21 reduces to zero, resulting in the following simplified version of the equation:

$$V_c = B \cdot \left(\frac{1}{k^{0.128}}\right)\left[\left(\frac{L}{d}\right)^{0.128} V_{av}\right]\left(\frac{2 \cdot r_{eff,t}}{d_f}\right)^n \quad [3.22]$$

An optimization procedure (RISKOptimizer trial version, Palisade Corp., Ithica, NY) was used to find the best-fit estimate of B and n based on minimization of the sum of squared errors between the model and Warsow's (2003) experimental data for *Salmonella* concentration profile.

3.8 *Salmonella* Location

A wave profile of the location of *Salmonella* in the meat was created, where a new group (or wave) of *Salmonella* enters the meat at each time step, flowing along with marinade. The location of each existing wave is recalculated at each time step, based on the new velocity at the current location.

$$X_t = X_{t-1} + V_{c,x,t} \cdot \Delta t \quad [3.22]$$

where:

X_t = location of the *Salmonella* at time t

X_{t-1} = location of the *Salmonella* at the previous time step

$V_{c,x,t}$ = *Salmonella* velocity at the given location and time

Δt = time step

The algorithm by which $V_{c,x,t}$ was determined within the model solution can be found in Appendix A.11.

3.9 *Salmonella* Concentration Profile

The number of cells entering the meat with each new wave was determined based on the velocity and concentration of the marinade.

$$N = n^{v} \cdot C_{s} \cdot \Delta t \cdot \frac{1}{\Delta x} \qquad [3.23]$$

where:

N = number of *Salmonella* cells entering the meat ($cells/cm^3$)

n^{v} = *Darcy's* velocity of the marinade ($m^3 \cdot s^{-1} \cdot m^{-2}$)

C_s = *Salmonella* concentration of the marinade (cells/ml)

Δt = time step (s)

Δx = layer thickness (m)

A *Salmonella* concentration profile was created by summing the number of *Salmonella* in each layer at each time step.

3.10 Model Inputs

3.10.1 Meat Properties

The initial percent area of muscle and pore spaces estimated from microscopy image (Figure 3.3) were:

$$Area_{muscle,0} = 0.87$$

$$Area_{gap,0} = 0.13$$

The percent area dry matter was calculated using equation 3.10

$$Area_{DM} = 0.24$$

The tortuosity factor (τ) introduced in equation 3.4 is an unknown variable; however, it was assumed to be three, because the pore space of the meat is not perfectly straight and therefore τ must be greater than one.

The density of the meat were assumed to be:

$$\rho_0 = 1120 \frac{kg}{m^3}$$

3.10.2 Marinade Properties

The viscosity (μ), surface tension (γ), and density (ρ) of the marinade was assumed equal to that of pure water at 4 °C:

$$\mu = 1.519^{-3} \frac{N \cdot s}{m^2}$$

$$\gamma = 0.0754 \frac{N}{m}$$

$$\rho = 1005 \frac{kg}{m^3}$$

These values are input values in the model and can be changed easily should more exact values for the marinade be found.

3.10.3 Salmonella Properties

Adams and Moss (2000) reported the length and diameter of *Salmonella* as:

Diameter of *Salmonella* = 5.E-07 m

Length of *Salmonella* = 2.E-06 m

The relative density of *Salmonella* is approximately the same as pure water; therefore, a relative density of 1.0 was used.

3.10.4 Calculated Initial Values

The initial capillary diffusivity calculated using equation 3.15 was:

$D = 1.55715E\text{-}05\ m^2/s$

The time step and the thickness of the layers was calculated using equation 3.17:

$\Delta t = 0.1s$

$\Delta x = 0.005m$

3.11 Validation

A moisture concentration test and a *Salmonella* log count test were conducted to validate the proposed model. These tests were conducted in a controlled temperature room at 4 °C.

3.11.1 Moisture content

The marination procedure used for the moisture concentration trials was the same as the one used by Warsow (2003) for his unidirectional marination study.

For the moisture concentration test, irradiated (10 kGy) whole-muscle, boneless, skinless turkey breast was used. The turkey breast was frozen and held in vacuum-packed bags at -15 ° C for ~2 years and then thawed for 48 h at 4 ° C. A 10x10x5 cm block was cut from a turkey breast and placed cut side down in a 15 cm diameter Petri dish containing a round perforated stainless steel plate and 40 ml of sterile marinade. The marinade reached approximately 5 mm up the side of the turkey breast. The marinade was composed of 95 % water (filtered and deionized), 3.3 % NaCl, and 1.7 % mixed phosphate solution. In order to limit the airflow around the marinating meat, the sample was sealed in a laboratory-scale tumbler during marination. After 20 min of marinating, the sample was removed from the marinade and placed on a new 15 cm diameter Petri dish. Two different methods of removing samples from the turkey block, described below, were tested to determine the method with the smallest degree of error in determining moisture content:

1. Four one-inch diameter cores were removed from the center of the turkey block and sliced into three pieces. The meat segments were cut into smaller pieces and placed into aluminum weighing dishes.
2. The block of meat was sliced using a dry knife into three layers, and each layer was ground separately in a small Black and Decker chopper. Four 10-15 g samples from each layer were placed into aluminum weighing dishes.

Before the meat was added to the dishes, the dishes were heated in a drying oven (Yamato DX400, Yamato Scientific America Inc., Santa Clara, CA) for 30 min at 120 °C to remove any moisture from the dish, placed in a desiccator to cool, and then weighed. The raw meat in the dish was weighed before being dried overnight (16 - 18 h) at 100 °C. After drying, the samples were allowed to cool in a desiccator before the final weight was taken.

3.11.2 Salmonella concentration

The procedure used for the log count test was the same as that used by Warsow (2003) for his unidirectional *Salmonella* log count tests. The inoculum was a *Salmonella* cocktail that consisted of eight strains of *Salmonella* (*S.* Thompson FSIS 120, *S.* Enteriditis H3527 and H3502, *S.* Typhimurium DT 104 H3380, *S.* Hadar MF60404, *S.* Copenhagen 8457, *S.* Montevideo FSIS 051, and *S.* Heildelberg FS038B61), previously acquired from Dr. V.K. Juneja (Agricultural Research Service, Eastern Regional Research Center, USDA-ARS, Philadelphia, Penn., U.S.A.). The individual strains were stored in tryptic soy broth (TSB) containing 10% glycerol in a -80 °C freezer. The cultures were propagated by two consecutive daily transfers of one loopful of culture to 9 ml of fresh TSB in a 20 ml culture tube. The cultures were incubated 18-24 h at 37 °C between each transfer. On the day of the experiment, 9 ml of each of the eight serovars grown separately in TSB were combined and centrifuged at 6,000 x g for 20 min at 4 °C. The supernatant was poured off, and the cell pellet was resuspended in approximately 520 ml of sterile marinade to give a final *Salmonella* concentration of ~10^9 CFU/ml. The *Salmonella* population in the marinade was confirmed by serial dilution in 0.1% peptone water with duplicate plating on Petrifilm™ Aerobic Count Plates (3M Corp., St. Paul, Minn., U.S.A.).

Four cores were removed from the block using a 1.23 cm inside diameter Warner-Bratzler hand coring device and placed in a disposable Petri dish containing a piece of sterile cotton gauze. The cored sample was cut into five 1 cm segments, starting from the end furtherest from the marinade, and placed in individual 4 oz Whirl-pak™ bags. Thereafter, 4 ml of 0.1 % peptone water was added to each bag to achieve the highest possible concentration while still adding sufficient peptone water for plating. The weight of each sample was taken before and after adding peptone. The samples were mechanically macerated for 180 s before being plated on Petrifilm™ Aerobic Count Plates. The plates were incubated for 48 h at 37 °C before enumeration.

3.12 Limitations

Multiple assumptions were made about the structure of meat and its pore space in order to develop a sufficiently simple model, which resulted in several limitations.

- This model relies solely on capillary potential as the major driving force transporting *Salmonella* into meat, neglecting other possible driving forces contributing to marinade uptake, such as osmotic potential due to salt and phosphates in the marinade.
- This model calculated the initial effective gap radius and the initial area of the gap from only one turkey microscopy image. In order to get more reliable values for these variables, the initial effective gap radius and the initial area of the gap, a minimum of three microscopy images should be analyzed and averaged.
- This model assumes that the pore space in the meat was a bundle of uniform straight cylindrical capillaries, even though the area between the cells is actually irregular, interconnected interstices.
- This model uses the Latto and Chow (1982) equation for *Salmonella* velocity; however, their equation was based on experimental data that is outside the range of the capsule to pipe diameter ratios of *Salmonella* moving through a capillary. Latto and Chow's equation was for capsule to pipe diameter ratios ranging from 0.49 to 0.82, while this model had capsule to pipe diameters ranging from 0.16 to 0.19.

4. RESULTS

4.1 Overview

This chapter is divided into three main sections. The first section (4.2) describes the actual outputs of the model. The second section (4.3) describes the sensitivity of the model to various critical input parameters. The third section (4.4) describes the attempted validation of the model and the problems associated with the model.

4.2 Model Outputs

The model outputs for moisture concentration, effective gap radius, *Darcy's* velocity, marinade velocity, *Salmonella* velocity, *Salmonella* location, and *Salmonella* concentration were based on a set of standard input variables values (Table 4.1).

Table 4.1: Input variable values used in the evaluation of the model. Starred (*) variables are analyzed in Section 4.3.

	Variables	Value	Units
	Meat Properties		
*	$r_{eff,0}$	3.125E-06	M
	$C_{wb,0}$	0.720	-
*	$C_{wb,sat}$	0.726	-
	$A_{gap,0}$	0.13	-
*	τ	3	-
	ρ_i	1120	kg/m^3
	A_{DM}	0.2436	-
	Marinade Properties		
	μ	1.519E-03	N·s/m^2
	γ	7.54E-02	N/m
	ρ	1005	kg/m^3
	Salmonella Properties		
	d_s	5.E-07	M
	L_s	2.E-06	M
	s	1	-
*	d_f	1.E-06	M
	Empirical Parameters		
	B	0.216	-
	n	0.770	-
	Misc.		
	Δx	0.005	M
	Δt	1.03	S

4.2.1 Moisture Concentration

The moisture concentration of the meat was calculated using equation 3.15. As expected, the moisture concentration profile increased with time and decreased as the distance from the marinade exposed surface increased (Figure 4.1). Given the conditions in Table 4.1, the moisture concentration approached equilibrium (± 0.1%) at ~4 min.

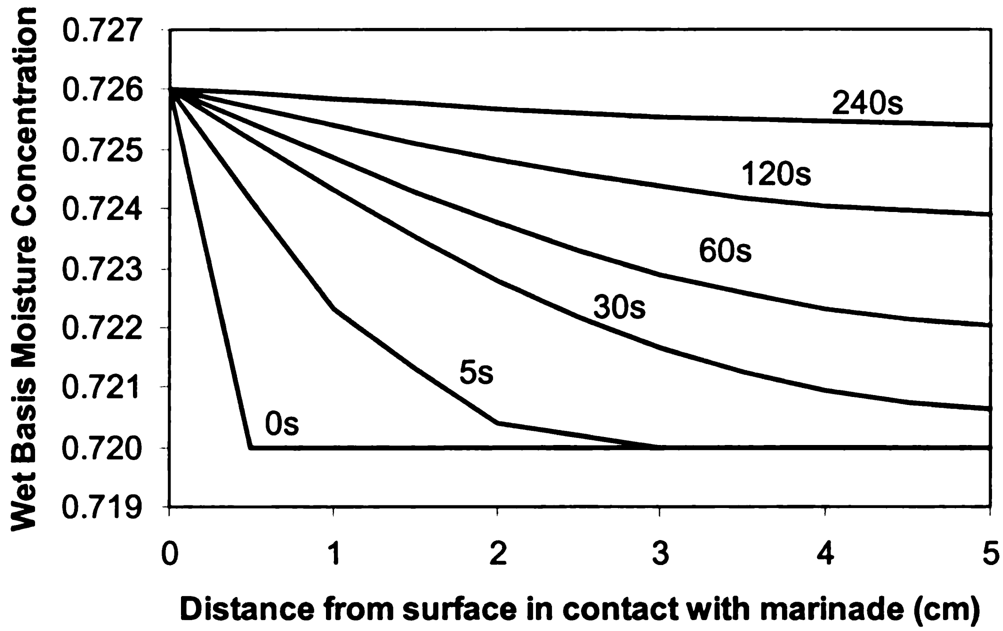

Figure 4.1: Predicted wet basis moisture concentration profile.

4.2.2 Effective Gap Radius

Given the conditions defined in Table 4.1 and using equations 3.8 and 3.9, the effective gap radius decreased from the initial value of 3.125 μm to 2.671 μm due to the increase in moisture concentration. The effective gap radius is derived from the moisture concentration profile; therefore, as expected, the effective gap radius profile is the inverse mirror of the moisture concentration profile (Figure 4.2). At equilibrium, the gap size shrinks to 85% of the initial gap size.

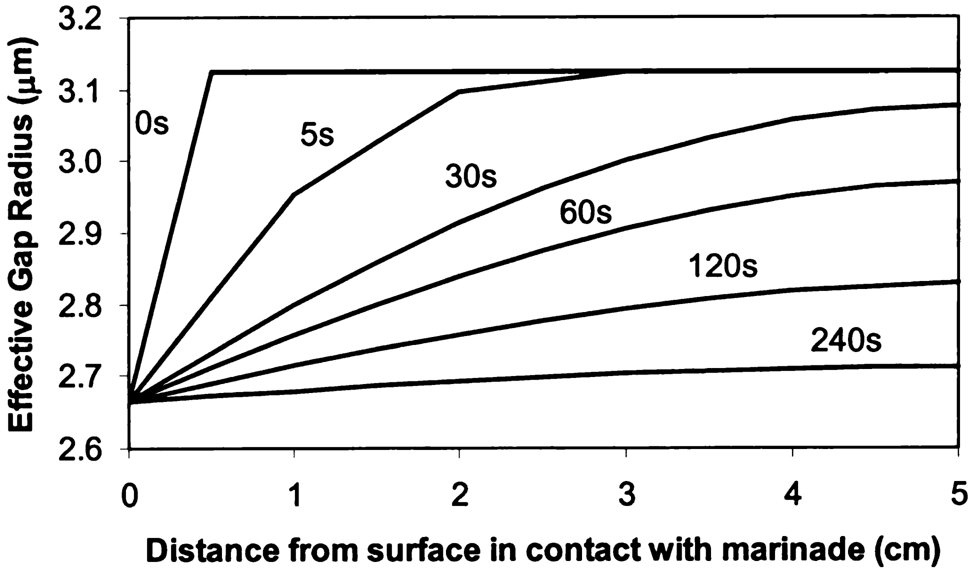

Figure 4.2: Predicted effective gap radius profile.

4.2.3 Darcy's Velocity

Darcy's velocity of the marinade is the volumetric flow rate of the marinade, relative to the cross-sectional area of the meat and was calculated using equation 3.17. *Darcy's* velocity of the marinade was found to decrease with time and distance into the meat. The non-smooth nature of the graph of *Darcy's* velocity at short time (Fig. 4.3) is because the thickness of the layers is such that a new velocity is calculated only every 0.005 m.

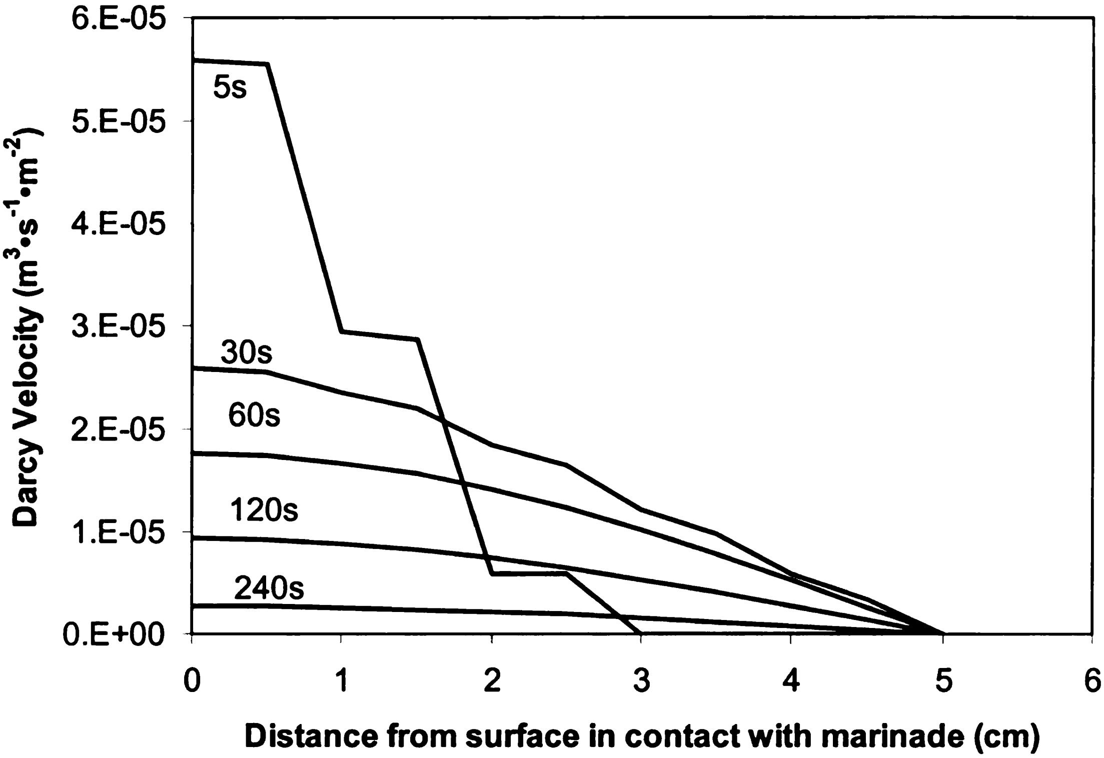

Figure 4.3: Darcy's velocity profile.

4.2.4 True Marinade Velocity

Because true marinade velocity was found by dividing the *Darcy's* velocity by the porosity of the meat, true marinade velocities had the same overall profile as the *Darcy's* velocities, but with larger magnitude (Figure 4.4).

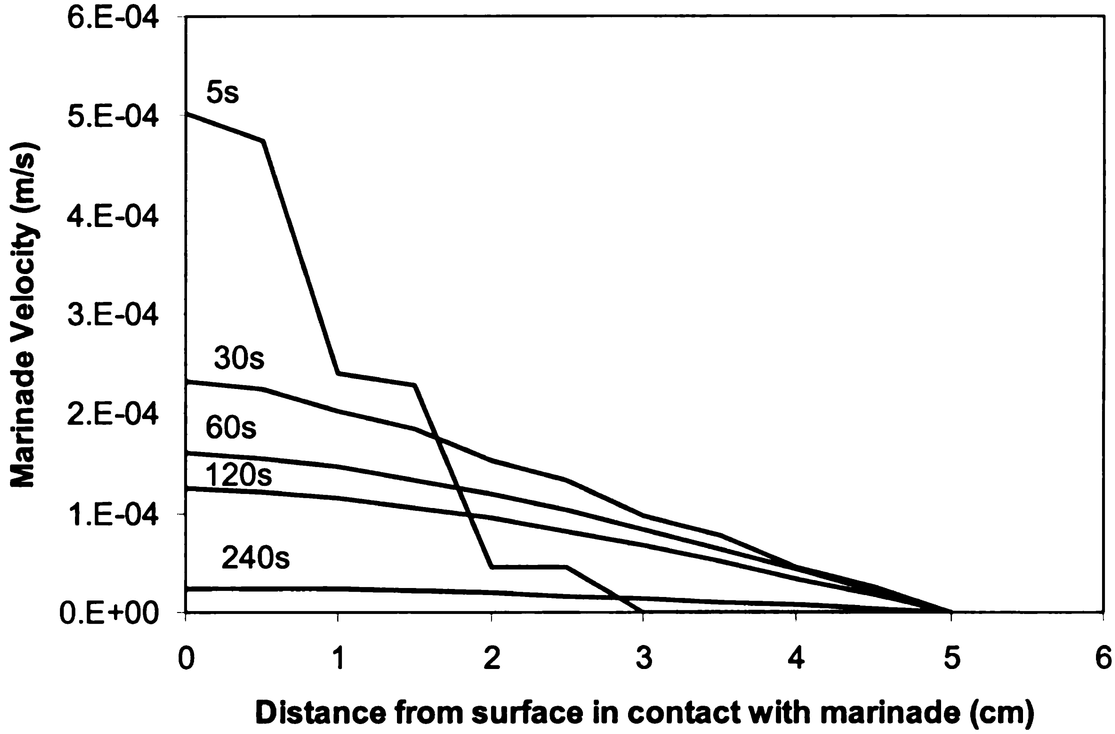

Figure 4.4: True marinade velocity profile.

4.2.5 Salmonella Velocity

The *Salmonella* velocity profile generated in Excel using the modified Latto and Chow equation (3.20) had the same overall trend as the true marinade velocity profile, but the values for *Salmonella* velocity are higher than those for marinade velocity (Figure 4.5).

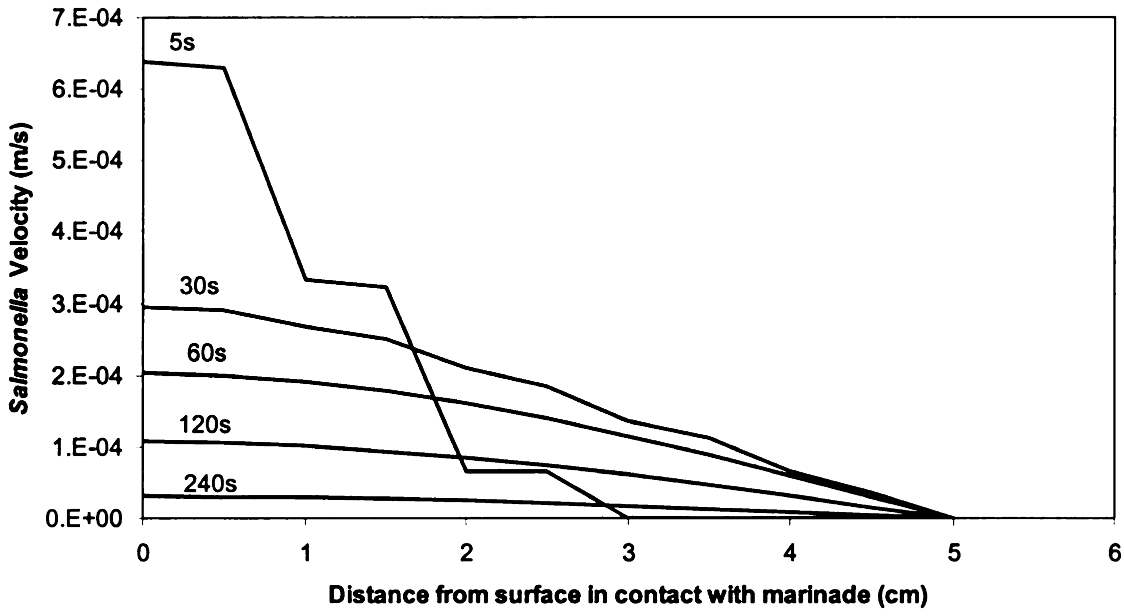

Figure 4.5: ***Salmonella*** **velocity profile.**

4.2.6 Salmonella Location

The location of *Salmonella* at any given time step was calculated using the wave theory described in section 3.8 (Figure 4.6). The wave profile shows that, as time increases, the velocity of the waves entering decreases; thus, each wave enters the meat at a slower velocity than the previous waves. The first wave of *Salmonella* travels the fastest and moves 0.035 m into the meat after 4.37 min. The decreasing velocity causes subsequent waves to get closer together, resulting in the majority of the waves being found in the first two layers of the meat after marination.

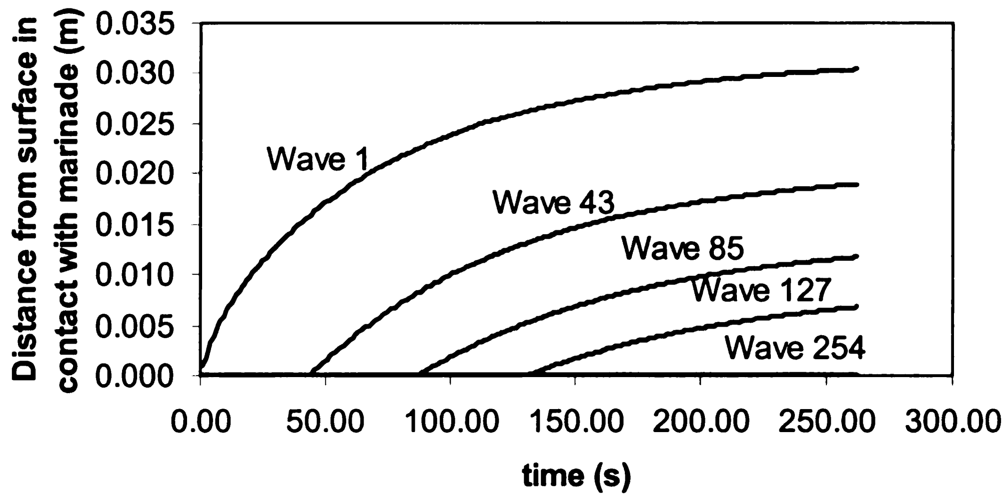

Figure 4.6: ***Salmonella*** **location wave profile.**

4.2.7 Salmonella Concentration Profile

As described in Section 3.9, the optimum predicted *Salmonella* concentration profile for the model was found by minimizing the sum of square errors between Warsow's (2003) experimental log counts and the predicted values, by changing the empirical parameters B and n found in the *Salmonella* velocity equation. Unfortunately, Figure 4.7 shows that the optimized predicted profile was not able to achieve a very good fit to the experimental results.

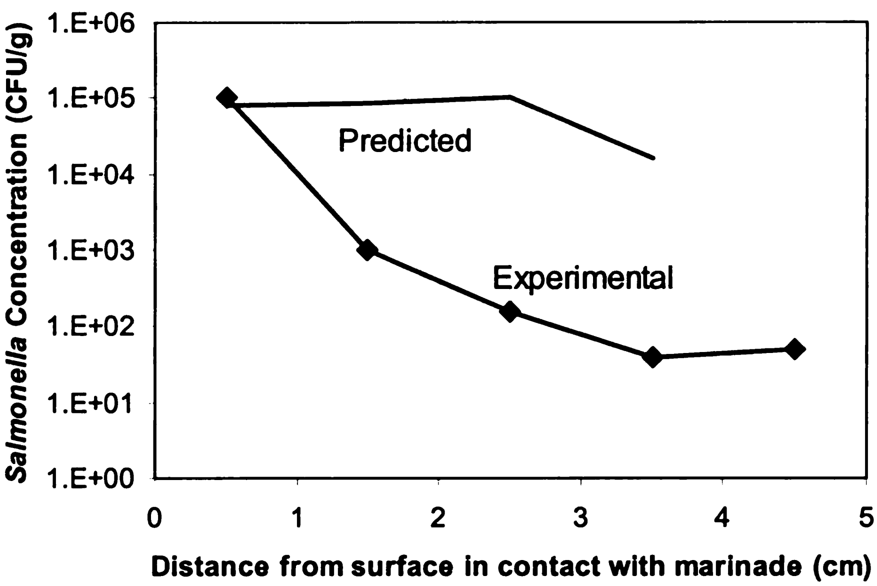

Figure 4.7: Comparison of predicted *Salmonella* concentration at t = 4.35 min versus Warsow's (2003) experimental results at t = 20 min.

4.3 Sensitivity Analysis

This model requires 18 input variables that can easily be adjusted to represent a specific case. Many of these inputs, such as the marinade properties, are reasonably well-known and should be very close to the actual values. However, there are other critical inputs used in the model that have a higher degree of uncertainty; therefore, changing them could have an unknown impact on the output of the model. This section evaluates the model sensitivity to changes in the saturation moisture concentration, tortuosity, initial effective gap radius, and the effective length of flagella. In order to compare the sensitivity to these variables, all runs were compared at t = 120 s, using a standard set of inputs (Table 4.1) and varying only one input variable at a time.

4.3.1 Saturation Moisture Concentration

The saturation moisture concentration used in the model is only 1% higher than the initial moisture concentration, which coincides with the results of the moisture concentration laboratory trials that can be found in Appendix A.3. However, this is much lower than the expected saturation moisture concentration. Increasing the saturation moisture concentration increases the moisture concentration throughout the meat at any given time (Figure 4.8) and thereby results in a high *Salmonella* concentration deeper in the meat (Figure 4.9).

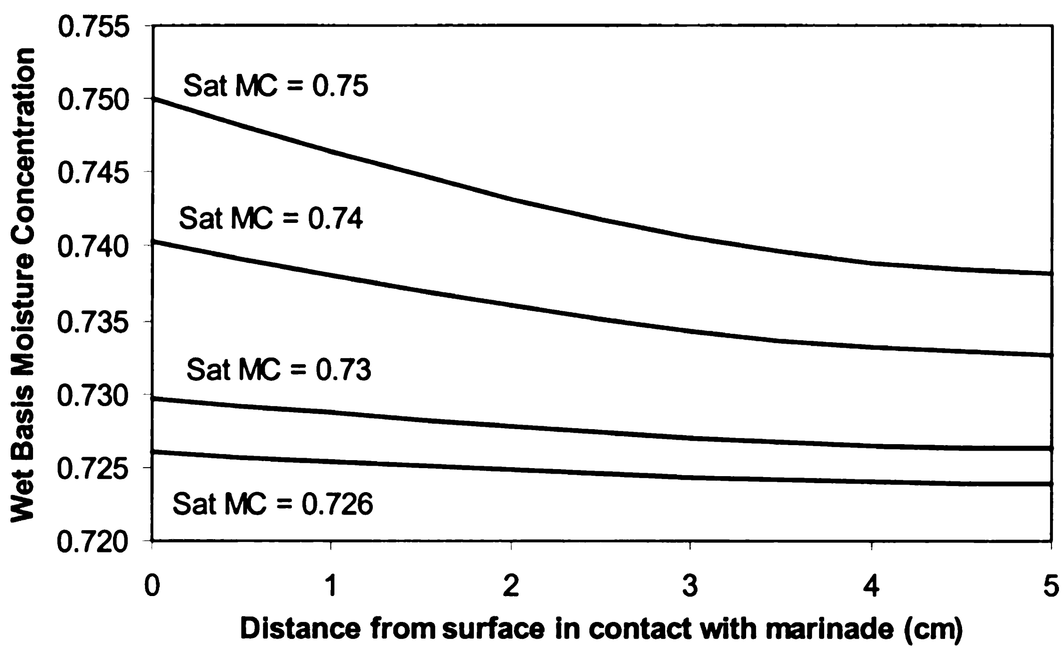

Figure 4.8: Wet basis moisture concentration with varying saturation moisture concentrations at t = 120 s.

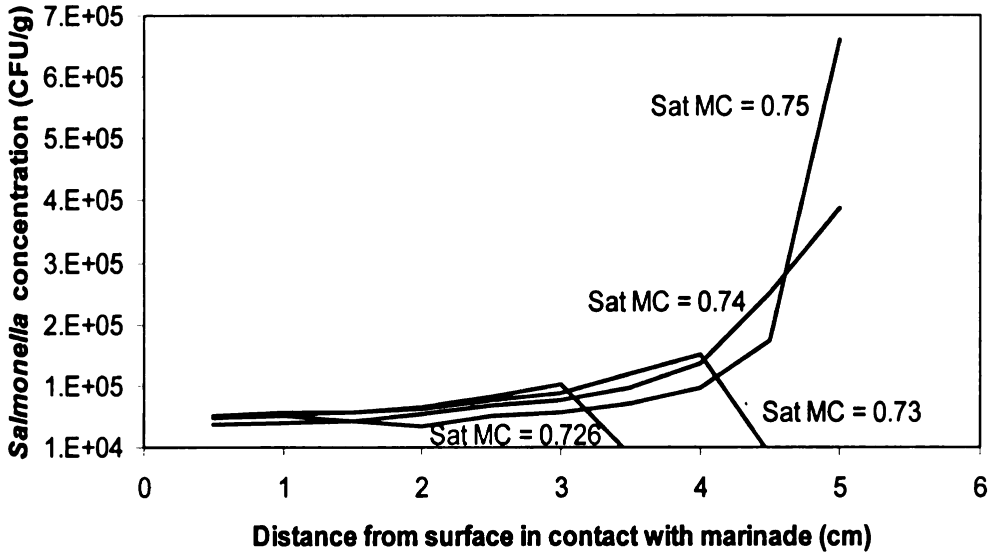

Figure 4.9: *Salmonella* concentration profile with varying saturation moisture concentrations at t = 120 s.

4.3.2 Tortuosity

The tortuosity of the meat is the most uncertain of the input variables, because the τ of whole-muscle turkey breast is unknown, and the value used was simply a reasonable guess. Therefore, it is important to determine the sensitivity of the model to a change in τ. Tortuosity represents the complexity of the path that the marinade travels; therefore, increasing τ decreases the diffusivity of the meat and increases the required time step in the solution. This change causes the moisture concentration at a given time to decrease with increasing τ (Figure 4.10). For example, an increase in τ from 3 to 4 resulted in a decrease in the minimum moisture concentration from ~ 72.4 to ~ 72.3 %.

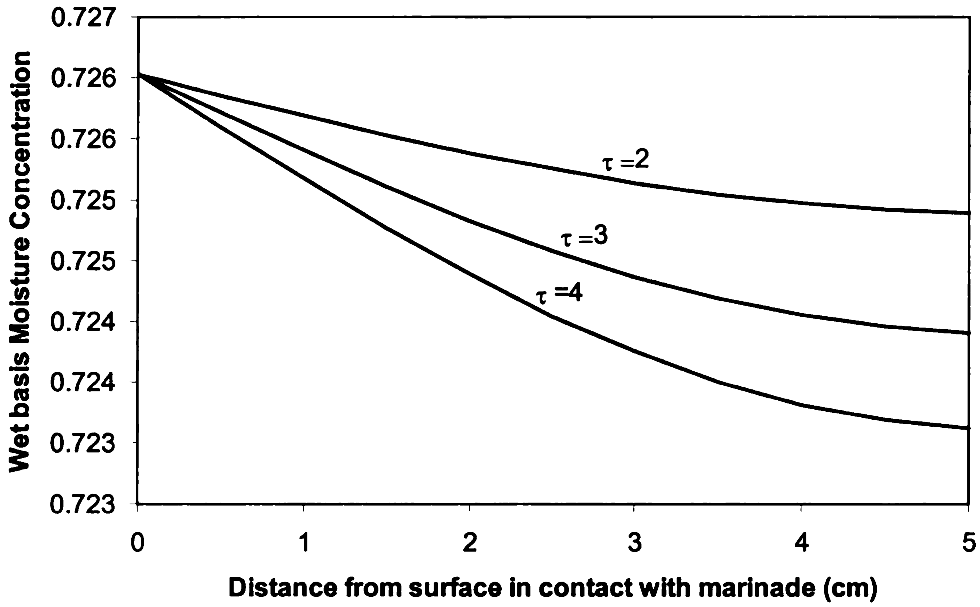

Figure 4.10: Wet basis moisture concentration with varying tortuosity at t = 120 s.

In addition, increasing τ also decreases the velocity of the marinade and *Salmonella* and ultimately decreases the depth of *Salmonella* penetration (Figure 4.11).

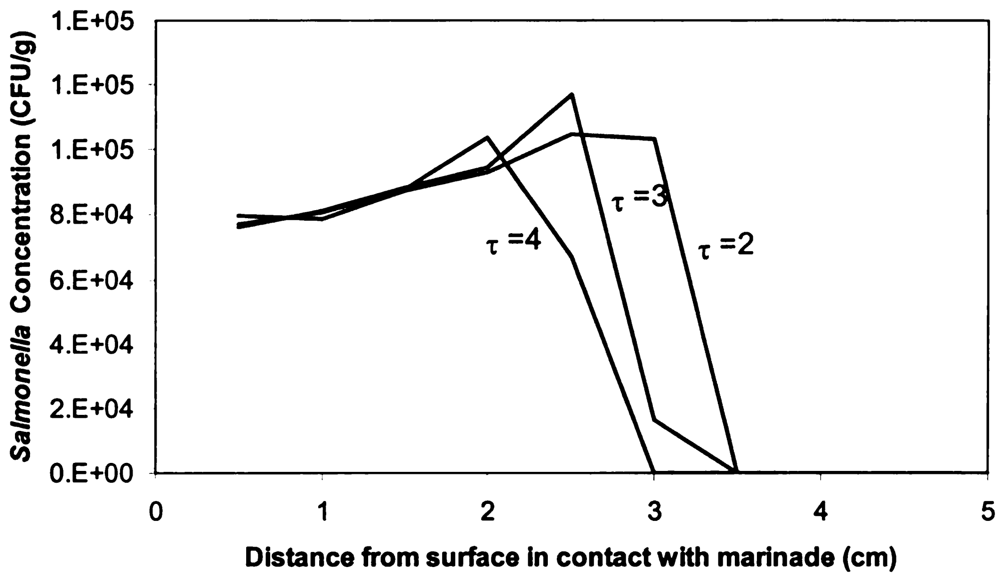

Figure 4.11: ***Salmonella* concentration profile with varying τ at t = 120 s.**

4.3.3 Initial Effective Gap Radius

The initial effective gap radius was estimated from only one micrograph; therefore, this parameter was also analyzed to see what effect changing this value might have on the overall solution. Increasing the initial effective gap radius causes the diffusivity of the meat to increase and, because the time step is calculated using the diffusivity of the meat, the time step decreases. The penetration depth of *Salmonella* decreases as the initial effective gap radius increases (Figure 4.12), due to a loss in capillary potential.

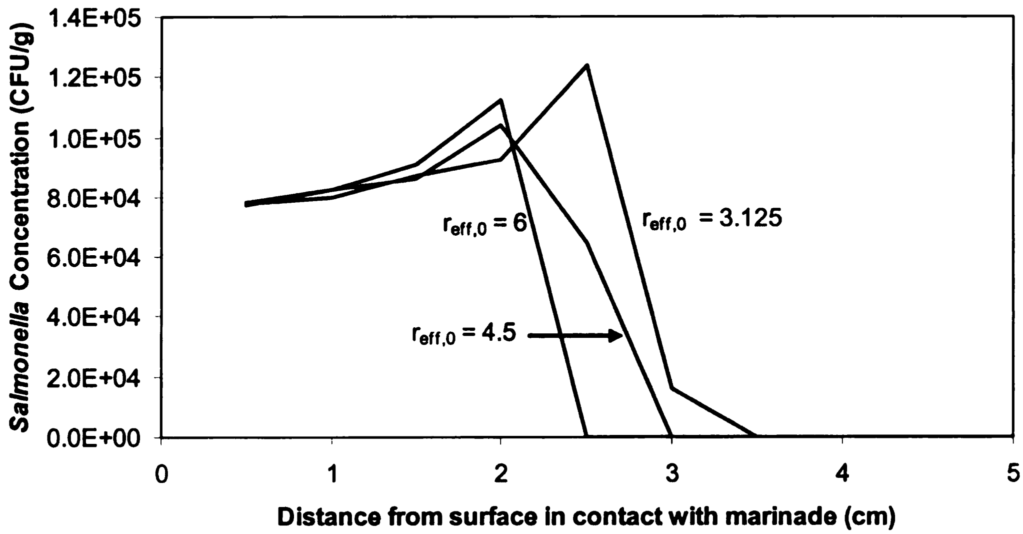

Figure 4.12: *Salmonella* concentration profile with varying initial effective gap radius at t = 120 s.

4.3.4 Effective Length of Flagella

The effective length of the flagella was combined with the effective diameter of the gap to form a dimensionless term that was added to the *Salmonella* velocity equation, to act as a "stickiness" term that would slow down the *Salmonella* velocity as the radius of the gap decreased. Figure 4.13 shows that, as the effective length of the flagella increases and the ratio of the effective diameter of the gap to effective length of flagella decreases, the slower the *Salmonella* move through the meat.

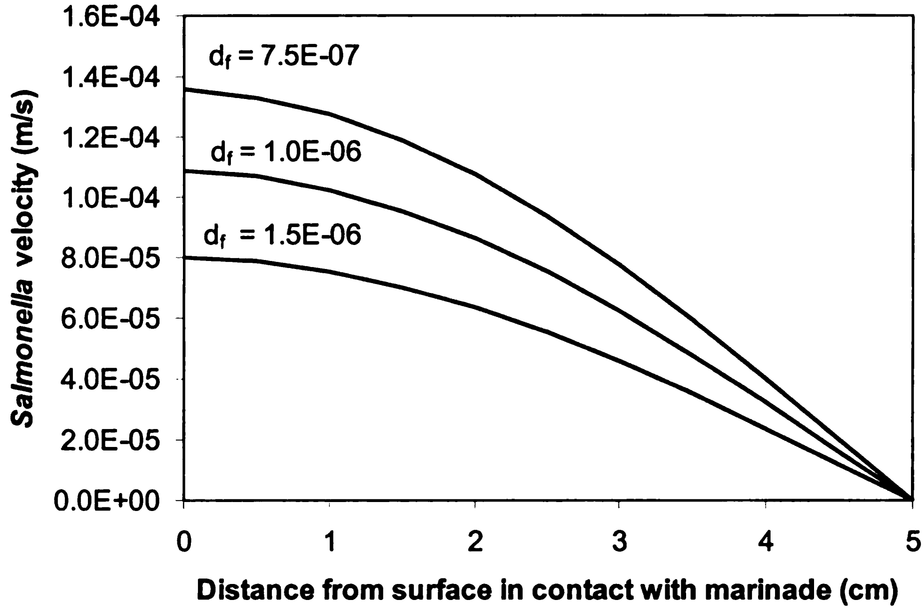

Figure 4.13: *Salmonella* velocity with varying effective lengths of flagella at t = 120 s.

As the effective length of the flagella increases, velocity of the *Salmonella* decreases, and therefore the final penetration depth of the bacteria decreases (Figure 4.14).

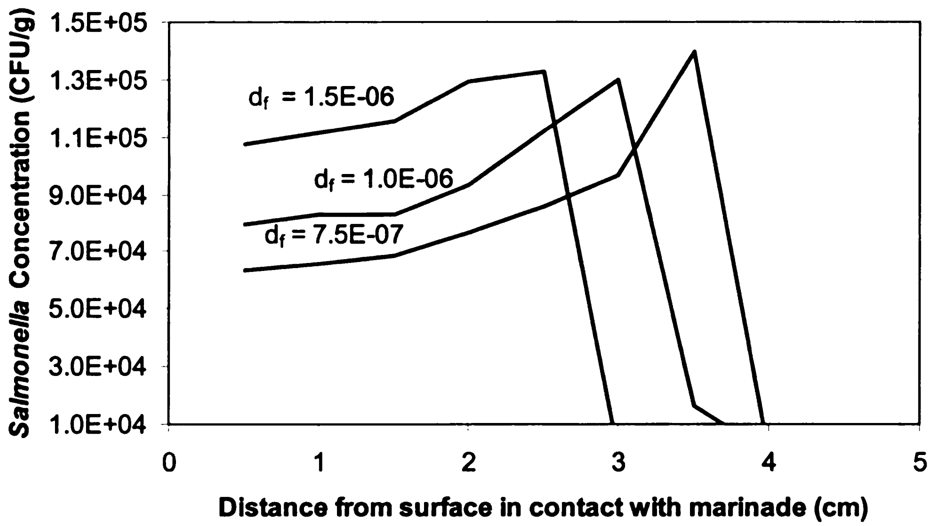

Figure 4.14: *Salmonella* concentration profile with varying effective length of flagella at t = 120 s.

4.4 Attempted Model Validation

The *Salmonella* log count trials described in section 3.10.2 were used to validate this model. These experimental results, Warsow's (2003) results, and the predicted *Salmonella* concentration profile are plotted together in Figure 4.15. Unfortunately, it is evident from Figure 4.15 that the predicted *Salmonella* concentration does not provide a good representation of the laboratory results.

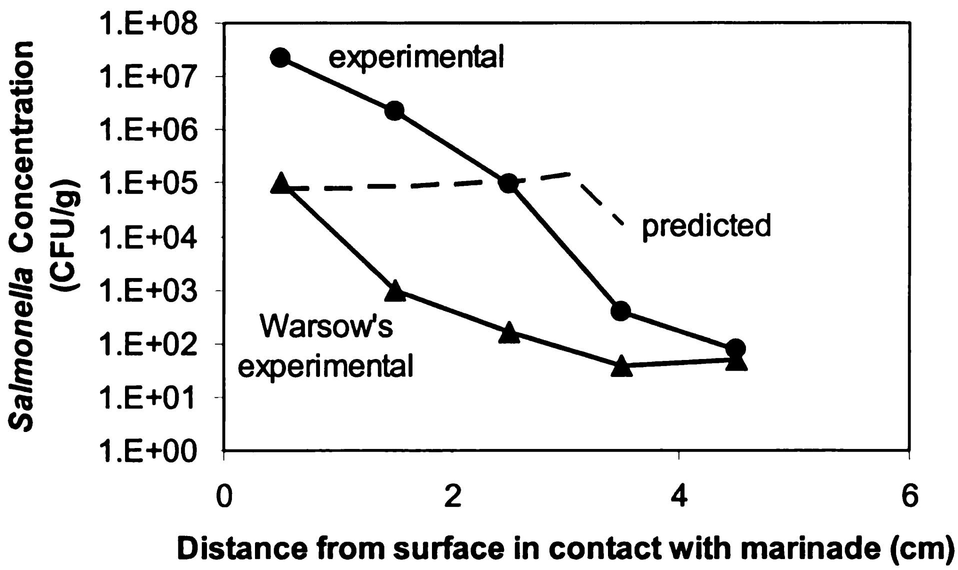

Figure 4.15: Comparison of predicted and experimental results for the *Salmonella* concentration profile of turkey breast.

Due to the limited number of columns in Excel, the predicted curve represents only the first 4 min of marination, while both sets of experimental data represent 20 min of marination. However, even if the predicted model were extended to 20 min it would still not provide an accurate representation of the *Salmonella* concentration, because the model is currently predicting a higher amount of *Salmonella* within the turkey breast after only 4 min of marination; therefore, extending the marination time would only increase the log counts.

Most likely, the major reason why the predicted results do not match the experimental results is the wave theory used to predict the location of the *Salmonella* at a given time. The wave theory assumes that a new group, or wave, of *Salmonella* enters the whole muscle at each new time step. The number of cells entering the meat with each new wave was calculated by equation 3.22, which was based on the velocity of

Salmonella and the concentration of the marinade. This creates a problem because the velocity of *Salmonella* is greater at the initial time steps before the effective gap radius shrinks due to moisture uptake. The higher velocity results in large initial concentrations entering the meat. The current model for marination allows for these high concentrations of cells to move rapidly through the meat and produce an unexpected high concentration of *Salmonella* in the interior of the meat. Using the wave profile approach, the cells in each wave move together at the same rate through the meat, creating clusters of cells. However, in reality, there would be more of a distribution of the cells. By analogy, if dye were dropped in a river, the dye would not stay together and flow down the river, but would spread and fade out as it moves. In an attempt to correct this problem and create a smoother distribution of the *Salmonella* a moving average ($\pm 2\Delta x$) at the final time step was found and graphed against the original predicted results in Figure 4.16.

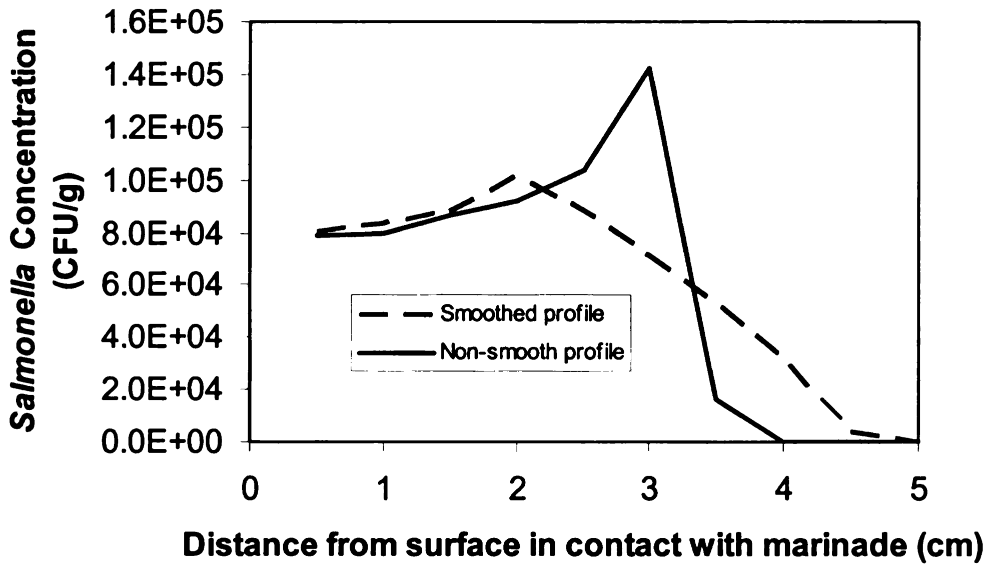

Figure 4.16: Comparison of smoothed ($\pm 2\Delta x$) and non-smoothed predicted *Salmonella* concentration profile at t = 261 s.

Taking the moving average of the profile did smooth out the distribution of *Salmonella* in the meat; however, even the smooth profile did not provide an accurate representation of the experimental results. In addition, averaging the cells creates additional data points and gives a false representation of the predicted distance that *Salmonella* moves through whole muscle.

4.12 Summary

The model was able to run and produce a result that reflects a logical relationship between input and output variables. In addition, the sensitivity analysis showed that the model was robust in the range of interest. Unfortunately, there was a problem in finding B and n values that resulted in a *Salmonella* concentration profile that resembled the experimental results.

5. CONCLUSION

This model does not predict the distribution of *Salmonella* in whole-muscle meat products during marination with sufficient accuracy to support the hypothesis regarding the underlying mechanism. Some key problems are as follows:

- The wave theory used to determine the location and concentration of *Salmonella* in the meat does not allow a smooth distribution of *Salmonella*, but rather a clumped, unrealistic distribution.
- Exact values for input variables are unknown.
- Based on current inputs and Excel limitations, the total time does not correspond to the experimental marination time.

However, even though this model does not provide a good representation of the experimental results for *Salmonella* transport into whole-muscle meat products during marination, there was some valuable information gained through this model.

- This model provides a good starting point on which to base future models.
- The results suggest that some of the model assumptions are incorrect. The moisture concentration tests performed in this study showed an immeasurable change after 20 min of marination. Prior to conducting these experiments, it was assumed that the meat was taking up more marinade during marination. With so little change in moisture concentration, the assumption that capillary diffusion is the primary driving force transporting the *Salmonella* into the meat may be incorrect.

6. FUTURE RESEARCH

This model provides a good starting point for modeling the transport of *Salmonella* through whole-muscle meat products; however, there is significant research that could be done to improve this model. Suggestions for future research include:

- Adjust the model so that capillary diffusion is not the only driving force transporting marinade into the meat. The moisture concentration tests conducted during this study showed that a very small amount of moisture uptake was needed to achieve *Salmonella* concentrations at the top of whole-muscle turkey breast. Therefore, capillary diffusion may not be the primary force responsible for the movement of *Salmonella* and marinade into meat.
- Conduct laboratory tests to determine whether *Salmonella's* flagella could transport *Salmonella* into meat without the aid of marinade. The model created in this study assumes that *Salmonella* are non-motile; therefore, if these tests reveal that the bacteria's motility has significant impact on the pathogens transport into whole muscle, then they should be incorporated into the model.
- Conduct additional moisture concentration trials to verify the rate at which marinade is being absorbed into the meat and test to see if the species of meat has any impact on the amount of marinade absorbed.
- Adjust the model to take into account the effects of salt and phosphate. The effects of salt and phosphate were neglected in order to simplify the model; however, to make the model more accurate, the osmotic potential caused by these additives found in marinades should be considered.

- Adjust the model so that it better represents the structure of meat. For simplicity, this model assumed that the meat is composed of a bundle of capillaries that are uniform cylindrical tubes of the same size, but instead the intercellular space in meat is actually various sized curvy flat spaces.
- Use micrographs taken after marination to compare the actual area gap change to the predicted change. In addition, additional premarination images are needed to find a more accurate initial effective gap radius and area of the gap.
- Improve the *Salmonella* velocity equation, so that it is more applicable to the range of parameters involved in marinade uptake.
- Confirm the effects of freezing and thawing meat on bacteria penetration and moisture uptake. Researchers have shown that freezing and thawing of meat can influence bacteria penetration (Maxcy 1981; Sikes and Maxcy 1980); however, it would be useful to further quantify the effects and, if they are significant, then account for the difference between fresh and frozen meat in the model.
- The current model has limitations due to the column restrictions in Excel; therefore, future models should be created in a program such as MATLAB to minimize the limitations associated with program capabilities.
- Finally, converting a working one-dimensional model to a two-dimensional model would better represent the actual marination process where meat is surrounded by marinade.

7. APPENDICES

The appendices are divided into the following 13 sections:

- Appendix 7.1: Derivative of Capillary Potential with Respect to Dry Basis Moisture Concentration
- Appendix 7.2: User Functions
- Appendix 7.3: Moisture Concentration Test Results
- Appendix 7.4: Marinade Percent Uptake Test Results
- Appendix 7.5: *Salmonella* Concentration Experimental Results
- Appendix 7.6: Calculation of Required Marinade Uptake to Achieve given Experimental *Salmonella* Log Counts
- Appendix 7.7: Master Input Page for Model
- Appendix 7.8: Model Output for Moisture Concentration
- Appendix 7.9: Model Output for Effective Gap Radius
- Appendix 7.10: Model Output for Darcy's Velocity
- Appendix 7.11: Model Output for *Salmonella* Velocity
- Appendix 7.12: Model Output for *Salmonella* Concentration
- Appendix 7.13: Three-Dimensional Graphs of Model Output

Appendix 7.1: Derivative of Capillary Potential with Respect to Dry Basis Moisture Concentration

Capillary pressure is expressed as two times the surface tension divided by the effective gap radius at time t ($\frac{2\cdot\gamma}{r_{eff_t}}$). Substituting in the equation for the effective gap radius at time t yields the following equation:

$$\frac{2\cdot\gamma}{r_{eff_t}}=\left(\frac{2\cdot\gamma\cdot\left(A_{gap_0}\right)^{\frac{1}{2}}}{r_{eff_0}}\right)\cdot\left(1-A_{DM}\cdot\left(1-\frac{C_{db_t}}{1+C_{db_t}}\right)^{-1}\right)^{\frac{-1}{2}} \qquad [7.1]$$

The devivative of capillary pressure with respect to moisture concentration can be found using the chain rule.

$$\frac{\partial\left(\frac{2\cdot\gamma}{r_{eff_t}}\right)}{\partial\left(C_{db_t}\right)}=\frac{-1}{2}\left(\frac{2\cdot\gamma\cdot\left(A_{gap_0}\right)^{\frac{1}{2}}}{r_{eff_0}}\right)\cdot\left(1-A_{DM}\cdot\left(1-\frac{C_{db_t}}{1+C_{db_t}}\right)^{-1}\right)^{\frac{-3}{2}}\cdot$$

$$\left(A_{DM}\cdot\left(1-\frac{C_{db_t}}{1+C_{db_t}}\right)^{-2}\right)\cdot\left(\frac{\left(1+C_{db_t}\right)-C_{db_t}\cdot(0+1)}{\left(1+C_{db_t}\right)^{2}}\right) \qquad [7.2]$$

Combining terms simplifies the equation to:

$$\frac{\partial\left(\frac{2\cdot\gamma}{r_{eff_t}}\right)}{\partial\left(C_{db_t}\right)}=\frac{\left(\frac{-\gamma\cdot\left(A_{gap_0}\right)^{\frac{1}{2}}}{r_{eff_0}}\right)}{\left(1-A_{DM}\cdot\left(1-\frac{C_{db_t}}{1+C_{db_t}}\right)^{-1}\right)^{\frac{3}{2}}}\cdot\left(\frac{A_{DM}}{\left(1-\frac{C_{db_t}}{1+C_{db_t}}\right)^{2}}\right)\cdot\left(\frac{-1}{\left(1+C_{db_t}\right)^{2}}\right)$$

This simplifies to:

$$\frac{\partial\left(\frac{2\cdot\gamma}{r_{eff_t}}\right)}{\partial\left(C_{db_t}\right)}=\frac{\gamma\cdot\left(A_{gap_0}\right)^{\frac{1}{2}}\cdot\left(A_{DM}\right)}{r_{eff_0}\cdot\left(1-\frac{A_{DM}}{\left(1-\frac{C_{db_t}}{1+C_{db_t}}\right)}\right)^{\frac{3}{2}}\cdot\left(\left(1-\frac{C_{db_t}}{1+C_{db_t}}\right)\cdot\left(1+C_{db_t}\right)\right)^{2}} \qquad [7.4]$$

Combining the terms in the denominator results in the final equation:

$$\frac{\partial\left(\frac{2\cdot\gamma}{r_{eff_t}}\right)}{\partial\left(C_{db_t}\right)}=\left(\frac{\gamma\cdot\left(A_{gap_0}\right)^{\frac{1}{2}}\left(A_{DM}\right)}{r_{eff_0}\cdot\left(1-\frac{A_{DM}}{\left(1-\frac{C_{db_t}}{1+C_{db_t}}\right)}\right)^{\frac{3}{2}}}\right) \qquad [7.5]$$

Appendix 7.2: User Functions

The user function used in equation 3.15 for calculating lambda was as follows:

```
Function Lambda(refft, Ct, dt, dx, vis, tor, st, Agi, DM, reffi)
D = (refft ^ 2 / (vis * 8 * tor)) * (((st * Agi ^ 0.5 * DM) / reffi) / ((1 - DM / (1 - Ct / (1 + Ct))) ^ (3 / 2)))
Lambda = (D * dt) / dx ^ 2
End Function
```

The user function used in equation 3.22 for calculating the *Salmonella* concentration at a given location was as follows:

```
Function Concentration(X, dx, Row, loc, cells)
   Concentration = 0
   Column = 1
   Xwave = loc(Row, Column)
   Do While Xwave > (X - dx)
      If Xwave <= X Then Concentration = Concentration + cells(Column)
      Column = Column + 1
      Xwave = loc(Row, Column)
   Loop
End Function
```

Appendix 7.3: Moisture Concentration Test Results

The exact moisture concentration profile of the meat after 20 min of marination could not be determined because the maximum change in moisture concentration was only 1% and that difference could be attributed to error associated with the procedure. However, these results do show that there is a lot less marinade being absorbed into the meat than was assumed. The results from the two different moisture concentration tests described in section 3.10.1 were:

Table 7.1: Moisture concentration results using the coring method described in section 3.11.1.

	Core - Slice	Dish	Dish +Raw Meat	Raw Meat	Dish + Dried Meat	Dried Meat	Moisture Content	average
TOP	1-1	1.2805	24.684	23.4035	7.5207	6.2402	0.733	0.731
	2-1	1.2682	16.8176	15.5494	5.5645	4.2963	0.724	0.730
	3-1	1.2711	14.9505	13.6794	4.8558	3.5847	0.738	0.730
	4-1	1.2691	14.1723	12.9032	4.7509	3.4818	0.730	
	1-2	1.2716	21.4134	20.1418	6.7785	5.5069	0.727	
	2-2	1.2809	16.2106	14.9297	5.3005	4.0196	0.731	
	3-2	1.2773	14.4263	13.149	4.8333	3.556	0.730	
	4-2	1.267	13.6046	12.3376	4.5664	3.2994	0.733	
	1-3	1.2771	20.1615	18.8844	6.499	5.2219	0.723	
	2-3	1.2734	20.4605	19.1871	6.3614	5.088	0.735	
	3-3	1.2735	12.215	10.9415	4.2368	2.9633	0.729	
BOTTOM	4-3	1.2706	10.0752	8.8046	3.6174	2.3468	0.733	
	initial	**1.2692**	**15.3803**	**14.1111**	**5.2252**	**3.956**	**0.720**	

Table 7.2: Moisture concentration results using the slicing method described in section 3.11.1.

		Dish	Dish + Raw Meat	Raw Meat	Dish + Dried Meat	Dried Meat	Moisture Content	average
TOP	1-1	1.2753	10.8599	9.5846	3.8741	2.5988	0.729	0.729
	2-1	1.2758	15.3639	14.0881	5.0929	3.8171	0.729	0.718
	3-1	1.2716	12.195	10.9234	4.2367	2.9651	0.729	0.722
	4-1	1.255	11.7325	10.4775	4.0862	2.8312	0.730	
	1-2	1.2723	11.6699	10.3976	4.2168	2.9445	0.717	
	2-2	1.277	11.0314	9.7544	4.018	2.741	0.719	
	3-2	1.2686	13.8091	12.5405	4.8461	3.5775	0.715	
	4-2	1.2735	10.4544	9.1809	3.8164	2.5429	0.723	
	1-3	1.2726	9.859	8.5864	3.6732	2.4006	0.720	
↓	2-3	1.2864	11.2238	9.9374	4.0358	2.7494	0.723	
	3-3	1.273	14.0432	12.7702	4.8589	3.5859	0.719	
BOTTOM	4-3	1.2685	10.7871	9.5186	3.8799	2.6114	0.726	

initial	**1.2692**	**15.3803**	**14.1111**	**5.2252**	**3.956**	**0.720**

Appendix 7.4: Marinade Percent Uptake Test Results

A laboratory test was conducted in order to determine how much marinade was being absorbed into the meat during marination. This experiment was done by placing a piece of whole-muscle pork roast in a Petri dish containing a measured amount of marinade and removing the meat after a set time and taking the weight of the remaining marinade. A new piece of meat was used for each of the time intervals. The result of this experiment is as follows:

Table 7.3: Marinade percent uptake test results.

sample	time (s)	time (min)	Meat Initial Weight (g)	Marinade Initial Wight (g)	Marinade weight after marination (g)	Uptake (g)	Percent Uptake
1	20	0.33	106.89	20.1	19.41	0.69	0.65%
2	50	0.83	92.01	20.58	20.05	0.53	0.58%
3	105	1.75	90.73	20.03	18.91	1.12	1.23%
4	225	3.75	83.63	19.54	18.65	0.89	1.06%
5	450	7.5	95.63	18.78	18.00	0.78	0.82%
6	900	15	91.68	21.63	20.87	0.76	0.83%
7	1200	20	88.78	20.32	19.72	0.60	0.68%

Appendix 7.5: *Salmonella* Concentration Experimental Results

The results of the *Salmonella* concentration tests described in section 3.11.2 are shown in Tables 7.4 and 7.5. Three trials were conducted where four cores were removed from each block of turkey and each core was sliced into five sections; therefore, the sample number corresponds to the rep number, core number, and the slice number. For example, sample 1-2-3 is rep 1 - core 2 – slice 3. The average for the second replication was based off from the results from two cores rather than four cores due to a problem with the initial sterility of two of the corers.

Table 7.4: *Salmonella* concentration experimental results.

Sample	Distance from surface in contact with marinade (m)	Meat (g)	Meat + Peptone (g)	log counts	log counts	Average	Adjusted Average
marinade				1.22E+09	1.36E+09	1.29E+09	
1-1-1	0.045	0.5	4.31	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-1-2	0.035	0.32	4.23	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-1-3	0.025	0.36	4.25	8.00E+01	1.30E+02	1.05E+02	4.46E+02
1-1-4	0.015	0.48	4.4	8.10E+03	9.40E+03	8.75E+03	3.85E+04
1-1-5	0.005	0.45	4.3	1.81E+06	1.92E+06	1.87E+06	8.02E+06
1-2-1	0.045	0.41	4.37	1.50E+02	2.30E+02	1.90E+02	8.30E+02
1-2-2	0.035	0.31	4.18	6.10E+02	6.40E+02	6.25E+02	2.61E+03
1-2-3	0.025	0.28	4.17	1.56E+04	1.56E+04	1.56E+04	6.51E+04
1-2-4	0.015	0.49	6.32	3.70E+05	5.20E+05	4.45E+05	2.81E+06
1-2-5	0.005	0.65	4.54	4.10E+06	5.00E+06	4.55E+06	2.07E+07
1-3-1	0.045	0.55	4.48	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-3-2	0.035	0.46	4.39	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-3-3	0.025	0.53	4.44	8.60E+03	8.60E+03	8.60E+03	3.82E+04
1-3-4	0.015	0.51	4.45	7.70E+05	6.70E+05	7.20E+05	3.20E+06
1-3-5	0.005	0.6	4.53	5.50E+06	5.20E+06	5.35E+06	2.42E+07
1-4-1	0.045	0.66	4.54	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-4-2	0.035	0.47	4.44	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-4-3	0.025	0.5	4.3	1.00E+02	8.00E+01	9.00E+01	3.87E+02
1-4-4	0.015	0.55	4.38	1.98E+04	2.00E+04	1.99E+04	8.72E+04
1-4-5	0.005	0.76	4.62	2.60E+06	1.80E+06	2.20E+06	1.02E+07
marinade				1.22E+09	1.36E+09	1.29E+09	
2-1-1	0.045	0.71	4.67	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-1-2	0.035	0.6	4.53	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-1-3	0.025	0.6	4.53	8.60E+02	9.10E+02	8.85E+02	4.01E+03
2-1-4	0.015	0.7	4.57	8.50E+05	9.50E+05	9.00E+05	4.11E+06
2-1-5	0.005	0.65	4.66	8.70E+06	7.10E+06	7.90E+06	3.68E+07
2-2-1	0.045	0.72	4.65	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-2-2	0.035	0.51	4.41	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 7.4 Continued

2-2-3	0.025	0.55	4.48	7.00E+01	1.70E+02	1.20E+02	5.38E+02
2-2-4	0.015	0.83	4.83	9.30E+04	8.10E+04	8.70E+04	4.20E+05
2-2-5	0.005	0.73	4.66	5.20E+06	4.10E+06	4.65E+06	2.17E+07
marinade				1.53E+09	1.43E+09	1.48E+09	
3-1-1	0.045	0.9	4.8	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3-1-2	0.035	0.7	4.6	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3-1-3	0.025	0.9	4.9	0.00E+00	1.00E+01	5.00E+00	2.45E+01
3-1-4	0.015	1.1	4.9	3.80E+05	3.90E+05	3.85E+05	1.89E+06
3-1-5	0.005	1.1	5	9.30E+06	9.00E+06	9.15E+06	4.58E+07
3-2-1	0.045	0.8	4.7	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3-2-2	0.035	0.8	4.6	2.30E+02	1.50E+02	1.90E+02	8.74E+02
3-2-3	0.025	0.9	4.8	1.12E+05	1.25E+05	1.19E+05	5.69E+05
3-2-4	0.015	0.9	4.9	1.26E+06	1.02E+06	1.14E+06	5.59E+06
3-2-5	0.005	0.9	4.9	3.20E+06	3.10E+06	3.15E+06	1.54E+07
3-3-1	0.045	0.9	4.7	1.00E+01	0.00E+00	5.00E+00	2.35E+01
3-3-2	0.035	0.8	4.6	1.70E+02	2.60E+02	2.15E+02	9.89E+02
3-3-3	0.025	0.9	4.9	6.00E+01	7.00E+01	6.50E+01	3.19E+02
3-3-4	0.015	1	4.9	4.40E+03	4.60E+03	4.50E+03	2.21E+04
3-3-5	0.005	1.1	5	1.68E+06	1.34E+06	1.51E+06	7.55E+06
3-4-1	0.045	1	4.8	1.00E+01	0.00E+00	5.00E+00	2.40E+01
3-4-2	0.035	1	4.8	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3-4-3	0.025	0.09	4.8	8.80E+04	1.11E+05	9.95E+04	4.78E+05
3-4-4	0.015	0.8	4.7	8.80E+05	1.09E+06	9.85E+05	4.63E+06
3-4-5	0.005	1.2	5.1	2.20E+06	2.50E+06	2.35E+06	1.20E+07

Table 7.5: *Salmonella* concentration average of all three replicates.

Combined Average	Distance from surface in contact with marinade (m)
7.32E+01	0.045
3.73E+02	0.035
9.67E+04	0.025
2.28E+06	0.015
2.17E+07	0.005

Appendix 7.6: Calculation of Required Marinade Uptake to Achieve given Experimental *Salmonella* Log Counts

The moisture concentration tests resulted in a much smaller change in moisture concentration than was expected; therefore, the following calculations were done to determine how much uptake was required to achieve the experimental log count results based on the concentration of the marinade:

Volume of meat layer = 100 cm^3

Density of Turkey = 1.12 g/cm^3

Based on the following experimental data from Table 7.5:

Slice 1: $$100cm^3\left(\frac{1.12g}{cm^3}\right)\left(\frac{2.17\cdot 10^7 CFU}{g}\right) = 2.43\cdot 10^9 CFU$$

Slice 2: $$100cm^3\left(\frac{1.12g}{cm^3}\right)\left(\frac{2.28\cdot 10^6 CFU}{g}\right) = 2.55\cdot 10^8 CFU$$

Slice 3: $$100cm^3\left(\frac{1.12g}{cm^3}\right)\left(\frac{9.67\cdot 10^4 CFU}{g}\right) = 1.08\cdot 10^7 CFU$$

Slice 4: $$100cm^3\left(\frac{1.12g}{cm^3}\right)\left(\frac{3.73\cdot 10^2 CFU}{g}\right) = 4.18\cdot 10^4 CFU$$

Slice 5: $$100cm^3\left(\frac{1.12g}{cm^3}\right)\left(\frac{7.32\cdot 10^1 CFU}{g}\right) = 8.20\cdot 10^3 CFU$$

Total CFU's per 10x10x5 cm^3 turkey block = $2.70\cdot 10^9$ CFU

Marinade concentration = $1.39\cdot 10^9$ CFU/ml

$$\text{Required } \textit{Salmonella} \text{ Uptake} = 2.70 \cdot 10^9 \left(\frac{1ml}{1.39 \cdot 10^9 CFU} \right) = 1.94ml$$

Appendix 7.7: Master Input Page for Model

The first sheet in Excel based model is a master page that contains all of the input variables and the graphs of the model outputs. The adjustable input variables are shown in Table 7.9, while the graphs are shown throughout this paper.

Table 7.6: Adjustable model input variables as they appear in the Excel Model

Meat Properties		Marinade Properties		Salmonella Properties	
$r_{eff,0}$ (m) =	3.125E-06	μ (N·s/m^2) =	1.519E-03	d_s (m) =	5.E-07
$C_{wb,0}$ =	0.72	γ (N/m) =	0.0754	L_s (m) =	2.E-06
$A_{gap,0}$ =	0.13	ρ (kg/m3) =	1005	s =	1
τ =	3			d_f (m) =	1.0E-06
ρ_0 (kg/m3) =	1120				
ρ_0 (g/cm3) =	1.12				
A_{DM} =	0.2436				

g (m/s^2) = 9.806	Δx (m) = 0.005

$C_{wb,sat}$	$C_{db,sat}$	$C_{db,0}$	$\frac{\partial\left(\frac{2\gamma}{r_{eff,i+1}}\right)}{\partial(MC_{i+1})}$	D (m^2/s)	Δt (s)
0.726	2.65	2.57	45212.16	1.21E-05	1.03

Appendix 7.8: Model Output for Moisture Concentration

Excel formula used to calculate the dry basis moisture concentration at t = 1.03 s and x = 0.005 m. (i.e. cell D5):

D5 =LAMBDA('Effective Gap Radius'!D4,D4,dt,dx,MASTER!vis,MASTER!tor,MASTER!st,MASTER!Agi,MASTER!ADM,MASTER!reffi)*C4+(1-2*LAMBDA('Effective Gap Radius'!D4,D4,dt,dx,MASTER!vis,MASTER!tor,MASTER!st,MASTER!Agi,MASTER!ADM,MASTER!reffi))*D4+LAMBDA('Effective Gap Radius'!D4,D4,dt,dx,MASTER!vis,MASTER!tor,MASTER!st,MASTER!Agi,MASTER!ADM,MASTER!reffi)*E4

Conversion from dry basis to wet basis:

D5 ='Moisture Content db'!D5/(1+'Moisture Content db'!D5)

Table 7.7: Predicted wet basis moisture concentration profile generated by Excel, given the input variables listed in Table 4.1.

Moisture Content												
	i =>	0	1	2	3	4	5	6	7	8	9	10
j		0	0.005	0.01	0.015	0.02	0.025	0.03	0.035	0.04	0.045	0.05
0	0	0.726	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720
1	1.03	0.726	0.723	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720
2	2.06	0.726	0.723	0.722	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720
3	3.10	0.726	0.724	0.722	0.721	0.720	0.720	0.720	0.720	0.720	0.720	0.720
4	4.13	0.726	0.724	0.722	0.721	0.720	0.720	0.720	0.720	0.720	0.720	0.720
5	5.16	0.726	0.724	0.722	0.721	0.720	0.720	0.720	0.720	0.720	0.720	0.720
6	6.19	0.726	0.724	0.723	0.721	0.721	0.720	0.720	0.720	0.720	0.720	0.720
7	7.22	0.726	0.724	0.723	0.722	0.721	0.720	0.720	0.720	0.720	0.720	0.720
8	8.26	0.726	0.724	0.723	0.722	0.721	0.720	0.720	0.720	0.720	0.720	0.720
9	9.29	0.726	0.725	0.723	0.722	0.721	0.721	0.720	0.720	0.720	0.720	0.720
10	10.32	0.726	0.725	0.723	0.722	0.721	0.721	0.720	0.720	0.720	0.720	0.720
11	11.35	0.726	0.725	0.723	0.722	0.721	0.721	0.720	0.720	0.720	0.720	0.720
12	12.39	0.726	0.725	0.723	0.722	0.722	0.721	0.721	0.720	0.720	0.720	0.720
13	13.42	0.726	0.725	0.724	0.723	0.722	0.721	0.721	0.720	0.720	0.720	0.720
14	14.45	0.726	0.725	0.724	0.723	0.722	0.721	0.721	0.720	0.720	0.720	0.720
15	15.48	0.726	0.725	0.724	0.723	0.722	0.721	0.721	0.720	0.720	0.720	0.720

Table 7.7 Continued

16	16.51	0.726	0.725	0.724	0.723	0.722	0.721	0.721	0.720	0.720	0.720	0.720
17	17.55	0.726	0.725	0.724	0.723	0.722	0.721	0.721	0.721	0.720	0.720	0.720
18	18.58	0.726	0.725	0.724	0.723	0.722	0.721	0.721	0.721	0.720	0.720	0.720
19	19.61	0.726	0.725	0.724	0.723	0.722	0.722	0.721	0.721	0.720	0.720	0.720
20	20.64	0.726	0.725	0.724	0.723	0.722	0.722	0.721	0.721	0.720	0.720	0.720
21	21.67	0.726	0.725	0.724	0.723	0.722	0.722	0.721	0.721	0.721	0.720	0.720
22	22.71	0.726	0.725	0.724	0.723	0.722	0.722	0.721	0.721	0.721	0.720	0.720
23	23.74	0.726	0.725	0.724	0.723	0.722	0.722	0.721	0.721	0.721	0.720	0.720
24	24.77	0.726	0.725	0.724	0.723	0.723	0.722	0.721	0.721	0.721	0.720	0.720
25	25.80	0.726	0.725	0.724	0.723	0.723	0.722	0.721	0.721	0.721	0.721	0.720
26	26.83	0.726	0.725	0.724	0.723	0.723	0.722	0.721	0.721	0.721	0.721	0.720
27	27.87	0.726	0.725	0.724	0.723	0.723	0.722	0.722	0.721	0.721	0.721	0.721
28	28.90	0.726	0.725	0.724	0.723	0.723	0.722	0.722	0.721	0.721	0.721	0.721
29	29.93	0.726	0.725	0.724	0.724	0.723	0.722	0.722	0.721	0.721	0.721	0.721
30	30.96	0.726	0.725	0.724	0.724	0.723	0.722	0.722	0.721	0.721	0.721	0.721
31	32.00	0.726	0.725	0.724	0.724	0.723	0.722	0.722	0.721	0.721	0.721	0.721
32	33.03	0.726	0.725	0.724	0.724	0.723	0.722	0.722	0.721	0.721	0.721	0.721
33	34.06	0.726	0.725	0.724	0.724	0.723	0.722	0.722	0.721	0.721	0.721	0.721
34	35.09	0.726	0.725	0.724	0.724	0.723	0.722	0.722	0.721	0.721	0.721	0.721
35	36.12	0.726	0.725	0.724	0.724	0.723	0.722	0.722	0.722	0.721	0.721	0.721
36	37.16	0.726	0.725	0.724	0.724	0.723	0.723	0.722	0.722	0.721	0.721	0.721
37	38.19	0.726	0.725	0.724	0.724	0.723	0.723	0.722	0.722	0.721	0.721	0.721
38	39.22	0.726	0.725	0.725	0.724	0.723	0.723	0.722	0.722	0.721	0.721	0.721
39	40.25	0.726	0.725	0.725	0.724	0.723	0.723	0.722	0.722	0.721	0.721	0.721
40	41.28	0.726	0.725	0.725	0.724	0.723	0.723	0.722	0.722	0.721	0.721	0.721
41	42.32	0.726	0.725	0.725	0.724	0.723	0.723	0.722	0.722	0.722	0.721	0.721
42	43.35	0.726	0.725	0.725	0.724	0.723	0.723	0.722	0.722	0.722	0.721	0.721
43	44.38	0.726	0.725	0.725	0.724	0.723	0.723	0.722	0.722	0.722	0.721	0.721
44	45.41	0.726	0.725	0.725	0.724	0.723	0.723	0.722	0.722	0.722	0.721	0.721
45	46.44	0.726	0.725	0.725	0.724	0.723	0.723	0.722	0.722	0.722	0.722	0.721
46	47.48	0.726	0.725	0.725	0.724	0.723	0.723	0.722	0.722	0.722	0.722	0.721
47	48.51	0.726	0.725	0.725	0.724	0.723	0.723	0.722	0.722	0.722	0.722	0.722
48	49.54	0.726	0.725	0.725	0.724	0.723	0.723	0.723	0.722	0.722	0.722	0.722
49	50.57	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.722	0.722	0.722	0.722
50	51.61	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.722	0.722	0.722	0.722
51	52.64	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.722	0.722	0.722	0.722
52	53.67	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.722	0.722	0.722	0.722
53	54.70	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.722	0.722	0.722	0.722
54	55.73	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.722	0.722	0.722	0.722
55	56.77	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.722	0.722	0.722	0.722
56	57.80	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.722	0.722	0.722	0.722
57	58.83	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.723	0.722	0.722	0.722
58	59.86	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.723	0.722	0.722	0.722
59	60.89	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.723	0.722	0.722	0.722
60	61.93	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.723	0.722	0.722	0.722
61	62.96	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.723	0.722	0.722	0.722
62	63.99	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.723	0.722	0.722	0.722
63	65.02	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.723	0.723	0.722	0.722
64	66.05	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.723	0.723	0.722	0.722
65	67.09	0.726	0.725	0.725	0.724	0.724	0.724	0.723	0.723	0.723	0.722	0.722
66	68.12	0.726	0.725	0.725	0.724	0.724	0.724	0.723	0.723	0.723	0.722	0.722
67	69.15	0.726	0.725	0.725	0.724	0.724	0.724	0.723	0.723	0.723	0.722	0.722
68	70.18	0.726	0.725	0.725	0.724	0.724	0.724	0.723	0.723	0.723	0.723	0.722
69	71.22	0.726	0.726	0.725	0.724	0.724	0.724	0.723	0.723	0.723	0.723	0.722
70	72.25	0.726	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.723	0.723	0.723
71	73.28	0.726	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.723	0.723	0.723
72	74.31	0.726	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.723	0.723	0.723
73	75.34	0.726	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.723	0.723	0.723
74	76.38	0.726	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.723	0.723	0.723
75	77.41	0.726	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.723	0.723	0.723
76	78.44	0.726	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.723	0.723	0.723
77	79.47	0.726	0.726	0.725	0.725	0.724	0.724	0.723	0.723	0.723	0.723	0.723

Table 7.7 Continued

78	80.50	0.726	0.726	0.725	0.725	0.724	0.724	0.724	0.723	0.723	0.723	0.723
79	81.54	0.726	0.726	0.725	0.725	0.724	0.724	0.724	0.723	0.723	0.723	0.723
80	82.57	0.726	0.726	0.725	0.725	0.724	0.724	0.724	0.723	0.723	0.723	0.723
81	83.60	0.726	0.726	0.725	0.725	0.724	0.724	0.724	0.723	0.723	0.723	0.723
82	84.63	0.726	0.726	0.725	0.725	0.724	0.724	0.724	0.723	0.723	0.723	0.723
83	85.66	0.726	0.726	0.725	0.725	0.724	0.724	0.724	0.723	0.723	0.723	0.723
84	86.70	0.726	0.726	0.725	0.725	0.724	0.724	0.724	0.723	0.723	0.723	0.723
85	87.73	0.726	0.726	0.725	0.725	0.724	0.724	0.724	0.723	0.723	0.723	0.723
86	88.76	0.726	0.726	0.725	0.725	0.724	0.724	0.724	0.723	0.723	0.723	0.723
87	89.79	0.726	0.726	0.725	0.725	0.724	0.724	0.724	0.724	0.723	0.723	0.723
88	90.83	0.726	0.726	0.725	0.725	0.724	0.724	0.724	0.724	0.723	0.723	0.723
89	91.86	0.726	0.726	0.725	0.725	0.724	0.724	0.724	0.724	0.723	0.723	0.723
90	92.89	0.726	0.726	0.725	0.725	0.724	0.724	0.724	0.724	0.723	0.723	0.723
91	93.92	0.726	0.726	0.725	0.725	0.724	0.724	0.724	0.724	0.723	0.723	0.723
92	94.95	0.726	0.726	0.725	0.725	0.724	0.724	0.724	0.724	0.723	0.723	0.723
93	95.99	0.726	0.726	0.725	0.725	0.724	0.724	0.724	0.724	0.723	0.723	0.723
94	97.02	0.726	0.726	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.723	0.723
95	98.05	0.726	0.726	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.723	0.723
96	99.08	0.726	0.726	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.723	0.723
97	100.11	0.726	0.726	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.723	0.723
98	101.15	0.726	0.726	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724	0.723
99	102.18	0.726	0.726	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724	0.723
100	103.21	0.726	0.726	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724	0.724
101	104.24	0.726	0.726	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724	0.724
102	105.27	0.726	0.726	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724	0.724
103	106.31	0.726	0.726	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724	0.724
104	107.34	0.726	0.726	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724	0.724
105	108.37	0.726	0.726	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724	0.724
106	109.40	0.726	0.726	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724	0.724
107	110.44	0.726	0.726	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724	0.724
108	111.47	0.726	0.726	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724	0.724
109	112.50	0.726	0.726	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724	0.724
110	113.53	0.726	0.726	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724	0.724
111	114.56	0.726	0.726	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724
112	115.60	0.726	0.726	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724
113	116.63	0.726	0.726	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724
114	117.66	0.726	0.726	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724
115	118.69	0.726	0.726	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724
116	119.72	0.726	0.726	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724
117	120.76	0.726	0.726	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724
118	121.79	0.726	0.726	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724
119	122.82	0.726	0.726	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724
120	123.85	0.726	0.726	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724
121	124.88	0.726	0.726	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724
122	125.92	0.726	0.726	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724
123	126.95	0.726	0.726	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724	0.724
124	127.98	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724
125	129.01	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724
126	130.05	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724
127	131.08	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724
128	132.11	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724
129	133.14	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724
130	134.17	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724
131	135.21	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724
132	136.24	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724
133	137.27	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.724	0.724	0.724	0.724
134	138.30	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.724	0.724	0.724
135	139.33	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.724	0.724	0.724
136	140.37	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.724	0.724	0.724
137	141.40	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.724	0.724	0.724
138	142.43	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.724	0.724	0.724
139	143.46	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.724	0.724	0.724

Table 7.7 Continued

140	144.49	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.724	0.724
141	145.53	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.724	0.724
142	146.56	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.724	0.724
143	147.59	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.724	0.724
144	148.62	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.724	0.724
145	149.66	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.724
146	150.69	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.724
147	151.72	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
148	152.75	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
149	153.78	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
150	154.82	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
151	155.85	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
152	156.88	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
153	157.91	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
154	158.94	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
155	159.98	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
156	161.01	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
157	162.04	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
158	163.07	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
159	164.10	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
160	165.14	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
161	166.17	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
162	167.20	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
163	168.23	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
164	169.27	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
165	170.30	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
166	171.33	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
167	172.36	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
168	173.39	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
169	174.43	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
170	175.46	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
171	176.49	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
172	177.52	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
173	178.55	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
174	179.59	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
175	180.62	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
176	181.65	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
177	182.68	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
178	183.71	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
179	184.75	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
180	185.78	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
181	186.81	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
182	187.84	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
183	188.88	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
184	189.91	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
185	190.94	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
186	191.97	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
187	193.00	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
188	194.04	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
189	195.07	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
190	196.10	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
191	197.13	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
192	198.16	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725	0.725
193	199.20	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725
194	200.23	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725
195	201.26	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725
196	202.29	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725
197	203.32	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725
198	204.36	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725
199	205.39	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725
200	206.42	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725
201	207.45	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725

Table 7.7 Continued

202	208.49	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725
203	209.52	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725
204	210.55	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725
205	211.58	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725
206	212.61	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725
207	213.65	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725
208	214.68	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725
209	215.71	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725
210	216.74	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725	0.725
211	217.77	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725
212	218.81	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725
213	219.84	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725
214	220.87	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725
215	221.90	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725
216	222.93	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725
217	223.97	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725
218	225.00	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725
219	226.03	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725
220	227.06	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725
221	228.10	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725
222	229.13	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725
223	230.16	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725	0.725
224	231.19	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725
225	232.22	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725
226	233.26	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725
227	234.29	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725
228	235.32	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725
229	236.35	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725
230	237.38	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725
231	238.42	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725
232	239.45	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725
233	240.48	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725	0.725
234	241.51	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725
235	242.54	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725
236	243.58	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725
237	244.61	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725
238	245.64	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725
239	246.67	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725	0.725
240	247.71	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725
241	248.74	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725
242	249.77	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725
243	250.80	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725
244	251.83	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725	0.725
245	252.87	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725
246	253.90	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.725
247	254.93	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726
248	255.96	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726
249	256.99	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726
250	258.03	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726
251	259.06	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726
252	260.09	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726
253	261.12	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726
254	262.15	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726

Appendix 7.9: Model Output for Effective Gap Radius

Excel formula used to calculate the effective gap radius at t = 1.03 s and x = 0.005 m. (i.e. cell D5):

D5 =(reffi*(1-MASTER!ADM/(1-'Moisture Content wb '!D5)))/Agi

Table 7.8: Predicted effective gap radius profile generated by Excel, given the input variables listed in Table 4.1.

Effective Gap Radius												
	i =>	0	1	2	3	4	5	6	7	8	9	10
j		0	0.005	0.01	0.015	0.02	0.025	0.03	0.035	0.04	0.045	0.05
0	0	2.66E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06
1	1.03	2.66E-06	2.89E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06
2	2.06	2.66E-06	2.89E-06	3.01E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06
3	3.10	2.66E-06	2.84E-06	3.01E-06	3.07E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06
4	4.13	2.66E-06	2.84E-06	2.95E-06	3.07E-06	3.10E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06
5	5.16	2.66E-06	2.81E-06	2.95E-06	3.03E-06	3.10E-06	3.11E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06
6	6.19	2.66E-06	2.81E-06	2.92E-06	3.02E-06	3.07E-06	3.11E-06	3.12E-06	3.13E-06	3.13E-06	3.13E-06	3.13E-06
7	7.22	2.66E-06	2.79E-06	2.92E-06	2.99E-06	3.07E-06	3.09E-06	3.12E-06	3.12E-06	3.13E-06	3.13E-06	3.13E-06
8	8.26	2.66E-06	2.79E-06	2.89E-06	2.99E-06	3.04E-06	3.09E-06	3.11E-06	3.12E-06	3.12E-06	3.13E-06	3.13E-06
9	9.29	2.66E-06	2.78E-06	2.89E-06	2.97E-06	3.04E-06	3.08E-06	3.11E-06	3.12E-06	3.12E-06	3.12E-06	3.13E-06
10	10.32	2.66E-06	2.78E-06	2.88E-06	2.97E-06	3.02E-06	3.07E-06	3.10E-06	3.12E-06	3.12E-06	3.12E-06	3.12E-06
11	11.35	2.66E-06	2.77E-06	2.87E-06	2.95E-06	3.02E-06	3.06E-06	3.09E-06	3.11E-06	3.12E-06	3.12E-06	3.12E-06
12	12.39	2.66E-06	2.77E-06	2.86E-06	2.95E-06	3.00E-06	3.06E-06	3.08E-06	3.11E-06	3.11E-06	3.12E-06	3.12E-06
13	13.42	2.66E-06	2.76E-06	2.86E-06	2.93E-06	3.00E-06	3.04E-06	3.08E-06	3.10E-06	3.11E-06	3.12E-06	3.12E-06
14	14.45	2.66E-06	2.76E-06	2.85E-06	2.93E-06	2.99E-06	3.04E-06	3.07E-06	3.10E-06	3.11E-06	3.12E-06	3.12E-06
15	15.48	2.66E-06	2.76E-06	2.85E-06	2.92E-06	2.99E-06	3.03E-06	3.07E-06	3.09E-06	3.11E-06	3.11E-06	3.12E-06
16	16.51	2.66E-06	2.76E-06	2.84E-06	2.92E-06	2.98E-06	3.03E-06	3.06E-06	3.09E-06	3.10E-06	3.11E-06	3.12E-06
17	17.55	2.66E-06	2.75E-06	2.84E-06	2.91E-06	2.97E-06	3.02E-06	3.06E-06	3.08E-06	3.10E-06	3.11E-06	3.12E-06
18	18.58	2.66E-06	2.75E-06	2.83E-06	2.90E-06	2.96E-06	3.02E-06	3.05E-06	3.08E-06	3.10E-06	3.11E-06	3.11E-06
19	19.61	2.66E-06	2.75E-06	2.83E-06	2.90E-06	2.96E-06	3.01E-06	3.05E-06	3.07E-06	3.09E-06	3.10E-06	3.11E-06
20	20.64	2.66E-06	2.75E-06	2.82E-06	2.89E-06	2.95E-06	3.00E-06	3.04E-06	3.07E-06	3.09E-06	3.10E-06	3.11E-06
21	21.67	2.66E-06	2.74E-06	2.82E-06	2.89E-06	2.95E-06	3.00E-06	3.04E-06	3.06E-06	3.09E-06	3.10E-06	3.11E-06
22	22.71	2.66E-06	2.74E-06	2.82E-06	2.88E-06	2.94E-06	2.99E-06	3.03E-06	3.06E-06	3.08E-06	3.10E-06	3.10E-06
23	23.74	2.66E-06	2.74E-06	2.81E-06	2.88E-06	2.94E-06	2.99E-06	3.03E-06	3.06E-06	3.08E-06	3.09E-06	3.10E-06
24	24.77	2.66E-06	2.74E-06	2.81E-06	2.88E-06	2.93E-06	2.98E-06	3.02E-06	3.05E-06	3.07E-06	3.09E-06	3.10E-06
25	25.80	2.66E-06	2.74E-06	2.81E-06	2.87E-06	2.93E-06	2.98E-06	3.02E-06	3.05E-06	3.07E-06	3.08E-06	3.09E-06
26	26.83	2.66E-06	2.74E-06	2.80E-06	2.87E-06	2.92E-06	2.97E-06	3.01E-06	3.05E-06	3.07E-06	3.08E-06	3.09E-06
27	27.87	2.66E-06	2.73E-06	2.80E-06	2.86E-06	2.92E-06	2.97E-06	3.01E-06	3.04E-06	3.06E-06	3.08E-06	3.09E-06
28	28.90	2.66E-06	2.73E-06	2.80E-06	2.86E-06	2.92E-06	2.97E-06	3.00E-06	3.04E-06	3.06E-06	3.07E-06	3.08E-06
29	29.93	2.66E-06	2.73E-06	2.80E-06	2.86E-06	2.91E-06	2.96E-06	3.00E-06	3.03E-06	3.06E-06	3.07E-06	3.08E-06
30	30.96	2.66E-06	2.73E-06	2.80E-06	2.86E-06	2.91E-06	2.96E-06	3.00E-06	3.03E-06	3.05E-06	3.07E-06	3.07E-06
31	32.00	2.66E-06	2.73E-06	2.79E-06	2.85E-06	2.91E-06	2.95E-06	2.99E-06	3.02E-06	3.05E-06	3.06E-06	3.07E-06
32	33.03	2.66E-06	2.73E-06	2.79E-06	2.85E-06	2.90E-06	2.95E-06	2.99E-06	3.02E-06	3.04E-06	3.06E-06	3.07E-06
33	34.06	2.66E-06	2.73E-06	2.79E-06	2.85E-06	2.90E-06	2.95E-06	2.99E-06	3.02E-06	3.04E-06	3.05E-06	3.06E-06
34	35.09	2.66E-06	2.73E-06	2.79E-06	2.85E-06	2.90E-06	2.94E-06	2.98E-06	3.01E-06	3.04E-06	3.05E-06	3.06E-06
35	36.12	2.66E-06	2.73E-06	2.79E-06	2.84E-06	2.89E-06	2.94E-06	2.98E-06	3.01E-06	3.03E-06	3.05E-06	3.05E-06
36	37.16	2.66E-06	2.73E-06	2.78E-06	2.84E-06	2.89E-06	2.94E-06	2.97E-06	3.01E-06	3.03E-06	3.04E-06	3.05E-06
37	38.19	2.66E-06	2.72E-06	2.78E-06	2.84E-06	2.89E-06	2.93E-06	2.97E-06	3.00E-06	3.02E-06	3.04E-06	3.05E-06

Table 7.8 Continued

38	39.22	2.66E-06	2.72E-06	2.78E-06	2.84E-06	2.89E-06	2.93E-06	2.97E-06	3.00E-06	3.02E-06	3.04E-06	3.04E-06
39	40.25	2.66E-06	2.72E-06	2.78E-06	2.83E-06	2.88E-06	2.93E-06	2.96E-06	2.99E-06	3.02E-06	3.03E-06	3.04E-06
40	41.28	2.66E-06	2.72E-06	2.78E-06	2.83E-06	2.88E-06	2.92E-06	2.96E-06	2.99E-06	3.01E-06	3.03E-06	3.04E-06
41	42.32	2.66E-06	2.72E-06	2.78E-06	2.83E-06	2.88E-06	2.92E-06	2.96E-06	2.99E-06	3.01E-06	3.02E-06	3.03E-06
42	43.35	2.66E-06	2.72E-06	2.78E-06	2.83E-06	2.87E-06	2.92E-06	2.95E-06	2.98E-06	3.01E-06	3.02E-06	3.03E-06
43	44.38	2.66E-06	2.72E-06	2.77E-06	2.83E-06	2.87E-06	2.91E-06	2.95E-06	2.98E-06	3.00E-06	3.02E-06	3.02E-06
44	45.41	2.66E-06	2.72E-06	2.77E-06	2.82E-06	2.87E-06	2.91E-06	2.95E-06	2.98E-06	3.00E-06	3.01E-06	3.02E-06
45	46.44	2.66E-06	2.72E-06	2.77E-06	2.82E-06	2.87E-06	2.91E-06	2.94E-06	2.97E-06	2.99E-06	3.01E-06	3.02E-06
46	47.48	2.66E-06	2.72E-06	2.77E-06	2.82E-06	2.87E-06	2.91E-06	2.94E-06	2.97E-06	2.99E-06	3.01E-06	3.01E-06
47	48.51	2.66E-06	2.72E-06	2.77E-06	2.82E-06	2.86E-06	2.90E-06	2.94E-06	2.97E-06	2.99E-06	3.00E-06	3.01E-06
48	49.54	2.66E-06	2.72E-06	2.77E-06	2.82E-06	2.86E-06	2.90E-06	2.93E-06	2.96E-06	2.98E-06	3.00E-06	3.01E-06
49	50.57	2.66E-06	2.72E-06	2.77E-06	2.81E-06	2.86E-06	2.90E-06	2.93E-06	2.96E-06	2.98E-06	3.00E-06	3.00E-06
50	51.61	2.66E-06	2.72E-06	2.77E-06	2.81E-06	2.86E-06	2.90E-06	2.93E-06	2.96E-06	2.98E-06	2.99E-06	3.00E-06
51	52.64	2.66E-06	2.72E-06	2.76E-06	2.81E-06	2.85E-06	2.89E-06	2.93E-06	2.95E-06	2.97E-06	2.99E-06	3.00E-06
52	53.67	2.66E-06	2.71E-06	2.76E-06	2.81E-06	2.85E-06	2.89E-06	2.92E-06	2.95E-06	2.97E-06	2.98E-06	2.99E-06
53	54.70	2.66E-06	2.71E-06	2.76E-06	2.81E-06	2.85E-06	2.89E-06	2.92E-06	2.95E-06	2.97E-06	2.98E-06	2.99E-06
54	55.73	2.66E-06	2.71E-06	2.76E-06	2.81E-06	2.85E-06	2.89E-06	2.92E-06	2.94E-06	2.96E-06	2.98E-06	2.98E-06
55	56.77	2.66E-06	2.71E-06	2.76E-06	2.80E-06	2.85E-06	2.88E-06	2.91E-06	2.94E-06	2.96E-06	2.97E-06	2.98E-06
56	57.80	2.66E-06	2.71E-06	2.76E-06	2.80E-06	2.84E-06	2.88E-06	2.91E-06	2.94E-06	2.96E-06	2.97E-06	2.98E-06
57	58.83	2.66E-06	2.71E-06	2.76E-06	2.80E-06	2.84E-06	2.88E-06	2.91E-06	2.93E-06	2.95E-06	2.97E-06	2.97E-06
58	59.86	2.66E-06	2.71E-06	2.76E-06	2.80E-06	2.84E-06	2.88E-06	2.91E-06	2.93E-06	2.95E-06	2.96E-06	2.97E-06
59	60.89	2.66E-06	2.71E-06	2.76E-06	2.80E-06	2.84E-06	2.87E-06	2.90E-06	2.93E-06	2.95E-06	2.96E-06	2.97E-06
60	61.93	2.66E-06	2.71E-06	2.75E-06	2.80E-06	2.84E-06	2.87E-06	2.90E-06	2.93E-06	2.95E-06	2.96E-06	2.96E-06
61	62.96	2.66E-06	2.71E-06	2.75E-06	2.80E-06	2.83E-06	2.87E-06	2.90E-06	2.92E-06	2.94E-06	2.96E-06	2.96E-06
62	63.99	2.66E-06	2.71E-06	2.75E-06	2.79E-06	2.83E-06	2.87E-06	2.90E-06	2.92E-06	2.94E-06	2.95E-06	2.96E-06
63	65.02	2.66E-06	2.71E-06	2.75E-06	2.79E-06	2.83E-06	2.86E-06	2.89E-06	2.92E-06	2.94E-06	2.95E-06	2.96E-06
64	66.05	2.66E-06	2.71E-06	2.75E-06	2.79E-06	2.83E-06	2.86E-06	2.89E-06	2.92E-06	2.93E-06	2.95E-06	2.95E-06
65	67.09	2.66E-06	2.71E-06	2.75E-06	2.79E-06	2.83E-06	2.86E-06	2.89E-06	2.91E-06	2.93E-06	2.94E-06	2.95E-06
66	68.12	2.66E-06	2.71E-06	2.75E-06	2.79E-06	2.82E-06	2.86E-06	2.89E-06	2.91E-06	2.93E-06	2.94E-06	2.95E-06
67	69.15	2.66E-06	2.71E-06	2.75E-06	2.79E-06	2.82E-06	2.86E-06	2.88E-06	2.91E-06	2.92E-06	2.94E-06	2.94E-06
68	70.18	2.66E-06	2.71E-06	2.75E-06	2.79E-06	2.82E-06	2.85E-06	2.88E-06	2.90E-06	2.92E-06	2.93E-06	2.94E-06
69	71.22	2.66E-06	2.71E-06	2.75E-06	2.78E-06	2.82E-06	2.85E-06	2.88E-06	2.90E-06	2.92E-06	2.93E-06	2.94E-06
70	72.25	2.66E-06	2.71E-06	2.75E-06	2.78E-06	2.82E-06	2.85E-06	2.88E-06	2.90E-06	2.92E-06	2.93E-06	2.93E-06
71	73.28	2.66E-06	2.71E-06	2.74E-06	2.78E-06	2.82E-06	2.85E-06	2.87E-06	2.90E-06	2.91E-06	2.93E-06	2.93E-06
72	74.31	2.66E-06	2.70E-06	2.74E-06	2.78E-06	2.81E-06	2.85E-06	2.87E-06	2.89E-06	2.91E-06	2.92E-06	2.93E-06
73	75.34	2.66E-06	2.70E-06	2.74E-06	2.78E-06	2.81E-06	2.84E-06	2.87E-06	2.89E-06	2.91E-06	2.92E-06	2.93E-06
74	76.38	2.66E-06	2.70E-06	2.74E-06	2.78E-06	2.81E-06	2.84E-06	2.87E-06	2.89E-06	2.91E-06	2.92E-06	2.92E-06
75	77.41	2.66E-06	2.70E-06	2.74E-06	2.78E-06	2.81E-06	2.84E-06	2.87E-06	2.89E-06	2.90E-06	2.91E-06	2.92E-06
76	78.44	2.66E-06	2.70E-06	2.74E-06	2.78E-06	2.81E-06	2.84E-06	2.86E-06	2.88E-06	2.90E-06	2.91E-06	2.92E-06
77	79.47	2.66E-06	2.70E-06	2.74E-06	2.77E-06	2.81E-06	2.84E-06	2.86E-06	2.88E-06	2.90E-06	2.91E-06	2.91E-06
78	80.50	2.66E-06	2.70E-06	2.74E-06	2.77E-06	2.81E-06	2.83E-06	2.86E-06	2.88E-06	2.90E-06	2.91E-06	2.91E-06
79	81.54	2.66E-06	2.70E-06	2.74E-06	2.77E-06	2.80E-06	2.83E-06	2.86E-06	2.88E-06	2.89E-06	2.90E-06	2.91E-06
80	82.57	2.66E-06	2.70E-06	2.74E-06	2.77E-06	2.80E-06	2.83E-06	2.85E-06	2.88E-06	2.89E-06	2.90E-06	2.91E-06
81	83.60	2.66E-06	2.70E-06	2.74E-06	2.77E-06	2.80E-06	2.83E-06	2.85E-06	2.87E-06	2.89E-06	2.90E-06	2.90E-06
82	84.63	2.66E-06	2.70E-06	2.74E-06	2.77E-06	2.80E-06	2.83E-06	2.85E-06	2.87E-06	2.89E-06	2.90E-06	2.90E-06
83	85.66	2.66E-06	2.70E-06	2.73E-06	2.77E-06	2.80E-06	2.83E-06	2.85E-06	2.87E-06	2.88E-06	2.89E-06	2.90E-06
84	86.70	2.66E-06	2.70E-06	2.73E-06	2.77E-06	2.80E-06	2.82E-06	2.85E-06	2.87E-06	2.88E-06	2.89E-06	2.90E-06
85	87.73	2.66E-06	2.70E-06	2.73E-06	2.77E-06	2.79E-06	2.82E-06	2.84E-06	2.86E-06	2.88E-06	2.89E-06	2.89E-06
86	88.76	2.66E-06	2.70E-06	2.73E-06	2.76E-06	2.79E-06	2.82E-06	2.84E-06	2.86E-06	2.88E-06	2.89E-06	2.89E-06
87	89.79	2.66E-06	2.70E-06	2.73E-06	2.76E-06	2.79E-06	2.82E-06	2.84E-06	2.86E-06	2.87E-06	2.88E-06	2.89E-06
88	90.83	2.66E-06	2.70E-06	2.73E-06	2.76E-06	2.79E-06	2.82E-06	2.84E-06	2.86E-06	2.87E-06	2.88E-06	2.89E-06
89	91.86	2.66E-06	2.70E-06	2.73E-06	2.76E-06	2.79E-06	2.82E-06	2.84E-06	2.86E-06	2.87E-06	2.88E-06	2.88E-06
90	92.89	2.66E-06	2.70E-06	2.73E-06	2.76E-06	2.79E-06	2.81E-06	2.84E-06	2.85E-06	2.87E-06	2.88E-06	2.88E-06
91	93.92	2.66E-06	2.70E-06	2.73E-06	2.76E-06	2.79E-06	2.81E-06	2.83E-06	2.85E-06	2.87E-06	2.87E-06	2.88E-06
92	94.95	2.66E-06	2.70E-06	2.73E-06	2.76E-06	2.79E-06	2.81E-06	2.83E-06	2.85E-06	2.86E-06	2.87E-06	2.88E-06
93	95.99	2.66E-06	2.70E-06	2.73E-06	2.76E-06	2.78E-06	2.81E-06	2.83E-06	2.85E-06	2.86E-06	2.87E-06	2.87E-06
94	97.02	2.66E-06	2.70E-06	2.73E-06	2.76E-06	2.78E-06	2.81E-06	2.83E-06	2.85E-06	2.86E-06	2.87E-06	2.87E-06
95	98.05	2.66E-06	2.70E-06	2.73E-06	2.75E-06	2.78E-06	2.81E-06	2.83E-06	2.84E-06	2.86E-06	2.87E-06	2.87E-06

Table 7.8 Continued

96	99.08	2.66E-06	2.70E-06	2.73E-06	2.75E-06	2.78E-06	2.80E-06	2.82E-06	2.84E-06	2.85E-06	2.86E-06	2.87E-06
97	100.11	2.66E-06	2.70E-06	2.72E-06	2.75E-06	2.78E-06	2.80E-06	2.82E-06	2.84E-06	2.85E-06	2.86E-06	2.87E-06
98	101.15	2.66E-06	2.69E-06	2.72E-06	2.75E-06	2.78E-06	2.80E-06	2.82E-06	2.84E-06	2.85E-06	2.86E-06	2.86E-06
99	102.18	2.66E-06	2.69E-06	2.72E-06	2.75E-06	2.78E-06	2.80E-06	2.82E-06	2.84E-06	2.85E-06	2.86E-06	2.86E-06
100	103.21	2.66E-06	2.69E-06	2.72E-06	2.75E-06	2.78E-06	2.80E-06	2.82E-06	2.83E-06	2.85E-06	2.86E-06	2.86E-06
101	104.24	2.66E-06	2.69E-06	2.72E-06	2.75E-06	2.77E-06	2.80E-06	2.82E-06	2.83E-06	2.84E-06	2.85E-06	2.86E-06
102	105.27	2.66E-06	2.69E-06	2.72E-06	2.75E-06	2.77E-06	2.80E-06	2.81E-06	2.83E-06	2.84E-06	2.85E-06	2.86E-06
103	106.31	2.66E-06	2.69E-06	2.72E-06	2.75E-06	2.77E-06	2.79E-06	2.81E-06	2.83E-06	2.84E-06	2.85E-06	2.85E-06
104	107.34	2.66E-06	2.69E-06	2.72E-06	2.75E-06	2.77E-06	2.79E-06	2.81E-06	2.83E-06	2.84E-06	2.85E-06	2.85E-06
105	108.37	2.66E-06	2.69E-06	2.72E-06	2.75E-06	2.77E-06	2.79E-06	2.81E-06	2.83E-06	2.84E-06	2.85E-06	2.85E-06
106	109.40	2.66E-06	2.69E-06	2.72E-06	2.74E-06	2.77E-06	2.79E-06	2.81E-06	2.82E-06	2.84E-06	2.84E-06	2.85E-06
107	110.44	2.66E-06	2.69E-06	2.72E-06	2.74E-06	2.77E-06	2.79E-06	2.81E-06	2.82E-06	2.83E-06	2.84E-06	2.85E-06
108	111.47	2.66E-06	2.69E-06	2.72E-06	2.74E-06	2.77E-06	2.79E-06	2.81E-06	2.82E-06	2.83E-06	2.84E-06	2.84E-06
109	112.50	2.66E-06	2.69E-06	2.72E-06	2.74E-06	2.77E-06	2.79E-06	2.80E-06	2.82E-06	2.83E-06	2.84E-06	2.84E-06
110	113.53	2.66E-06	2.69E-06	2.72E-06	2.74E-06	2.76E-06	2.78E-06	2.80E-06	2.82E-06	2.83E-06	2.84E-06	2.84E-06
111	114.56	2.66E-06	2.69E-06	2.72E-06	2.74E-06	2.76E-06	2.78E-06	2.80E-06	2.82E-06	2.83E-06	2.83E-06	2.84E-06
112	115.60	2.66E-06	2.69E-06	2.72E-06	2.74E-06	2.76E-06	2.78E-06	2.80E-06	2.81E-06	2.82E-06	2.83E-06	2.84E-06
113	116.63	2.66E-06	2.69E-06	2.72E-06	2.74E-06	2.76E-06	2.78E-06	2.80E-06	2.81E-06	2.82E-06	2.83E-06	2.83E-06
114	117.66	2.66E-06	2.69E-06	2.71E-06	2.74E-06	2.76E-06	2.78E-06	2.80E-06	2.81E-06	2.82E-06	2.83E-06	2.83E-06
115	118.69	2.66E-06	2.69E-06	2.71E-06	2.74E-06	2.76E-06	2.78E-06	2.80E-06	2.81E-06	2.82E-06	2.83E-06	2.83E-06
116	119.72	2.66E-06	2.69E-06	2.71E-06	2.74E-06	2.76E-06	2.78E-06	2.79E-06	2.81E-06	2.82E-06	2.83E-06	2.83E-06
117	120.76	2.66E-06	2.69E-06	2.71E-06	2.74E-06	2.76E-06	2.78E-06	2.79E-06	2.81E-06	2.82E-06	2.82E-06	2.83E-06
118	121.79	2.66E-06	2.69E-06	2.71E-06	2.74E-06	2.76E-06	2.77E-06	2.79E-06	2.80E-06	2.81E-06	2.82E-06	2.83E-06
119	122.82	2.66E-06	2.69E-06	2.71E-06	2.73E-06	2.75E-06	2.77E-06	2.79E-06	2.80E-06	2.81E-06	2.82E-06	2.82E-06
120	123.85	2.66E-06	2.69E-06	2.71E-06	2.73E-06	2.75E-06	2.77E-06	2.79E-06	2.80E-06	2.81E-06	2.82E-06	2.82E-06
121	124.88	2.66E-06	2.69E-06	2.71E-06	2.73E-06	2.75E-06	2.77E-06	2.79E-06	2.80E-06	2.81E-06	2.82E-06	2.82E-06
122	125.92	2.66E-06	2.69E-06	2.71E-06	2.73E-06	2.75E-06	2.77E-06	2.79E-06	2.80E-06	2.81E-06	2.82E-06	2.82E-06
123	126.95	2.66E-06	2.69E-06	2.71E-06	2.73E-06	2.75E-06	2.77E-06	2.78E-06	2.80E-06	2.81E-06	2.81E-06	2.82E-06
124	127.98	2.66E-06	2.69E-06	2.71E-06	2.73E-06	2.75E-06	2.77E-06	2.78E-06	2.80E-06	2.81E-06	2.81E-06	2.82E-06
125	129.01	2.66E-06	2.69E-06	2.71E-06	2.73E-06	2.75E-06	2.77E-06	2.78E-06	2.79E-06	2.80E-06	2.81E-06	2.81E-06
126	130.05	2.66E-06	2.69E-06	2.71E-06	2.73E-06	2.75E-06	2.77E-06	2.78E-06	2.79E-06	2.80E-06	2.81E-06	2.81E-06
127	131.08	2.66E-06	2.69E-06	2.71E-06	2.73E-06	2.75E-06	2.76E-06	2.78E-06	2.79E-06	2.80E-06	2.81E-06	2.81E-06
128	132.11	2.66E-06	2.69E-06	2.71E-06	2.73E-06	2.75E-06	2.76E-06	2.78E-06	2.79E-06	2.80E-06	2.81E-06	2.81E-06
129	133.14	2.66E-06	2.69E-06	2.71E-06	2.73E-06	2.75E-06	2.76E-06	2.78E-06	2.79E-06	2.80E-06	2.80E-06	2.81E-06
130	134.17	2.66E-06	2.69E-06	2.71E-06	2.73E-06	2.74E-06	2.76E-06	2.78E-06	2.79E-06	2.80E-06	2.80E-06	2.81E-06
131	135.21	2.66E-06	2.69E-06	2.71E-06	2.73E-06	2.74E-06	2.76E-06	2.77E-06	2.79E-06	2.80E-06	2.80E-06	2.80E-06
132	136.24	2.66E-06	2.69E-06	2.71E-06	2.73E-06	2.74E-06	2.76E-06	2.77E-06	2.79E-06	2.79E-06	2.80E-06	2.80E-06
133	137.27	2.66E-06	2.69E-06	2.71E-06	2.72E-06	2.74E-06	2.76E-06	2.77E-06	2.78E-06	2.79E-06	2.80E-06	2.80E-06
134	138.30	2.66E-06	2.69E-06	2.71E-06	2.72E-06	2.74E-06	2.76E-06	2.77E-06	2.78E-06	2.79E-06	2.80E-06	2.80E-06
135	139.33	2.66E-06	2.69E-06	2.70E-06	2.72E-06	2.74E-06	2.76E-06	2.77E-06	2.78E-06	2.79E-06	2.80E-06	2.80E-06
136	140.37	2.66E-06	2.68E-06	2.70E-06	2.72E-06	2.74E-06	2.76E-06	2.77E-06	2.78E-06	2.79E-06	2.79E-06	2.80E-06
137	141.40	2.66E-06	2.68E-06	2.70E-06	2.72E-06	2.74E-06	2.75E-06	2.77E-06	2.78E-06	2.79E-06	2.79E-06	2.80E-06
138	142.43	2.66E-06	2.68E-06	2.70E-06	2.72E-06	2.74E-06	2.75E-06	2.77E-06	2.78E-06	2.79E-06	2.79E-06	2.79E-06
139	143.46	2.66E-06	2.68E-06	2.70E-06	2.72E-06	2.74E-06	2.75E-06	2.77E-06	2.78E-06	2.78E-06	2.79E-06	2.79E-06
140	144.49	2.66E-06	2.68E-06	2.70E-06	2.72E-06	2.74E-06	2.75E-06	2.76E-06	2.78E-06	2.78E-06	2.79E-06	2.79E-06
141	145.53	2.66E-06	2.68E-06	2.70E-06	2.72E-06	2.74E-06	2.75E-06	2.76E-06	2.77E-06	2.78E-06	2.79E-06	2.79E-06
142	146.56	2.66E-06	2.68E-06	2.70E-06	2.72E-06	2.74E-06	2.75E-06	2.76E-06	2.77E-06	2.78E-06	2.79E-06	2.79E-06
143	147.59	2.66E-06	2.68E-06	2.70E-06	2.72E-06	2.73E-06	2.75E-06	2.76E-06	2.77E-06	2.78E-06	2.78E-06	2.79E-06
144	148.62	2.66E-06	2.68E-06	2.70E-06	2.72E-06	2.73E-06	2.75E-06	2.76E-06	2.77E-06	2.78E-06	2.78E-06	2.79E-06
145	149.66	2.66E-06	2.68E-06	2.70E-06	2.72E-06	2.73E-06	2.75E-06	2.76E-06	2.77E-06	2.78E-06	2.78E-06	2.78E-06
146	150.69	2.66E-06	2.68E-06	2.70E-06	2.72E-06	2.73E-06	2.75E-06	2.76E-06	2.77E-06	2.78E-06	2.78E-06	2.78E-06
147	151.72	2.66E-06	2.68E-06	2.70E-06	2.72E-06	2.73E-06	2.75E-06	2.76E-06	2.77E-06	2.77E-06	2.78E-06	2.78E-06
148	152.75	2.66E-06	2.68E-06	2.70E-06	2.72E-06	2.73E-06	2.74E-06	2.76E-06	2.77E-06	2.77E-06	2.78E-06	2.78E-06
149	153.78	2.66E-06	2.68E-06	2.70E-06	2.72E-06	2.73E-06	2.74E-06	2.76E-06	2.77E-06	2.77E-06	2.78E-06	2.78E-06
150	154.82	2.66E-06	2.68E-06	2.70E-06	2.71E-06	2.73E-06	2.74E-06	2.75E-06	2.76E-06	2.77E-06	2.78E-06	2.78E-06
151	155.85	2.66E-06	2.68E-06	2.70E-06	2.71E-06	2.73E-06	2.74E-06	2.75E-06	2.76E-06	2.77E-06	2.78E-06	2.78E-06
152	156.88	2.66E-06	2.68E-06	2.70E-06	2.71E-06	2.73E-06	2.74E-06	2.75E-06	2.76E-06	2.77E-06	2.77E-06	2.78E-06
153	157.91	2.66E-06	2.68E-06	2.70E-06	2.71E-06	2.73E-06	2.74E-06	2.75E-06	2.76E-06	2.77E-06	2.77E-06	2.78E-06

Table 7.8 Continued

154	158.94	2.66E-06	2.68E-06	2.70E-06	2.71E-06	2.73E-06	2.74E-06	2.75E-06	2.76E-06	2.77E-06	2.77E-06	2.77E-06
155	159.98	2.66E-06	2.68E-06	2.70E-06	2.71E-06	2.73E-06	2.74E-06	2.75E-06	2.76E-06	2.77E-06	2.77E-06	2.77E-06
156	161.01	2.66E-06	2.68E-06	2.70E-06	2.71E-06	2.73E-06	2.74E-06	2.75E-06	2.76E-06	2.76E-06	2.77E-06	2.77E-06
157	162.04	2.66E-06	2.68E-06	2.70E-06	2.71E-06	2.72E-06	2.74E-06	2.75E-06	2.76E-06	2.76E-06	2.77E-06	2.77E-06
158	163.07	2.66E-06	2.68E-06	2.70E-06	2.71E-06	2.72E-06	2.74E-06	2.75E-06	2.76E-06	2.76E-06	2.77E-06	2.77E-06
159	164.10	2.66E-06	2.68E-06	2.70E-06	2.71E-06	2.72E-06	2.74E-06	2.75E-06	2.75E-06	2.76E-06	2.77E-06	2.77E-06
160	165.14	2.66E-06	2.68E-06	2.70E-06	2.71E-06	2.72E-06	2.74E-06	2.75E-06	2.75E-06	2.76E-06	2.77E-06	2.77E-06
161	166.17	2.66E-06	2.68E-06	2.70E-06	2.71E-06	2.72E-06	2.73E-06	2.74E-06	2.75E-06	2.76E-06	2.76E-06	2.77E-06
162	167.20	2.66E-06	2.68E-06	2.69E-06	2.71E-06	2.72E-06	2.73E-06	2.74E-06	2.75E-06	2.76E-06	2.76E-06	2.77E-06
163	168.23	2.66E-06	2.68E-06	2.69E-06	2.71E-06	2.72E-06	2.73E-06	2.74E-06	2.75E-06	2.76E-06	2.76E-06	2.76E-06
164	169.27	2.66E-06	2.68E-06	2.69E-06	2.71E-06	2.72E-06	2.73E-06	2.74E-06	2.75E-06	2.76E-06	2.76E-06	2.76E-06
165	170.30	2.66E-06	2.68E-06	2.69E-06	2.71E-06	2.72E-06	2.73E-06	2.74E-06	2.75E-06	2.76E-06	2.76E-06	2.76E-06
166	171.33	2.66E-06	2.68E-06	2.69E-06	2.71E-06	2.72E-06	2.73E-06	2.74E-06	2.75E-06	2.75E-06	2.76E-06	2.76E-06
167	172.36	2.66E-06	2.68E-06	2.69E-06	2.71E-06	2.72E-06	2.73E-06	2.74E-06	2.75E-06	2.75E-06	2.76E-06	2.76E-06
168	173.39	2.66E-06	2.68E-06	2.69E-06	2.71E-06	2.72E-06	2.73E-06	2.74E-06	2.75E-06	2.75E-06	2.76E-06	2.76E-06
169	174.43	2.66E-06	2.68E-06	2.69E-06	2.71E-06	2.72E-06	2.73E-06	2.74E-06	2.75E-06	2.75E-06	2.76E-06	2.76E-06
170	175.46	2.66E-06	2.68E-06	2.69E-06	2.71E-06	2.72E-06	2.73E-06	2.74E-06	2.75E-06	2.75E-06	2.75E-06	2.76E-06
171	176.49	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.72E-06	2.73E-06	2.74E-06	2.74E-06	2.75E-06	2.75E-06	2.76E-06
172	177.52	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.72E-06	2.73E-06	2.74E-06	2.74E-06	2.75E-06	2.75E-06	2.75E-06
173	178.55	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.72E-06	2.73E-06	2.74E-06	2.74E-06	2.75E-06	2.75E-06	2.75E-06
174	179.59	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.73E-06	2.73E-06	2.74E-06	2.75E-06	2.75E-06	2.75E-06
175	180.62	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.73E-06	2.74E-06	2.75E-06	2.75E-06	2.75E-06
176	181.65	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.73E-06	2.74E-06	2.75E-06	2.75E-06	2.75E-06
177	182.68	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.73E-06	2.74E-06	2.74E-06	2.75E-06	2.75E-06
178	183.71	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.73E-06	2.74E-06	2.74E-06	2.75E-06	2.75E-06
179	184.75	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.73E-06	2.74E-06	2.74E-06	2.75E-06	2.75E-06
180	185.78	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.73E-06	2.74E-06	2.74E-06	2.75E-06	2.75E-06
181	186.81	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.73E-06	2.74E-06	2.74E-06	2.74E-06	2.75E-06
182	187.84	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.73E-06	2.74E-06	2.74E-06	2.74E-06	2.75E-06
183	188.88	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.73E-06	2.73E-06	2.74E-06	2.74E-06	2.75E-06
184	189.91	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.73E-06	2.73E-06	2.74E-06	2.74E-06	2.74E-06
185	190.94	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.73E-06	2.73E-06	2.74E-06	2.74E-06	2.74E-06
186	191.97	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.73E-06	2.73E-06	2.74E-06	2.74E-06	2.74E-06
187	193.00	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.73E-06	2.73E-06	2.74E-06	2.74E-06	2.74E-06
188	194.04	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.72E-06	2.73E-06	2.74E-06	2.74E-06	2.74E-06
189	195.07	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.72E-06	2.73E-06	2.74E-06	2.74E-06	2.74E-06
190	196.10	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.72E-06	2.73E-06	2.73E-06	2.74E-06	2.74E-06
191	197.13	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.72E-06	2.73E-06	2.73E-06	2.74E-06	2.74E-06
192	198.16	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.71E-06	2.72E-06	2.73E-06	2.73E-06	2.74E-06	2.74E-06
193	199.20	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.71E-06	2.72E-06	2.73E-06	2.73E-06	2.74E-06	2.74E-06
194	200.23	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.71E-06	2.72E-06	2.73E-06	2.73E-06	2.73E-06	2.74E-06
195	201.26	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.72E-06	2.73E-06	2.73E-06	2.73E-06	2.74E-06
196	202.29	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.72E-06	2.73E-06	2.73E-06	2.73E-06	2.73E-06
197	203.32	2.66E-06	2.68E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.72E-06	2.73E-06	2.73E-06	2.73E-06	2.73E-06
198	204.36	2.66E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.72E-06	2.73E-06	2.73E-06	2.73E-06
199	205.39	2.66E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.72E-06	2.73E-06	2.73E-06	2.73E-06
200	206.42	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.72E-06	2.73E-06	2.73E-06	2.73E-06
201	207.45	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.72E-06	2.73E-06	2.73E-06	2.73E-06
202	208.49	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.72E-06	2.73E-06	2.73E-06	2.73E-06
203	209.52	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.72E-06	2.73E-06	2.73E-06	2.73E-06
204	210.55	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.72E-06	2.72E-06	2.72E-06	2.73E-06	2.73E-06
205	211.58	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.71E-06	2.72E-06	2.72E-06	2.73E-06	2.73E-06
206	212.61	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.71E-06	2.72E-06	2.72E-06	2.73E-06	2.73E-06
207	213.65	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.71E-06	2.72E-06	2.72E-06	2.73E-06	2.73E-06
208	214.68	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.71E-06	2.72E-06	2.72E-06	2.73E-06	2.73E-06
209	215.71	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.71E-06	2.72E-06	2.72E-06	2.72E-06	2.73E-06
210	216.74	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.71E-06	2.72E-06	2.72E-06	2.72E-06	2.73E-06
211	217.77	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.71E-06	2.72E-06	2.72E-06	2.72E-06	2.72E-06

Table 7.8 Continued

212	218.81	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.71E-06	2.71E-06	2.72E-06	2.72E-06	2.72E-06	2.72E-06
213	219.84	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.72E-06	2.72E-06	2.72E-06	2.72E-06
214	220.87	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.72E-06	2.72E-06	2.72E-06	2.72E-06
215	221.90	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.72E-06	2.72E-06	2.72E-06
216	222.93	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.72E-06	2.72E-06	2.72E-06
217	223.97	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.72E-06	2.72E-06	2.72E-06
218	225.00	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.72E-06	2.72E-06	2.72E-06
219	226.03	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.72E-06	2.72E-06	2.72E-06
220	227.06	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.72E-06	2.72E-06	2.72E-06
221	228.10	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06	2.72E-06	2.72E-06
222	229.13	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06	2.72E-06	2.72E-06
223	230.16	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06	2.72E-06	2.72E-06
224	231.19	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06	2.72E-06	2.72E-06
225	232.22	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06	2.72E-06	2.72E-06
226	233.26	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06	2.72E-06
227	234.29	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06	2.72E-06
228	235.32	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06	2.71E-06
229	236.35	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06	2.71E-06
230	237.38	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06	2.71E-06
231	238.42	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06	2.71E-06
232	239.45	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06	2.71E-06
233	240.48	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06	2.71E-06
234	241.51	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06	2.71E-06
235	242.54	2.66E-06	2.67E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06	2.71E-06
236	243.58	2.66E-06	2.67E-06	2.68E-06	2.68E-06	2.69E-06	2.70E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06
237	244.61	2.66E-06	2.67E-06	2.68E-06	2.68E-06	2.69E-06	2.70E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06
238	245.64	2.66E-06	2.67E-06	2.68E-06	2.68E-06	2.69E-06	2.70E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06
239	246.67	2.66E-06	2.67E-06	2.68E-06	2.68E-06	2.69E-06	2.70E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06
240	247.71	2.66E-06	2.67E-06	2.68E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06
241	248.74	2.66E-06	2.67E-06	2.68E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06
242	249.77	2.66E-06	2.67E-06	2.68E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06	2.71E-06
243	250.80	2.66E-06	2.67E-06	2.68E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06
244	251.83	2.66E-06	2.67E-06	2.68E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06
245	252.87	2.66E-06	2.67E-06	2.68E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06
246	253.90	2.66E-06	2.67E-06	2.68E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.70E-06	2.71E-06	2.71E-06
247	254.93	2.66E-06	2.67E-06	2.68E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.70E-06	2.70E-06	2.71E-06
248	255.96	2.66E-06	2.67E-06	2.68E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.70E-06	2.70E-06	2.71E-06
249	256.99	2.66E-06	2.67E-06	2.68E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.70E-06	2.70E-06	2.70E-06
250	258.03	2.66E-06	2.67E-06	2.68E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.70E-06	2.70E-06	2.70E-06
251	259.06	2.66E-06	2.67E-06	2.68E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.70E-06	2.70E-06	2.70E-06
252	260.09	2.66E-06	2.67E-06	2.68E-06	2.68E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.70E-06	2.70E-06	2.70E-06
253	261.12	2.66E-06	2.67E-06	2.68E-06	2.68E-06	2.69E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.70E-06	2.70E-06
254	262.15	2.66E-06	2.67E-06	2.68E-06	2.68E-06	2.69E-06	2.69E-06	2.69E-06	2.70E-06	2.70E-06	2.70E-06	2.70E-06

Appendix 7.10: Model Output for Darcy's Velocity

Excel formula used to calculate the *Darcy's* velocity at t = 1.03 s and x = 0.005 m. (i.e. cell D5):

D5 =-('Effective Gap Radius'!D5^2/(MASTER!vis*8*MASTER!tor)*(MASTER!st*MASTER!Agi^0.5*MASTER!ADM)/(MASTER!reffi*(1-MASTER!ADM/(1-'Moisture Content db'!D5/(1+'Moisture Content db'!D5)))^(3/2))*('Moisture Content db'!E5-'Moisture Content db'!D5))/dx

Table 7.9: Predicted Darcy's velocity profile generated by Excel, given the input variables listed in Table 4.1.

Darcy's Velocity												
	i =>	0	1	2	3	4	5	6	7	8	9	10
j		0	0.0050	0.0100	0.0150	0.0200	0.0250	0.0300	0.0350	0.0400	0.0450	0.0500
0	0	1.76E-04	0	0	0	0	0	0	0	0	0	0
1	1.03	8.79E-05	9.16E-05	0	0	0	0	0	0	0	0	0
2	2.06	8.79E-05	4.58E-05	4.67E-05	0	0	0	0	0	0	0	0
3	3.10	6.67E-05	6.72E-05	2.33E-05	2.36E-05	0	0	0	0	0	0	0
4	4.13	6.59E-05	4.61E-05	4.54E-05	1.18E-05	1.18E-05	0	0	0	0	0	0
5	5.16	5.58E-05	5.55E-05	2.94E-05	2.87E-05	5.92E-06	5.93E-06	0	0	0	0	0
6	6.19	5.50E-05	4.33E-05	4.20E-05	1.79E-05	1.73E-05	2.97E-06	2.97E-06	0	0	0	0
7	7.22	4.89E-05	4.84E-05	3.10E-05	2.96E-05	1.05E-05	1.02E-05	1.49E-06	1.49E-06	0	0	0
8	8.26	4.81E-05	4.05E-05	3.89E-05	2.10E-05	1.99E-05	6.01E-06	5.83E-06	7.43E-07	7.43E-07	0	0
9	9.29	4.41E-05	4.35E-05	3.11E-05	2.93E-05	1.36E-05	1.29E-05	3.38E-06	3.29E-06	3.72E-07	3.72E-07	0
10	10.32	4.34E-05	3.79E-05	3.63E-05	2.25E-05	2.11E-05	8.52E-06	8.08E-06	1.88E-06	1.83E-06	1.86E-07	0
11	11.35	4.04E-05	3.98E-05	3.05E-05	2.86E-05	1.56E-05	1.46E-05	5.21E-06	4.95E-06	1.03E-06	9.15E-07	0
12	12.39	3.98E-05	3.57E-05	3.41E-05	2.32E-05	2.16E-05	1.05E-05	9.75E-06	3.13E-06	2.94E-06	5.17E-07	0
13	13.42	3.75E-05	3.69E-05	2.97E-05	2.78E-05	1.69E-05	1.56E-05	6.82E-06	6.34E-06	1.82E-06	1.47E-06	0
14	14.45	3.69E-05	3.38E-05	3.23E-05	2.35E-05	2.17E-05	1.19E-05	1.10E-05	4.33E-06	3.91E-06	9.13E-07	0
15	15.48	3.52E-05	3.46E-05	2.88E-05	2.69E-05	1.78E-05	1.63E-05	8.16E-06	7.44E-06	2.63E-06	1.95E-06	0
16	16.51	3.46E-05	3.22E-05	3.07E-05	2.35E-05	2.16E-05	1.30E-05	1.19E-05	5.41E-06	4.70E-06	1.31E-06	0
17	17.55	3.32E-05	3.27E-05	2.80E-05	2.61E-05	1.83E-05	1.67E-05	9.26E-06	8.27E-06	3.37E-06	2.35E-06	0
18	18.58	3.27E-05	3.08E-05	2.94E-05	2.33E-05	2.14E-05	1.39E-05	1.25E-05	6.33E-06	5.31E-06	1.68E-06	0
19	19.61	3.16E-05	3.11E-05	2.72E-05	2.53E-05	1.87E-05	1.69E-05	1.01E-05	8.88E-06	4.01E-06	2.65E-06	0
20	20.64	3.11E-05	2.95E-05	2.82E-05	2.30E-05	2.11E-05	1.44E-05	1.29E-05	7.09E-06	5.77E-06	2.01E-06	0
21	21.67	3.01E-05	2.97E-05	2.64E-05	2.46E-05	1.88E-05	1.70E-05	1.08E-05	9.31E-06	4.56E-06	2.88E-06	0
22	22.71	2.97E-05	2.83E-05	2.71E-05	2.27E-05	2.07E-05	1.49E-05	1.31E-05	7.70E-06	6.10E-06	2.28E-06	0
23	23.74	2.89E-05	2.84E-05	2.56E-05	2.39E-05	1.88E-05	1.69E-05	1.13E-05	9.60E-06	5.00E-06	3.04E-06	0
24	24.77	2.85E-05	2.73E-05	2.62E-05	2.23E-05	2.04E-05	1.51E-05	1.32E-05	8.18E-06	6.32E-06	2.50E-06	0
25	25.80	2.78E-05	2.73E-05	2.49E-05	2.33E-05	1.88E-05	1.68E-05	1.17E-05	9.78E-06	5.35E-06	3.15E-06	0
26	26.83	2.74E-05	2.64E-05	2.53E-05	2.19E-05	2.00E-05	1.53E-05	1.33E-05	8.54E-06	6.46E-06	2.67E-06	0
27	27.87	2.68E-05	2.64E-05	2.42E-05	2.26E-05	1.87E-05	1.66E-05	1.19E-05	9.86E-06	5.62E-06	3.22E-06	0
28	28.90	2.64E-05	2.56E-05	2.45E-05	2.15E-05	1.96E-05	1.53E-05	1.32E-05	8.80E-06	6.54E-06	2.80E-06	0
29	29.93	2.59E-05	2.55E-05	2.36E-05	2.21E-05	1.85E-05	1.64E-05	1.21E-05	9.89E-06	5.81E-06	3.26E-06	0
30	30.96	2.55E-05	2.48E-05	2.38E-05	2.11E-05	1.92E-05	1.53E-05	1.31E-05	8.98E-06	6.57E-06	2.90E-06	0
31	32.00	2.50E-05	2.47E-05	2.30E-05	2.15E-05	1.83E-05	1.62E-05	1.22E-05	9.86E-06	5.95E-06	3.28E-06	0
32	33.03	2.47E-05	2.41E-05	2.31E-05	2.07E-05	1.88E-05	1.53E-05	1.30E-05	9.08E-06	6.57E-06	2.97E-06	0
33	34.06	2.43E-05	2.39E-05	2.24E-05	2.10E-05	1.80E-05	1.59E-05	1.22E-05	9.79E-06	6.04E-06	3.27E-06	0

Table 7.9 Continued

34	35.09	2.40E-05	2.34E-05	2.25E-05	2.03E-05	1.84E-05	1.51E-05	1.29E-05	9.13E-06	6.53E-06	3.01E-06	0
35	36.12	2.36E-05	2.32E-05	2.19E-05	2.04E-05	1.77E-05	1.56E-05	1.22E-05	9.69E-06	6.08E-06	3.25E-06	0
36	37.16	2.33E-05	2.28E-05	2.19E-05	1.98E-05	1.80E-05	1.50E-05	1.27E-05	9.14E-06	6.47E-06	3.03E-06	0
37	38.19	2.29E-05	2.26E-05	2.13E-05	2.00E-05	1.74E-05	1.54E-05	1.21E-05	9.57E-06	6.10E-06	3.22E-06	0
38	39.22	2.27E-05	2.22E-05	2.13E-05	1.94E-05	1.77E-05	1.48E-05	1.25E-05	9.10E-06	6.40E-06	3.03E-06	0
39	40.25	2.23E-05	2.20E-05	2.08E-05	1.95E-05	1.71E-05	1.51E-05	1.20E-05	9.43E-06	6.08E-06	3.18E-06	0
40	41.28	2.20E-05	2.16E-05	2.07E-05	1.90E-05	1.73E-05	1.46E-05	1.23E-05	9.04E-06	6.31E-06	3.02E-06	0
41	42.32	2.17E-05	2.14E-05	2.03E-05	1.90E-05	1.68E-05	1.48E-05	1.18E-05	9.28E-06	6.04E-06	3.13E-06	0
42	43.35	2.15E-05	2.11E-05	2.02E-05	1.86E-05	1.69E-05	1.43E-05	1.20E-05	8.95E-06	6.21E-06	3.00E-06	0
43	44.38	2.12E-05	2.09E-05	1.99E-05	1.86E-05	1.65E-05	1.45E-05	1.17E-05	9.12E-06	5.98E-06	3.08E-06	0
44	45.41	2.09E-05	2.06E-05	1.97E-05	1.82E-05	1.65E-05	1.41E-05	1.18E-05	8.84E-06	6.11E-06	2.97E-06	0
45	46.44	2.07E-05	2.04E-05	1.94E-05	1.81E-05	1.62E-05	1.42E-05	1.15E-05	8.96E-06	5.91E-06	3.03E-06	0
46	47.48	2.04E-05	2.01E-05	1.93E-05	1.78E-05	1.62E-05	1.39E-05	1.16E-05	8.71E-06	6.00E-06	2.94E-06	0
47	48.51	2.02E-05	1.99E-05	1.90E-05	1.77E-05	1.59E-05	1.39E-05	1.13E-05	8.79E-06	5.83E-06	2.98E-06	0
48	49.54	1.99E-05	1.96E-05	1.88E-05	1.74E-05	1.58E-05	1.36E-05	1.13E-05	8.58E-06	5.89E-06	2.89E-06	0
49	50.57	1.97E-05	1.94E-05	1.85E-05	1.73E-05	1.55E-05	1.36E-05	1.11E-05	8.62E-06	5.74E-06	2.92E-06	0
50	51.61	1.95E-05	1.91E-05	1.84E-05	1.71E-05	1.55E-05	1.33E-05	1.11E-05	8.43E-06	5.77E-06	2.85E-06	0
51	52.64	1.92E-05	1.89E-05	1.81E-05	1.69E-05	1.52E-05	1.33E-05	1.09E-05	8.45E-06	5.65E-06	2.86E-06	0
52	53.67	1.90E-05	1.87E-05	1.80E-05	1.67E-05	1.51E-05	1.31E-05	1.09E-05	8.28E-06	5.66E-06	2.80E-06	0
53	54.70	1.88E-05	1.85E-05	1.77E-05	1.66E-05	1.49E-05	1.30E-05	1.07E-05	8.28E-06	5.55E-06	2.80E-06	0
54	55.73	1.86E-05	1.83E-05	1.75E-05	1.63E-05	1.48E-05	1.28E-05	1.07E-05	8.13E-06	5.54E-06	2.75E-06	0
55	56.77	1.83E-05	1.81E-05	1.73E-05	1.62E-05	1.46E-05	1.27E-05	1.05E-05	8.11E-06	5.45E-06	2.74E-06	0
56	57.80	1.81E-05	1.78E-05	1.71E-05	1.60E-05	1.45E-05	1.25E-05	1.04E-05	7.97E-06	5.43E-06	2.69E-06	0
57	58.83	1.79E-05	1.77E-05	1.69E-05	1.58E-05	1.43E-05	1.25E-05	1.03E-05	7.94E-06	5.34E-06	2.69E-06	0
58	59.86	1.77E-05	1.74E-05	1.68E-05	1.56E-05	1.42E-05	1.23E-05	1.02E-05	7.82E-06	5.32E-06	2.64E-06	0
59	60.89	1.75E-05	1.73E-05	1.65E-05	1.55E-05	1.40E-05	1.22E-05	1.01E-05	7.77E-06	5.24E-06	2.63E-06	0
60	61.93	1.73E-05	1.71E-05	1.64E-05	1.53E-05	1.38E-05	1.20E-05	9.99E-06	7.66E-06	5.20E-06	2.59E-06	0
61	62.96	1.71E-05	1.69E-05	1.62E-05	1.51E-05	1.37E-05	1.19E-05	9.85E-06	7.60E-06	5.13E-06	2.57E-06	0
62	63.99	1.70E-05	1.67E-05	1.60E-05	1.49E-05	1.35E-05	1.18E-05	9.77E-06	7.50E-06	5.09E-06	2.53E-06	0
63	65.02	1.68E-05	1.65E-05	1.58E-05	1.48E-05	1.34E-05	1.17E-05	9.65E-06	7.44E-06	5.02E-06	2.51E-06	0
64	66.05	1.66E-05	1.63E-05	1.57E-05	1.46E-05	1.32E-05	1.15E-05	9.56E-06	7.34E-06	4.98E-06	2.48E-06	0
65	67.09	1.64E-05	1.61E-05	1.55E-05	1.45E-05	1.31E-05	1.14E-05	9.44E-06	7.28E-06	4.92E-06	2.46E-06	0
66	68.12	1.62E-05	1.59E-05	1.53E-05	1.43E-05	1.29E-05	1.13E-05	9.35E-06	7.19E-06	4.87E-06	2.43E-06	0
67	69.15	1.60E-05	1.58E-05	1.51E-05	1.41E-05	1.28E-05	1.12E-05	9.24E-06	7.12E-06	4.81E-06	2.40E-06	0
68	70.18	1.59E-05	1.56E-05	1.50E-05	1.40E-05	1.27E-05	1.10E-05	9.15E-06	7.03E-06	4.77E-06	2.37E-06	0
69	71.22	1.57E-05	1.54E-05	1.48E-05	1.38E-05	1.25E-05	1.09E-05	9.04E-06	6.96E-06	4.71E-06	2.35E-06	0
70	72.25	1.55E-05	1.53E-05	1.46E-05	1.37E-05	1.24E-05	1.08E-05	8.95E-06	6.88E-06	4.66E-06	2.32E-06	0
71	73.28	1.53E-05	1.51E-05	1.45E-05	1.35E-05	1.22E-05	1.07E-05	8.84E-06	6.81E-06	4.61E-06	2.30E-06	0
72	74.31	1.52E-05	1.49E-05	1.43E-05	1.34E-05	1.21E-05	1.06E-05	8.75E-06	6.73E-06	4.56E-06	2.27E-06	0
73	75.34	1.50E-05	1.48E-05	1.42E-05	1.32E-05	1.20E-05	1.04E-05	8.65E-06	6.66E-06	4.51E-06	2.25E-06	0
74	76.38	1.48E-05	1.46E-05	1.40E-05	1.31E-05	1.18E-05	1.03E-05	8.56E-06	6.59E-06	4.46E-06	2.22E-06	0
75	77.41	1.47E-05	1.44E-05	1.39E-05	1.29E-05	1.17E-05	1.02E-05	8.46E-06	6.52E-06	4.41E-06	2.19E-06	0
76	78.44	1.45E-05	1.43E-05	1.37E-05	1.28E-05	1.16E-05	1.01E-05	8.37E-06	6.44E-06	4.36E-06	2.17E-06	0
77	79.47	1.44E-05	1.41E-05	1.35E-05	1.27E-05	1.15E-05	9.99E-06	8.28E-06	6.37E-06	4.31E-06	2.15E-06	0
78	80.50	1.42E-05	1.40E-05	1.34E-05	1.25E-05	1.13E-05	9.88E-06	8.19E-06	6.30E-06	4.26E-06	2.12E-06	0
79	81.54	1.40E-05	1.38E-05	1.33E-05	1.24E-05	1.12E-05	9.77E-06	8.10E-06	6.23E-06	4.22E-06	2.10E-06	0
80	82.57	1.39E-05	1.37E-05	1.31E-05	1.22E-05	1.11E-05	9.66E-06	8.01E-06	6.16E-06	4.17E-06	2.07E-06	0
81	83.60	1.37E-05	1.35E-05	1.30E-05	1.21E-05	1.10E-05	9.56E-06	7.92E-06	6.10E-06	4.12E-06	2.05E-06	0
82	84.63	1.36E-05	1.34E-05	1.28E-05	1.20E-05	1.08E-05	9.45E-06	7.83E-06	6.03E-06	4.08E-06	2.03E-06	0
83	85.66	1.34E-05	1.32E-05	1.27E-05	1.18E-05	1.07E-05	9.35E-06	7.75E-06	5.96E-06	4.03E-06	2.00E-06	0
84	86.70	1.33E-05	1.31E-05	1.25E-05	1.17E-05	1.06E-05	9.24E-06	7.66E-06	5.89E-06	3.99E-06	1.98E-06	0
85	87.73	1.32E-05	1.29E-05	1.24E-05	1.16E-05	1.05E-05	9.14E-06	7.58E-06	5.83E-06	3.94E-06	1.96E-06	0
86	88.76	1.30E-05	1.28E-05	1.23E-05	1.15E-05	1.04E-05	9.04E-06	7.49E-06	5.77E-06	3.90E-06	1.94E-06	0
87	89.79	1.29E-05	1.27E-05	1.21E-05	1.13E-05	1.03E-05	8.94E-06	7.41E-06	5.70E-06	3.85E-06	1.91E-06	0
88	90.83	1.27E-05	1.25E-05	1.20E-05	1.12E-05	1.01E-05	8.84E-06	7.33E-06	5.64E-06	3.81E-06	1.89E-06	0
89	91.86	1.26E-05	1.24E-05	1.19E-05	1.11E-05	1.00E-05	8.75E-06	7.25E-06	5.58E-06	3.77E-06	1.87E-06	0
90	92.89	1.25E-05	1.23E-05	1.17E-05	1.10E-05	9.93E-06	8.65E-06	7.17E-06	5.51E-06	3.73E-06	1.85E-06	0

Table 7.9 Continued

91	93.92	1.23E-05	1.21E-05	1.16E-05	1.08E-05	9.82E-06	8.56E-06	7.09E-06	5.45E-06	3.69E-06	1.83E-06	0
92	94.95	1.22E-05	1.20E-05	1.15E-05	1.07E-05	9.71E-06	8.46E-06	7.01E-06	5.39E-06	3.64E-06	1.81E-06	0
93	95.99	1.21E-05	1.19E-05	1.14E-05	1.06E-05	9.60E-06	8.37E-06	6.93E-06	5.33E-06	3.60E-06	1.79E-06	0
94	97.02	1.19E-05	1.17E-05	1.12E-05	1.05E-05	9.50E-06	8.28E-06	6.86E-06	5.27E-06	3.56E-06	1.77E-06	0
95	98.05	1.18E-05	1.16E-05	1.11E-05	1.04E-05	9.40E-06	8.19E-06	6.78E-06	5.22E-06	3.52E-06	1.75E-06	0
96	99.08	1.17E-05	1.15E-05	1.10E-05	1.03E-05	9.29E-06	8.10E-06	6.71E-06	5.16E-06	3.49E-06	1.73E-06	0
97	100.11	1.16E-05	1.14E-05	1.09E-05	1.02E-05	9.19E-06	8.01E-06	6.63E-06	5.10E-06	3.45E-06	1.71E-06	0
98	101.15	1.14E-05	1.12E-05	1.08E-05	1.00E-05	9.09E-06	7.92E-06	6.56E-06	5.05E-06	3.41E-06	1.69E-06	0
99	102.18	1.13E-05	1.11E-05	1.06E-05	9.94E-06	8.99E-06	7.83E-06	6.49E-06	4.99E-06	3.37E-06	1.67E-06	0
100	103.21	1.12E-05	1.10E-05	1.05E-05	9.83E-06	8.89E-06	7.75E-06	6.42E-06	4.93E-06	3.33E-06	1.65E-06	0
101	104.24	1.11E-05	1.09E-05	1.04E-05	9.72E-06	8.80E-06	7.66E-06	6.35E-06	4.88E-06	3.30E-06	1.63E-06	0
102	105.27	1.09E-05	1.08E-05	1.03E-05	9.62E-06	8.70E-06	7.58E-06	6.28E-06	4.83E-06	3.26E-06	1.61E-06	0
103	106.31	1.08E-05	1.06E-05	1.02E-05	9.51E-06	8.61E-06	7.50E-06	6.21E-06	4.77E-06	3.22E-06	1.59E-06	0
104	107.34	1.07E-05	1.05E-05	1.01E-05	9.41E-06	8.51E-06	7.41E-06	6.14E-06	4.72E-06	3.19E-06	1.58E-06	0
105	108.37	1.06E-05	1.04E-05	9.97E-06	9.31E-06	8.42E-06	7.33E-06	6.07E-06	4.67E-06	3.15E-06	1.56E-06	0
106	109.40	1.05E-05	1.03E-05	9.87E-06	9.21E-06	8.33E-06	7.25E-06	6.01E-06	4.62E-06	3.12E-06	1.54E-06	0
107	110.44	1.04E-05	1.02E-05	9.76E-06	9.11E-06	8.24E-06	7.17E-06	5.94E-06	4.57E-06	3.08E-06	1.52E-06	0
108	111.47	1.03E-05	1.01E-05	9.65E-06	9.01E-06	8.15E-06	7.10E-06	5.88E-06	4.52E-06	3.05E-06	1.51E-06	0
109	112.50	1.02E-05	9.97E-06	9.55E-06	8.91E-06	8.06E-06	7.02E-06	5.81E-06	4.47E-06	3.01E-06	1.49E-06	0
110	113.53	1.00E-05	9.86E-06	9.45E-06	8.81E-06	7.97E-06	6.94E-06	5.75E-06	4.42E-06	2.98E-06	1.47E-06	0
111	114.56	9.94E-06	9.75E-06	9.35E-06	8.72E-06	7.89E-06	6.87E-06	5.69E-06	4.37E-06	2.95E-06	1.46E-06	0
112	115.60	9.83E-06	9.65E-06	9.24E-06	8.62E-06	7.80E-06	6.79E-06	5.62E-06	4.32E-06	2.92E-06	1.44E-06	0
113	116.63	9.73E-06	9.55E-06	9.15E-06	8.53E-06	7.71E-06	6.72E-06	5.56E-06	4.27E-06	2.88E-06	1.42E-06	0
114	117.66	9.62E-06	9.44E-06	9.05E-06	8.44E-06	7.63E-06	6.64E-06	5.50E-06	4.23E-06	2.85E-06	1.41E-06	0
115	118.69	9.52E-06	9.34E-06	8.95E-06	8.35E-06	7.55E-06	6.57E-06	5.44E-06	4.18E-06	2.82E-06	1.39E-06	0
116	119.72	9.42E-06	9.24E-06	8.85E-06	8.26E-06	7.47E-06	6.50E-06	5.38E-06	4.13E-06	2.79E-06	1.38E-06	0
117	120.76	9.32E-06	9.14E-06	8.76E-06	8.17E-06	7.39E-06	6.43E-06	5.32E-06	4.09E-06	2.76E-06	1.36E-06	0
118	121.79	9.22E-06	9.04E-06	8.66E-06	8.08E-06	7.31E-06	6.36E-06	5.26E-06	4.04E-06	2.73E-06	1.35E-06	0
119	122.82	9.12E-06	8.95E-06	8.57E-06	7.99E-06	7.23E-06	6.29E-06	5.21E-06	4.00E-06	2.70E-06	1.33E-06	0
120	123.85	9.02E-06	8.85E-06	8.48E-06	7.91E-06	7.15E-06	6.22E-06	5.15E-06	3.96E-06	2.67E-06	1.32E-06	0
121	124.88	8.92E-06	8.76E-06	8.39E-06	7.82E-06	7.07E-06	6.16E-06	5.09E-06	3.91E-06	2.64E-06	1.30E-06	0
122	125.92	8.83E-06	8.66E-06	8.30E-06	7.74E-06	6.99E-06	6.09E-06	5.04E-06	3.87E-06	2.61E-06	1.29E-06	0
123	126.95	8.73E-06	8.57E-06	8.21E-06	7.65E-06	6.92E-06	6.02E-06	4.98E-06	3.83E-06	2.58E-06	1.27E-06	0
124	127.98	8.64E-06	8.48E-06	8.12E-06	7.57E-06	6.84E-06	5.96E-06	4.93E-06	3.79E-06	2.55E-06	1.26E-06	0
125	129.01	8.55E-06	8.39E-06	8.03E-06	7.49E-06	6.77E-06	5.89E-06	4.88E-06	3.75E-06	2.53E-06	1.24E-06	0
126	130.05	8.46E-06	8.30E-06	7.94E-06	7.41E-06	6.70E-06	5.83E-06	4.82E-06	3.70E-06	2.50E-06	1.23E-06	0
127	131.08	8.37E-06	8.21E-06	7.86E-06	7.33E-06	6.62E-06	5.77E-06	4.77E-06	3.66E-06	2.47E-06	1.22E-06	0
128	132.11	8.28E-06	8.12E-06	7.78E-06	7.25E-06	6.55E-06	5.70E-06	4.72E-06	3.62E-06	2.44E-06	1.20E-06	0
129	133.14	8.19E-06	8.03E-06	7.69E-06	7.17E-06	6.48E-06	5.64E-06	4.67E-06	3.58E-06	2.42E-06	1.19E-06	0
130	134.17	8.10E-06	7.95E-06	7.61E-06	7.09E-06	6.41E-06	5.58E-06	4.62E-06	3.55E-06	2.39E-06	1.18E-06	0
131	135.21	8.02E-06	7.86E-06	7.53E-06	7.02E-06	6.34E-06	5.52E-06	4.57E-06	3.51E-06	2.36E-06	1.16E-06	0
132	136.24	7.93E-06	7.78E-06	7.45E-06	6.94E-06	6.27E-06	5.46E-06	4.52E-06	3.47E-06	2.34E-06	1.15E-06	0
133	137.27	7.85E-06	7.70E-06	7.37E-06	6.87E-06	6.21E-06	5.40E-06	4.47E-06	3.43E-06	2.31E-06	1.14E-06	0
134	138.30	7.76E-06	7.61E-06	7.29E-06	6.79E-06	6.14E-06	5.34E-06	4.42E-06	3.39E-06	2.29E-06	1.13E-06	0
135	139.33	7.68E-06	7.53E-06	7.21E-06	6.72E-06	6.07E-06	5.28E-06	4.37E-06	3.36E-06	2.26E-06	1.11E-06	0
136	140.37	7.60E-06	7.45E-06	7.13E-06	6.65E-06	6.01E-06	5.23E-06	4.32E-06	3.32E-06	2.24E-06	1.10E-06	0
137	141.40	7.52E-06	7.37E-06	7.06E-06	6.58E-06	5.94E-06	5.17E-06	4.28E-06	3.28E-06	2.21E-06	1.09E-06	0
138	142.43	7.44E-06	7.29E-06	6.98E-06	6.51E-06	5.88E-06	5.12E-06	4.23E-06	3.25E-06	2.19E-06	1.08E-06	0
139	143.46	7.36E-06	7.22E-06	6.91E-06	6.44E-06	5.82E-06	5.06E-06	4.19E-06	3.21E-06	2.16E-06	1.06E-06	0
140	144.49	7.28E-06	7.14E-06	6.83E-06	6.37E-06	5.75E-06	5.01E-06	4.14E-06	3.18E-06	2.14E-06	1.05E-06	0
141	145.53	7.20E-06	7.06E-06	6.76E-06	6.30E-06	5.69E-06	4.95E-06	4.10E-06	3.14E-06	2.12E-06	1.04E-06	0
142	146.56	7.13E-06	6.99E-06	6.69E-06	6.23E-06	5.63E-06	4.90E-06	4.05E-06	3.11E-06	2.09E-06	1.03E-06	0
143	147.59	7.05E-06	6.91E-06	6.61E-06	6.16E-06	5.57E-06	4.85E-06	4.01E-06	3.08E-06	2.07E-06	1.02E-06	0
144	148.62	6.98E-06	6.84E-06	6.54E-06	6.10E-06	5.51E-06	4.79E-06	3.96E-06	3.04E-06	2.05E-06	1.01E-06	0
145	149.66	6.90E-06	6.77E-06	6.47E-06	6.03E-06	5.45E-06	4.74E-06	3.92E-06	3.01E-06	2.03E-06	9.96E-07	0
146	150.69	6.83E-06	6.69E-06	6.41E-06	5.97E-06	5.39E-06	4.69E-06	3.88E-06	2.98E-06	2.00E-06	9.85E-07	0

Table 7.9 Continued

147	151.72	6.76E-06	6.62E-06	6.34E-06	5.90E-06	5.33E-06	4.64E-06	3.84E-06	2.94E-06	1.98E-06	9.74E-07	0
148	152.75	6.68E-06	6.55E-06	6.27E-06	5.84E-06	5.28E-06	4.59E-06	3.80E-06	2.91E-06	1.96E-06	9.64E-07	0
149	153.78	6.61E-06	6.48E-06	6.20E-06	5.78E-06	5.22E-06	4.54E-06	3.76E-06	2.88E-06	1.94E-06	9.53E-07	0
150	154.82	6.54E-06	6.41E-06	6.14E-06	5.72E-06	5.16E-06	4.49E-06	3.71E-06	2.85E-06	1.92E-06	9.43E-07	0
151	155.85	6.47E-06	6.34E-06	6.07E-06	5.65E-06	5.11E-06	4.44E-06	3.67E-06	2.82E-06	1.90E-06	9.32E-07	0
152	156.88	6.40E-06	6.28E-06	6.01E-06	5.59E-06	5.05E-06	4.40E-06	3.63E-06	2.79E-06	1.88E-06	9.22E-07	0
153	157.91	6.34E-06	6.21E-06	5.94E-06	5.53E-06	5.00E-06	4.35E-06	3.60E-06	2.76E-06	1.86E-06	9.12E-07	0
154	158.94	6.27E-06	6.14E-06	5.88E-06	5.48E-06	4.95E-06	4.30E-06	3.56E-06	2.73E-06	1.84E-06	9.02E-07	0
155	159.98	6.20E-06	6.08E-06	5.82E-06	5.42E-06	4.89E-06	4.26E-06	3.52E-06	2.70E-06	1.82E-06	8.92E-07	0
156	161.01	6.14E-06	6.01E-06	5.75E-06	5.36E-06	4.84E-06	4.21E-06	3.48E-06	2.67E-06	1.80E-06	8.82E-07	0
157	162.04	6.07E-06	5.95E-06	5.69E-06	5.30E-06	4.79E-06	4.16E-06	3.44E-06	2.64E-06	1.78E-06	8.73E-07	0
158	163.07	6.01E-06	5.89E-06	5.63E-06	5.24E-06	4.74E-06	4.12E-06	3.41E-06	2.61E-06	1.76E-06	8.63E-07	0
159	164.10	5.94E-06	5.82E-06	5.57E-06	5.19E-06	4.69E-06	4.08E-06	3.37E-06	2.59E-06	1.74E-06	8.54E-07	0
160	165.14	5.88E-06	5.76E-06	5.51E-06	5.13E-06	4.64E-06	4.03E-06	3.33E-06	2.56E-06	1.72E-06	8.44E-07	0
161	166.17	5.82E-06	5.70E-06	5.45E-06	5.08E-06	4.59E-06	3.99E-06	3.30E-06	2.53E-06	1.70E-06	8.35E-07	0
162	167.20	5.76E-06	5.64E-06	5.39E-06	5.02E-06	4.54E-06	3.95E-06	3.26E-06	2.50E-06	1.68E-06	8.26E-07	0
163	168.23	5.70E-06	5.58E-06	5.34E-06	4.97E-06	4.49E-06	3.90E-06	3.23E-06	2.48E-06	1.67E-06	8.17E-07	0
164	169.27	5.64E-06	5.52E-06	5.28E-06	4.92E-06	4.44E-06	3.86E-06	3.19E-06	2.45E-06	1.65E-06	8.08E-07	0
165	170.30	5.58E-06	5.46E-06	5.22E-06	4.87E-06	4.39E-06	3.82E-06	3.16E-06	2.42E-06	1.63E-06	7.99E-07	0
166	171.33	5.52E-06	5.40E-06	5.17E-06	4.81E-06	4.35E-06	3.78E-06	3.12E-06	2.40E-06	1.61E-06	7.90E-07	0
167	172.36	5.46E-06	5.35E-06	5.11E-06	4.76E-06	4.30E-06	3.74E-06	3.09E-06	2.37E-06	1.59E-06	7.82E-07	0
168	173.39	5.40E-06	5.29E-06	5.06E-06	4.71E-06	4.25E-06	3.70E-06	3.06E-06	2.35E-06	1.58E-06	7.73E-07	0
169	174.43	5.34E-06	5.23E-06	5.01E-06	4.66E-06	4.21E-06	3.66E-06	3.02E-06	2.32E-06	1.56E-06	7.65E-07	0
170	175.46	5.29E-06	5.18E-06	4.95E-06	4.61E-06	4.16E-06	3.62E-06	2.99E-06	2.29E-06	1.54E-06	7.57E-07	0
171	176.49	5.23E-06	5.12E-06	4.90E-06	4.56E-06	4.12E-06	3.58E-06	2.96E-06	2.27E-06	1.53E-06	7.48E-07	0
172	177.52	5.17E-06	5.07E-06	4.85E-06	4.51E-06	4.08E-06	3.54E-06	2.93E-06	2.25E-06	1.51E-06	7.40E-07	0
173	178.55	5.12E-06	5.02E-06	4.80E-06	4.47E-06	4.03E-06	3.51E-06	2.90E-06	2.22E-06	1.49E-06	7.32E-07	0
174	179.59	5.07E-06	4.96E-06	4.74E-06	4.42E-06	3.99E-06	3.47E-06	2.87E-06	2.20E-06	1.48E-06	7.24E-07	0
175	180.62	5.01E-06	4.91E-06	4.69E-06	4.37E-06	3.95E-06	3.43E-06	2.84E-06	2.17E-06	1.46E-06	7.16E-07	0
176	181.65	4.96E-06	4.86E-06	4.64E-06	4.32E-06	3.90E-06	3.39E-06	2.81E-06	2.15E-06	1.45E-06	7.09E-07	0
177	182.68	4.91E-06	4.81E-06	4.60E-06	4.28E-06	3.86E-06	3.36E-06	2.78E-06	2.13E-06	1.43E-06	7.01E-07	0
178	183.71	4.85E-06	4.76E-06	4.55E-06	4.23E-06	3.82E-06	3.32E-06	2.75E-06	2.11E-06	1.42E-06	6.93E-07	0
179	184.75	4.80E-06	4.70E-06	4.50E-06	4.19E-06	3.78E-06	3.29E-06	2.72E-06	2.08E-06	1.40E-06	6.86E-07	0
180	185.78	4.75E-06	4.65E-06	4.45E-06	4.14E-06	3.74E-06	3.25E-06	2.69E-06	2.06E-06	1.39E-06	6.78E-07	0
181	186.81	4.70E-06	4.61E-06	4.40E-06	4.10E-06	3.70E-06	3.22E-06	2.66E-06	2.04E-06	1.37E-06	6.71E-07	0
182	187.84	4.65E-06	4.56E-06	4.36E-06	4.06E-06	3.66E-06	3.18E-06	2.63E-06	2.02E-06	1.36E-06	6.64E-07	0
183	188.88	4.60E-06	4.51E-06	4.31E-06	4.01E-06	3.62E-06	3.15E-06	2.60E-06	1.99E-06	1.34E-06	6.56E-07	0
184	189.91	4.55E-06	4.46E-06	4.26E-06	3.97E-06	3.58E-06	3.11E-06	2.57E-06	1.97E-06	1.33E-06	6.49E-07	0
185	190.94	4.51E-06	4.41E-06	4.22E-06	3.93E-06	3.55E-06	3.08E-06	2.55E-06	1.95E-06	1.31E-06	6.42E-07	0
186	191.97	4.46E-06	4.37E-06	4.17E-06	3.89E-06	3.51E-06	3.05E-06	2.52E-06	1.93E-06	1.30E-06	6.35E-07	0
187	193.00	4.41E-06	4.32E-06	4.13E-06	3.84E-06	3.47E-06	3.02E-06	2.49E-06	1.91E-06	1.28E-06	6.28E-07	0
188	194.04	4.37E-06	4.27E-06	4.09E-06	3.80E-06	3.43E-06	2.98E-06	2.47E-06	1.89E-06	1.27E-06	6.22E-07	0
189	195.07	4.32E-06	4.23E-06	4.04E-06	3.76E-06	3.40E-06	2.95E-06	2.44E-06	1.87E-06	1.26E-06	6.15E-07	0
190	196.10	4.27E-06	4.18E-06	4.00E-06	3.72E-06	3.36E-06	2.92E-06	2.41E-06	1.85E-06	1.24E-06	6.08E-07	0
191	197.13	4.23E-06	4.14E-06	3.96E-06	3.68E-06	3.32E-06	2.89E-06	2.39E-06	1.83E-06	1.23E-06	6.02E-07	0
192	198.16	4.18E-06	4.10E-06	3.92E-06	3.64E-06	3.29E-06	2.86E-06	2.36E-06	1.81E-06	1.22E-06	5.95E-07	0
193	199.20	4.14E-06	4.05E-06	3.87E-06	3.61E-06	3.25E-06	2.83E-06	2.34E-06	1.79E-06	1.20E-06	5.89E-07	0
194	200.23	4.10E-06	4.01E-06	3.83E-06	3.57E-06	3.22E-06	2.80E-06	2.31E-06	1.77E-06	1.19E-06	5.82E-07	0
195	201.26	4.05E-06	3.97E-06	3.79E-06	3.53E-06	3.19E-06	2.77E-06	2.29E-06	1.75E-06	1.18E-06	5.76E-07	0
196	202.29	4.01E-06	3.93E-06	3.75E-06	3.49E-06	3.15E-06	2.74E-06	2.26E-06	1.73E-06	1.17E-06	5.70E-07	0
197	203.32	3.97E-06	3.88E-06	3.71E-06	3.45E-06	3.12E-06	2.71E-06	2.24E-06	1.72E-06	1.15E-06	5.64E-07	0
198	204.36	3.93E-06	3.84E-06	3.67E-06	3.42E-06	3.09E-06	2.68E-06	2.21E-06	1.70E-06	1.14E-06	5.58E-07	0
199	205.39	3.88E-06	3.80E-06	3.63E-06	3.38E-06	3.05E-06	2.65E-06	2.19E-06	1.68E-06	1.13E-06	5.52E-07	0
200	206.42	3.84E-06	3.76E-06	3.60E-06	3.35E-06	3.02E-06	2.62E-06	2.17E-06	1.66E-06	1.12E-06	5.46E-07	0
201	207.45	3.80E-06	3.72E-06	3.56E-06	3.31E-06	2.99E-06	2.60E-06	2.14E-06	1.64E-06	1.10E-06	5.40E-07	0
202	208.49	3.76E-06	3.68E-06	3.52E-06	3.28E-06	2.96E-06	2.57E-06	2.12E-06	1.63E-06	1.09E-06	5.34E-07	0

Table 7.9 Continued

203	209.52	3.72E-06	3.64E-06	3.48E-06	3.24E-06	2.92E-06	2.54E-06	2.10E-06	1.61E-06	1.08E-06	5.28E-07	0
204	210.55	3.68E-06	3.61E-06	3.45E-06	3.21E-06	2.89E-06	2.51E-06	2.08E-06	1.59E-06	1.07E-06	5.23E-07	0
205	211.58	3.64E-06	3.57E-06	3.41E-06	3.17E-06	2.86E-06	2.49E-06	2.05E-06	1.57E-06	1.06E-06	5.17E-07	0
206	212.61	3.61E-06	3.53E-06	3.37E-06	3.14E-06	2.83E-06	2.46E-06	2.03E-06	1.56E-06	1.05E-06	5.11E-07	0
207	213.65	3.57E-06	3.49E-06	3.34E-06	3.11E-06	2.80E-06	2.44E-06	2.01E-06	1.54E-06	1.04E-06	5.06E-07	0
208	214.68	3.53E-06	3.46E-06	3.30E-06	3.07E-06	2.77E-06	2.41E-06	1.99E-06	1.53E-06	1.02E-06	5.01E-07	0
209	215.71	3.49E-06	3.42E-06	3.27E-06	3.04E-06	2.74E-06	2.38E-06	1.97E-06	1.51E-06	1.01E-06	4.95E-07	0
210	216.74	3.46E-06	3.38E-06	3.23E-06	3.01E-06	2.71E-06	2.36E-06	1.95E-06	1.49E-06	1.00E-06	4.90E-07	0
211	217.77	3.42E-06	3.35E-06	3.20E-06	2.98E-06	2.69E-06	2.33E-06	1.93E-06	1.48E-06	9.92E-07	4.85E-07	0
212	218.81	3.38E-06	3.31E-06	3.16E-06	2.94E-06	2.66E-06	2.31E-06	1.91E-06	1.46E-06	9.82E-07	4.79E-07	0
213	219.84	3.35E-06	3.28E-06	3.13E-06	2.91E-06	2.63E-06	2.28E-06	1.89E-06	1.45E-06	9.71E-07	4.74E-07	0
214	220.87	3.31E-06	3.24E-06	3.10E-06	2.88E-06	2.60E-06	2.26E-06	1.87E-06	1.43E-06	9.61E-07	4.69E-07	0
215	221.90	3.28E-06	3.21E-06	3.07E-06	2.85E-06	2.57E-06	2.24E-06	1.85E-06	1.41E-06	9.51E-07	4.64E-07	0
216	222.93	3.24E-06	3.17E-06	3.03E-06	2.82E-06	2.55E-06	2.21E-06	1.83E-06	1.40E-06	9.40E-07	4.59E-07	0
217	223.97	3.21E-06	3.14E-06	3.00E-06	2.79E-06	2.52E-06	2.19E-06	1.81E-06	1.38E-06	9.30E-07	4.54E-07	0
218	225.00	3.18E-06	3.11E-06	2.97E-06	2.76E-06	2.49E-06	2.17E-06	1.79E-06	1.37E-06	9.20E-07	4.49E-07	0
219	226.03	3.14E-06	3.07E-06	2.94E-06	2.73E-06	2.47E-06	2.14E-06	1.77E-06	1.36E-06	9.11E-07	4.45E-07	0
220	227.06	3.11E-06	3.04E-06	2.91E-06	2.70E-06	2.44E-06	2.12E-06	1.75E-06	1.34E-06	9.01E-07	4.40E-07	0
221	228.10	3.08E-06	3.01E-06	2.88E-06	2.68E-06	2.41E-06	2.10E-06	1.73E-06	1.33E-06	8.91E-07	4.35E-07	0
222	229.13	3.04E-06	2.98E-06	2.85E-06	2.65E-06	2.39E-06	2.07E-06	1.71E-06	1.31E-06	8.82E-07	4.30E-07	0
223	230.16	3.01E-06	2.95E-06	2.82E-06	2.62E-06	2.36E-06	2.05E-06	1.70E-06	1.30E-06	8.72E-07	4.26E-07	0
224	231.19	2.98E-06	2.92E-06	2.79E-06	2.59E-06	2.34E-06	2.03E-06	1.68E-06	1.29E-06	8.63E-07	4.21E-07	0
225	232.22	2.95E-06	2.89E-06	2.76E-06	2.56E-06	2.31E-06	2.01E-06	1.66E-06	1.27E-06	8.54E-07	4.17E-07	0
226	233.26	2.92E-06	2.85E-06	2.73E-06	2.54E-06	2.29E-06	1.99E-06	1.64E-06	1.26E-06	8.45E-07	4.12E-07	0
227	234.29	2.89E-06	2.82E-06	2.70E-06	2.51E-06	2.26E-06	1.97E-06	1.62E-06	1.24E-06	8.36E-07	4.08E-07	0
228	235.32	2.86E-06	2.79E-06	2.67E-06	2.48E-06	2.24E-06	1.95E-06	1.61E-06	1.23E-06	8.27E-07	4.04E-07	0
229	236.35	2.83E-06	2.77E-06	2.64E-06	2.46E-06	2.22E-06	1.93E-06	1.59E-06	1.22E-06	8.18E-07	3.99E-07	0
230	237.38	2.80E-06	2.74E-06	2.61E-06	2.43E-06	2.19E-06	1.91E-06	1.57E-06	1.21E-06	8.10E-07	3.95E-07	0
231	238.42	2.77E-06	2.71E-06	2.59E-06	2.41E-06	2.17E-06	1.89E-06	1.56E-06	1.19E-06	8.01E-07	3.91E-07	0
232	239.45	2.74E-06	2.68E-06	2.56E-06	2.38E-06	2.15E-06	1.87E-06	1.54E-06	1.18E-06	7.92E-07	3.87E-07	0
233	240.48	2.71E-06	2.65E-06	2.53E-06	2.36E-06	2.12E-06	1.85E-06	1.52E-06	1.17E-06	7.84E-07	3.82E-07	0
234	241.51	2.68E-06	2.62E-06	2.51E-06	2.33E-06	2.10E-06	1.83E-06	1.51E-06	1.16E-06	7.76E-07	3.78E-07	0
235	242.54	2.65E-06	2.59E-06	2.48E-06	2.31E-06	2.08E-06	1.81E-06	1.49E-06	1.14E-06	7.67E-07	3.74E-07	0
236	243.58	2.62E-06	2.57E-06	2.45E-06	2.28E-06	2.06E-06	1.79E-06	1.48E-06	1.13E-06	7.59E-07	3.70E-07	0
237	244.61	2.60E-06	2.54E-06	2.43E-06	2.26E-06	2.04E-06	1.77E-06	1.46E-06	1.12E-06	7.51E-07	3.66E-07	0
238	245.64	2.57E-06	2.51E-06	2.40E-06	2.23E-06	2.01E-06	1.75E-06	1.44E-06	1.11E-06	7.43E-07	3.62E-07	0
239	246.67	2.54E-06	2.49E-06	2.38E-06	2.21E-06	1.99E-06	1.73E-06	1.43E-06	1.10E-06	7.35E-07	3.59E-07	0
240	247.71	2.52E-06	2.46E-06	2.35E-06	2.19E-06	1.97E-06	1.71E-06	1.41E-06	1.08E-06	7.27E-07	3.55E-07	0
241	248.74	2.49E-06	2.44E-06	2.33E-06	2.16E-06	1.95E-06	1.69E-06	1.40E-06	1.07E-06	7.20E-07	3.51E-07	0
242	249.77	2.46E-06	2.41E-06	2.30E-06	2.14E-06	1.93E-06	1.68E-06	1.38E-06	1.06E-06	7.12E-07	3.47E-07	0
243	250.80	2.44E-06	2.38E-06	2.28E-06	2.12E-06	1.91E-06	1.66E-06	1.37E-06	1.05E-06	7.05E-07	3.44E-07	0
244	251.83	2.41E-06	2.36E-06	2.25E-06	2.10E-06	1.89E-06	1.64E-06	1.36E-06	1.04E-06	6.97E-07	3.40E-07	0
245	252.87	2.39E-06	2.33E-06	2.23E-06	2.07E-06	1.87E-06	1.62E-06	1.34E-06	1.03E-06	6.90E-07	3.36E-07	0
246	253.90	2.36E-06	2.31E-06	2.21E-06	2.05E-06	1.85E-06	1.61E-06	1.33E-06	1.02E-06	6.82E-07	3.33E-07	0
247	254.93	2.34E-06	2.29E-06	2.18E-06	2.03E-06	1.83E-06	1.59E-06	1.31E-06	1.01E-06	6.75E-07	3.29E-07	0
248	255.96	2.31E-06	2.26E-06	2.16E-06	2.01E-06	1.81E-06	1.57E-06	1.30E-06	9.95E-07	6.68E-07	3.26E-07	0
249	256.99	2.29E-06	2.24E-06	2.14E-06	1.99E-06	1.79E-06	1.56E-06	1.29E-06	9.84E-07	6.61E-07	3.22E-07	0
250	258.03	2.26E-06	2.21E-06	2.11E-06	1.97E-06	1.77E-06	1.54E-06	1.27E-06	9.74E-07	6.54E-07	3.19E-07	0
251	259.06	2.24E-06	2.19E-06	2.09E-06	1.95E-06	1.75E-06	1.52E-06	1.26E-06	9.64E-07	6.47E-07	3.15E-07	0
252	260.09	2.22E-06	2.17E-06	2.07E-06	1.93E-06	1.74E-06	1.51E-06	1.25E-06	9.53E-07	6.40E-07	3.12E-07	0
253	261.12	2.19E-06	2.14E-06	2.05E-06	1.90E-06	1.72E-06	1.49E-06	1.23E-06	9.43E-07	6.33E-07	3.09E-07	0
254	262.15	2.17E-06	2.12E-06	2.03E-06	1.88E-06	1.70E-06	1.48E-06	1.22E-06	9.33E-07	6.27E-07	3.05E-07	0

Appendix 7.11: Model Output for *Salmonella* Velocity

Excel formula used to calculate the *Salmonella* concentration at t = 1.03 s and x = 0.005 m. (i.e. cell D5):

D5 =B*(1/(MASTER!dsal/(2*'Effective Gap Radius'!D5))^0.128)*((MASTER!Lsal/MASTER!dsal)^0.128*'Marinade Velocity'!D5-SQRT(2*MASTER!g*(2*'Effective Gap Radius'!D5)*(MASTER!rdsal-1)*(MASTER!Lsal/MASTER!dsal))*(1-(MASTER!dsal/(2*'Effective Gap Radius'!D5))^2))*((2*'Effective Gap Radius'!D5)/df)^n

Table 7.10: Predicted *Salmonella* velocity profile generated by Excel, given the input variables listed in Table 4.1.

***Salmonella* Velocity**												
	i =>	0	1	2	3	4	5	6	7	8	9	10
j		0	0.005	0.01	0.015	0.02	0.025	0.03	0.035	0.04	0.045	0.05
0	0	1.5E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
1	1.38	7.4E-04	7.7E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
2	2.75	7.4E-04	3.8E-04	3.9E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
3	4.13	5.6E-04	5.6E-04	1.9E-04	2.0E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
4	5.50	5.6E-04	3.9E-04	3.8E-04	9.8E-05	9.9E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
5	6.88	4.7E-04	4.7E-04	2.5E-04	2.4E-04	4.9E-05	4.9E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
6	8.26	4.7E-04	3.6E-04	3.5E-04	1.5E-04	1.4E-04	2.5E-05	2.5E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00
7	9.63	4.1E-04	4.1E-04	2.6E-04	2.5E-04	8.7E-05	8.5E-05	1.2E-05	1.2E-05	0.0E+00	0.0E+00	0.0E+00
8	11.01	4.1E-04	3.4E-04	3.3E-04	1.8E-04	1.7E-04	5.0E-05	4.9E-05	6.2E-06	6.2E-06	0.0E+00	0.0E+00
9	12.39	3.7E-04	3.7E-04	2.6E-04	2.5E-04	1.1E-04	1.1E-04	2.8E-05	2.7E-05	3.1E-06	3.1E-06	0.0E+00
10	13.76	3.7E-04	3.2E-04	3.0E-04	1.9E-04	1.8E-04	7.1E-05	6.7E-05	1.6E-05	1.5E-05	1.5E-06	0.0E+00
11	15.14	3.4E-04	3.4E-04	2.6E-04	2.4E-04	1.3E-04	1.2E-04	4.3E-05	4.1E-05	8.6E-06	7.6E-06	0.0E+00
12	16.51	3.4E-04	3.0E-04	2.9E-04	1.9E-04	1.8E-04	8.7E-05	8.1E-05	2.6E-05	2.4E-05	4.3E-06	0.0E+00
13	17.89	3.2E-04	3.1E-04	2.5E-04	2.3E-04	1.4E-04	1.3E-04	5.7E-05	5.3E-05	1.5E-05	1.2E-05	0.0E+00
14	19.27	3.1E-04	2.9E-04	2.7E-04	2.0E-04	1.8E-04	1.0E-04	9.1E-05	3.6E-05	3.3E-05	7.6E-06	0.0E+00
15	20.64	3.0E-04	2.9E-04	2.4E-04	2.3E-04	1.5E-04	1.4E-04	6.8E-05	6.2E-05	2.2E-05	1.6E-05	0.0E+00
16	22.02	2.9E-04	2.7E-04	2.6E-04	2.0E-04	1.8E-04	1.1E-04	9.9E-05	4.5E-05	3.9E-05	1.1E-05	0.0E+00
17	23.39	2.8E-04	2.8E-04	2.4E-04	2.2E-04	1.5E-04	1.4E-04	7.7E-05	6.9E-05	2.8E-05	2.0E-05	0.0E+00
18	24.77	2.8E-04	2.6E-04	2.5E-04	2.0E-04	1.8E-04	1.2E-04	1.0E-04	5.3E-05	4.4E-05	1.4E-05	0.0E+00
19	26.15	2.7E-04	2.6E-04	2.3E-04	2.1E-04	1.6E-04	1.4E-04	8.4E-05	7.4E-05	3.3E-05	2.2E-05	0.0E+00
20	27.52	2.6E-04	2.5E-04	2.4E-04	1.9E-04	1.8E-04	1.2E-04	1.1E-04	5.9E-05	4.8E-05	1.7E-05	0.0E+00
21	28.90	2.6E-04	2.5E-04	2.2E-04	2.1E-04	1.6E-04	1.4E-04	9.0E-05	7.8E-05	3.8E-05	2.4E-05	0.0E+00
22	30.28	2.5E-04	2.4E-04	2.3E-04	1.9E-04	1.7E-04	1.2E-04	1.1E-04	6.4E-05	5.1E-05	1.9E-05	0.0E+00
23	31.65	2.4E-04	2.4E-04	2.2E-04	2.0E-04	1.6E-04	1.4E-04	9.4E-05	8.0E-05	4.2E-05	2.5E-05	0.0E+00
24	33.03	2.4E-04	2.3E-04	2.2E-04	1.9E-04	1.7E-04	1.3E-04	1.1E-04	6.8E-05	5.3E-05	2.1E-05	0.0E+00
25	34.40	2.3E-04	2.3E-04	2.1E-04	2.0E-04	1.6E-04	1.4E-04	9.8E-05	8.2E-05	4.5E-05	2.6E-05	0.0E+00

Table 7.10 Continued

26	35.78	2.3E-04	2.2E-04	2.1E-04	1.8E-04	1.7E-04	1.3E-04	1.1E-04	7.1E-05	5.4E-05	2.2E-05	0.0E+00
27	37.16	2.3E-04	2.2E-04	2.0E-04	1.9E-04	1.6E-04	1.4E-04	1.0E-04	8.2E-05	4.7E-05	2.7E-05	0.0E+00
28	38.53	2.2E-04	2.2E-04	2.1E-04	1.8E-04	1.6E-04	1.3E-04	1.1E-04	7.3E-05	5.5E-05	2.3E-05	0.0E+00
29	39.91	2.2E-04	2.1E-04	2.0E-04	1.9E-04	1.5E-04	1.4E-04	1.0E-04	8.2E-05	4.8E-05	2.7E-05	0.0E+00
30	41.28	2.2E-04	2.1E-04	2.0E-04	1.8E-04	1.6E-04	1.3E-04	1.1E-04	7.5E-05	5.5E-05	2.4E-05	0.0E+00
31	42.66	2.1E-04	2.1E-04	1.9E-04	1.8E-04	1.5E-04	1.4E-04	1.0E-04	8.2E-05	5.0E-05	2.7E-05	0.0E+00
32	44.04	2.1E-04	2.0E-04	1.9E-04	1.7E-04	1.6E-04	1.3E-04	1.1E-04	7.6E-05	5.5E-05	2.5E-05	0.0E+00
33	45.41	2.1E-04	2.0E-04	1.9E-04	1.8E-04	1.5E-04	1.3E-04	1.0E-04	8.2E-05	5.0E-05	2.7E-05	0.0E+00
34	46.79	2.0E-04	2.0E-04	1.9E-04	1.7E-04	1.5E-04	1.3E-04	1.1E-04	7.6E-05	5.4E-05	2.5E-05	0.0E+00
35	48.16	2.0E-04	2.0E-04	1.8E-04	1.7E-04	1.5E-04	1.3E-04	1.0E-04	8.1E-05	5.1E-05	2.7E-05	0.0E+00
36	49.54	2.0E-04	1.9E-04	1.8E-04	1.7E-04	1.5E-04	1.3E-04	1.1E-04	7.6E-05	5.4E-05	2.5E-05	0.0E+00
37	50.92	1.9E-04	1.9E-04	1.8E-04	1.7E-04	1.5E-04	1.3E-04	1.0E-04	8.0E-05	5.1E-05	2.7E-05	0.0E+00
38	52.29	1.9E-04	1.9E-04	1.8E-04	1.6E-04	1.5E-04	1.2E-04	1.0E-04	7.6E-05	5.3E-05	2.5E-05	0.0E+00
39	53.67	1.9E-04	1.9E-04	1.8E-04	1.6E-04	1.4E-04	1.3E-04	1.0E-04	7.9E-05	5.1E-05	2.7E-05	0.0E+00
40	55.05	1.9E-04	1.8E-04	1.7E-04	1.6E-04	1.4E-04	1.2E-04	1.0E-04	7.6E-05	5.3E-05	2.5E-05	0.0E+00
41	56.42	1.8E-04	1.8E-04	1.7E-04	1.6E-04	1.4E-04	1.2E-04	9.9E-05	7.8E-05	5.0E-05	2.6E-05	0.0E+00
42	57.80	1.8E-04	1.8E-04	1.7E-04	1.6E-04	1.4E-04	1.2E-04	1.0E-04	7.5E-05	5.2E-05	2.5E-05	0.0E+00
43	59.17	1.8E-04	1.8E-04	1.7E-04	1.6E-04	1.4E-04	1.2E-04	9.8E-05	7.6E-05	5.0E-05	2.6E-05	0.0E+00
44	60.55	1.8E-04	1.7E-04	1.7E-04	1.5E-04	1.4E-04	1.2E-04	9.9E-05	7.4E-05	5.1E-05	2.5E-05	0.0E+00
45	61.93	1.7E-04	1.7E-04	1.6E-04	1.5E-04	1.4E-04	1.2E-04	9.6E-05	7.5E-05	4.9E-05	2.5E-05	0.0E+00
46	63.30	1.7E-04	1.7E-04	1.6E-04	1.5E-04	1.4E-04	1.2E-04	9.7E-05	7.3E-05	5.0E-05	2.5E-05	0.0E+00
47	64.68	1.7E-04	1.7E-04	1.6E-04	1.5E-04	1.3E-04	1.2E-04	9.5E-05	7.4E-05	4.9E-05	2.5E-05	0.0E+00
48	66.05	1.7E-04	1.7E-04	1.6E-04	1.5E-04	1.3E-04	1.1E-04	9.5E-05	7.2E-05	4.9E-05	2.4E-05	0.0E+00
49	67.43	1.7E-04	1.6E-04	1.6E-04	1.5E-04	1.3E-04	1.1E-04	9.3E-05	7.2E-05	4.8E-05	2.4E-05	0.0E+00
50	68.81	1.6E-04	1.6E-04	1.5E-04	1.4E-04	1.3E-04	1.1E-04	9.3E-05	7.1E-05	4.8E-05	2.4E-05	0.0E+00
51	70.18	1.6E-04	1.6E-04	1.5E-04	1.4E-04	1.3E-04	1.1E-04	9.1E-05	7.1E-05	4.7E-05	2.4E-05	0.0E+00
52	71.56	1.6E-04	1.6E-04	1.5E-04	1.4E-04	1.3E-04	1.1E-04	9.1E-05	6.9E-05	4.7E-05	2.3E-05	0.0E+00
53	72.94	1.6E-04	1.6E-04	1.5E-04	1.4E-04	1.3E-04	1.1E-04	9.0E-05	6.9E-05	4.6E-05	2.3E-05	0.0E+00
54	74.31	1.6E-04	1.5E-04	1.5E-04	1.4E-04	1.2E-04	1.1E-04	8.9E-05	6.8E-05	4.6E-05	2.3E-05	0.0E+00
55	75.69	1.6E-04	1.5E-04	1.5E-04	1.4E-04	1.2E-04	1.1E-04	8.8E-05	6.8E-05	4.6E-05	2.3E-05	0.0E+00
56	77.06	1.5E-04	1.5E-04	1.4E-04	1.3E-04	1.2E-04	1.1E-04	8.7E-05	6.7E-05	4.5E-05	2.3E-05	0.0E+00
57	78.44	1.5E-04	1.5E-04	1.4E-04	1.3E-04	1.2E-04	1.0E-04	8.6E-05	6.6E-05	4.5E-05	2.2E-05	0.0E+00
58	79.82	1.5E-04	1.5E-04	1.4E-04	1.3E-04	1.2E-04	1.0E-04	8.6E-05	6.5E-05	4.4E-05	2.2E-05	0.0E+00
59	81.19	1.5E-04	1.5E-04	1.4E-04	1.3E-04	1.2E-04	1.0E-04	8.4E-05	6.5E-05	4.4E-05	2.2E-05	0.0E+00
60	82.57	1.5E-04	1.4E-04	1.4E-04	1.3E-04	1.2E-04	1.0E-04	8.4E-05	6.4E-05	4.4E-05	2.2E-05	0.0E+00
61	83.94	1.5E-04	1.4E-04	1.4E-04	1.3E-04	1.1E-04	1.0E-04	8.3E-05	6.4E-05	4.3E-05	2.2E-05	0.0E+00
62	85.32	1.4E-04	1.4E-04	1.4E-04	1.3E-04	1.1E-04	9.9E-05	8.2E-05	6.3E-05	4.3E-05	2.1E-05	0.0E+00
63	86.70	1.4E-04	1.4E-04	1.3E-04	1.2E-04	1.1E-04	9.8E-05	8.1E-05	6.2E-05	4.2E-05	2.1E-05	0.0E+00
64	88.07	1.4E-04	1.4E-04	1.3E-04	1.2E-04	1.1E-04	9.7E-05	8.0E-05	6.2E-05	4.2E-05	2.1E-05	0.0E+00
65	89.45	1.4E-04	1.4E-04	1.3E-04	1.2E-04	1.1E-04	9.6E-05	7.9E-05	6.1E-05	4.1E-05	2.1E-05	0.0E+00
66	90.83	1.4E-04	1.3E-04	1.3E-04	1.2E-04	1.1E-04	9.5E-05	7.8E-05	6.0E-05	4.1E-05	2.0E-05	0.0E+00
67	92.20	1.4E-04	1.3E-04	1.3E-04	1.2E-04	1.1E-04	9.4E-05	7.8E-05	6.0E-05	4.0E-05	2.0E-05	0.0E+00
68	93.58	1.3E-04	1.3E-04	1.3E-04	1.2E-04	1.1E-04	9.3E-05	7.7E-05	5.9E-05	4.0E-05	2.0E-05	0.0E+00
69	94.95	1.3E-04	1.3E-04	1.2E-04	1.2E-04	1.1E-04	9.2E-05	7.6E-05	5.8E-05	3.9E-05	2.0E-05	0.0E+00
70	96.33	1.3E-04	1.3E-04	1.2E-04	1.2E-04	1.0E-04	9.1E-05	7.5E-05	5.8E-05	3.9E-05	1.9E-05	0.0E+00
71	97.71	1.3E-04	1.3E-04	1.2E-04	1.1E-04	1.0E-04	9.0E-05	7.4E-05	5.7E-05	3.9E-05	1.9E-05	0.0E+00
72	99.08	1.3E-04	1.3E-04	1.2E-04	1.1E-04	1.0E-04	8.9E-05	7.3E-05	5.6E-05	3.8E-05	1.9E-05	0.0E+00
73	100.46	1.3E-04	1.2E-04	1.2E-04	1.1E-04	1.0E-04	8.8E-05	7.3E-05	5.6E-05	3.8E-05	1.9E-05	0.0E+00
74	101.83	1.3E-04	1.2E-04	1.2E-04	1.1E-04	1.0E-04	8.7E-05	7.2E-05	5.5E-05	3.7E-05	1.9E-05	0.0E+00
75	103.21	1.2E-04	1.2E-04	1.2E-04	1.1E-04	9.9E-05	8.6E-05	7.1E-05	5.5E-05	3.7E-05	1.8E-05	0.0E+00
76	104.59	1.2E-04	1.2E-04	1.2E-04	1.1E-04	9.8E-05	8.5E-05	7.0E-05	5.4E-05	3.7E-05	1.8E-05	0.0E+00
77	105.96	1.2E-04	1.2E-04	1.1E-04	1.1E-04	9.6E-05	8.4E-05	7.0E-05	5.3E-05	3.6E-05	1.8E-05	0.0E+00
78	107.34	1.2E-04	1.2E-04	1.1E-04	1.1E-04	9.5E-05	8.3E-05	6.9E-05	5.3E-05	3.6E-05	1.8E-05	0.0E+00
79	108.72	1.2E-04	1.2E-04	1.1E-04	1.0E-04	9.4E-05	8.2E-05	6.8E-05	5.2E-05	3.5E-05	1.8E-05	0.0E+00
80	110.09	1.2E-04	1.2E-04	1.1E-04	1.0E-04	9.3E-05	8.1E-05	6.7E-05	5.2E-05	3.5E-05	1.7E-05	0.0E+00
81	111.47	1.2E-04	1.1E-04	1.1E-04	1.0E-04	9.2E-05	8.0E-05	6.7E-05	5.1E-05	3.5E-05	1.7E-05	0.0E+00
82	112.84	1.2E-04	1.1E-04	1.1E-04	1.0E-04	9.1E-05	7.9E-05	6.6E-05	5.1E-05	3.4E-05	1.7E-05	0.0E+00
83	114.22	1.1E-04	1.1E-04	1.1E-04	1.0E-04	9.0E-05	7.9E-05	6.5E-05	5.0E-05	3.4E-05	1.7E-05	0.0E+00

Table 7.10 Continued

84	115.60	1.1E-04	1.1E-04	1.1E-04	9.9E-05	8.9E-05	7.8E-05	6.4E-05	4.9E-05	3.3E-05	1.7E-05	0.0E+00
85	116.97	1.1E-04	1.1E-04	1.0E-04	9.8E-05	8.8E-05	7.7E-05	6.4E-05	4.9E-05	3.3E-05	1.6E-05	0.0E+00
86	118.35	1.1E-04	1.1E-04	1.0E-04	9.7E-05	8.7E-05	7.6E-05	6.3E-05	4.8E-05	3.3E-05	1.6E-05	0.0E+00
87	119.72	1.1E-04	1.1E-04	1.0E-04	9.6E-05	8.6E-05	7.5E-05	6.2E-05	4.8E-05	3.2E-05	1.6E-05	0.0E+00
88	121.10	1.1E-04	1.1E-04	1.0E-04	9.5E-05	8.5E-05	7.4E-05	6.2E-05	4.7E-05	3.2E-05	1.6E-05	0.0E+00
89	122.48	1.1E-04	1.0E-04	1.0E-04	9.3E-05	8.5E-05	7.4E-05	6.1E-05	4.7E-05	3.2E-05	1.6E-05	0.0E+00
90	123.85	1.1E-04	1.0E-04	9.9E-05	9.2E-05	8.4E-05	7.3E-05	6.0E-05	4.6E-05	3.1E-05	1.6E-05	0.0E+00
91	125.23	1.0E-04	1.0E-04	9.8E-05	9.1E-05	8.3E-05	7.2E-05	6.0E-05	4.6E-05	3.1E-05	1.5E-05	0.0E+00
92	126.60	1.0E-04	1.0E-04	9.7E-05	9.0E-05	8.2E-05	7.1E-05	5.9E-05	4.5E-05	3.1E-05	1.5E-05	0.0E+00
93	127.98	1.0E-04	1.0E-04	9.6E-05	8.9E-05	8.1E-05	7.0E-05	5.8E-05	4.5E-05	3.0E-05	1.5E-05	0.0E+00
94	129.36	1.0E-04	9.9E-05	9.5E-05	8.9E-05	8.0E-05	7.0E-05	5.8E-05	4.4E-05	3.0E-05	1.5E-05	0.0E+00
95	130.73	1.0E-04	9.8E-05	9.4E-05	8.8E-05	7.9E-05	6.9E-05	5.7E-05	4.4E-05	3.0E-05	1.5E-05	0.0E+00
96	132.11	9.9E-05	9.7E-05	9.3E-05	8.7E-05	7.8E-05	6.8E-05	5.6E-05	4.3E-05	2.9E-05	1.4E-05	0.0E+00
97	133.49	9.8E-05	9.6E-05	9.2E-05	8.6E-05	7.7E-05	6.7E-05	5.6E-05	4.3E-05	2.9E-05	1.4E-05	0.0E+00
98	134.86	9.7E-05	9.5E-05	9.1E-05	8.5E-05	7.7E-05	6.7E-05	5.5E-05	4.2E-05	2.9E-05	1.4E-05	0.0E+00
99	136.24	9.6E-05	9.4E-05	9.0E-05	8.4E-05	7.6E-05	6.6E-05	5.5E-05	4.2E-05	2.8E-05	1.4E-05	0.0E+00
100	137.61	9.5E-05	9.3E-05	8.9E-05	8.3E-05	7.5E-05	6.5E-05	5.4E-05	4.1E-05	2.8E-05	1.4E-05	0.0E+00
101	138.99	9.4E-05	9.2E-05	8.8E-05	8.2E-05	7.4E-05	6.5E-05	5.3E-05	4.1E-05	2.8E-05	1.4E-05	0.0E+00
102	140.37	9.3E-05	9.1E-05	8.7E-05	8.1E-05	7.3E-05	6.4E-05	5.3E-05	4.1E-05	2.7E-05	1.4E-05	0.0E+00
103	141.74	9.2E-05	9.0E-05	8.6E-05	8.0E-05	7.3E-05	6.3E-05	5.2E-05	4.0E-05	2.7E-05	1.3E-05	0.0E+00
104	143.12	9.1E-05	8.9E-05	8.5E-05	7.9E-05	7.2E-05	6.2E-05	5.2E-05	4.0E-05	2.7E-05	1.3E-05	0.0E+00
105	144.49	9.0E-05	8.8E-05	8.4E-05	7.9E-05	7.1E-05	6.2E-05	5.1E-05	3.9E-05	2.6E-05	1.3E-05	0.0E+00
106	145.87	8.9E-05	8.7E-05	8.3E-05	7.8E-05	7.0E-05	6.1E-05	5.1E-05	3.9E-05	2.6E-05	1.3E-05	0.0E+00
107	147.25	8.8E-05	8.6E-05	8.2E-05	7.7E-05	6.9E-05	6.0E-05	5.0E-05	3.8E-05	2.6E-05	1.3E-05	0.0E+00
108	148.62	8.7E-05	8.5E-05	8.2E-05	7.6E-05	6.9E-05	6.0E-05	4.9E-05	3.8E-05	2.6E-05	1.3E-05	0.0E+00
109	150.00	8.6E-05	8.4E-05	8.1E-05	7.5E-05	6.8E-05	5.9E-05	4.9E-05	3.8E-05	2.5E-05	1.3E-05	0.0E+00
110	151.38	8.5E-05	8.3E-05	8.0E-05	7.4E-05	6.7E-05	5.8E-05	4.8E-05	3.7E-05	2.5E-05	1.2E-05	0.0E+00
111	152.75	8.4E-05	8.2E-05	7.9E-05	7.4E-05	6.6E-05	5.8E-05	4.8E-05	3.7E-05	2.5E-05	1.2E-05	0.0E+00
112	154.13	8.3E-05	8.2E-05	7.8E-05	7.3E-05	6.6E-05	5.7E-05	4.7E-05	3.6E-05	2.5E-05	1.2E-05	0.0E+00
113	155.50	8.2E-05	8.1E-05	7.7E-05	7.2E-05	6.5E-05	5.7E-05	4.7E-05	3.6E-05	2.4E-05	1.2E-05	0.0E+00
114	156.88	8.1E-05	8.0E-05	7.6E-05	7.1E-05	6.4E-05	5.6E-05	4.6E-05	3.6E-05	2.4E-05	1.2E-05	0.0E+00
115	158.26	8.1E-05	7.9E-05	7.6E-05	7.0E-05	6.4E-05	5.5E-05	4.6E-05	3.5E-05	2.4E-05	1.2E-05	0.0E+00
116	159.63	8.0E-05	7.8E-05	7.5E-05	7.0E-05	6.3E-05	5.5E-05	4.5E-05	3.5E-05	2.3E-05	1.2E-05	0.0E+00
117	161.01	7.9E-05	7.7E-05	7.4E-05	6.9E-05	6.2E-05	5.4E-05	4.5E-05	3.4E-05	2.3E-05	1.1E-05	0.0E+00
118	162.38	7.8E-05	7.6E-05	7.3E-05	6.8E-05	6.2E-05	5.4E-05	4.4E-05	3.4E-05	2.3E-05	1.1E-05	0.0E+00
119	163.76	7.7E-05	7.6E-05	7.2E-05	6.7E-05	6.1E-05	5.3E-05	4.4E-05	3.4E-05	2.3E-05	1.1E-05	0.0E+00
120	165.14	7.6E-05	7.5E-05	7.2E-05	6.7E-05	6.0E-05	5.2E-05	4.3E-05	3.3E-05	2.2E-05	1.1E-05	0.0E+00
121	166.51	7.6E-05	7.4E-05	7.1E-05	6.6E-05	6.0E-05	5.2E-05	4.3E-05	3.3E-05	2.2E-05	1.1E-05	0.0E+00
122	167.89	7.5E-05	7.3E-05	7.0E-05	6.5E-05	5.9E-05	5.1E-05	4.2E-05	3.3E-05	2.2E-05	1.1E-05	0.0E+00
123	169.27	7.4E-05	7.2E-05	6.9E-05	6.5E-05	5.8E-05	5.1E-05	4.2E-05	3.2E-05	2.2E-05	1.1E-05	0.0E+00
124	170.64	7.3E-05	7.2E-05	6.9E-05	6.4E-05	5.8E-05	5.0E-05	4.2E-05	3.2E-05	2.1E-05	1.1E-05	0.0E+00
125	172.02	7.2E-05	7.1E-05	6.8E-05	6.3E-05	5.7E-05	5.0E-05	4.1E-05	3.2E-05	2.1E-05	1.0E-05	0.0E+00
126	173.39	7.2E-05	7.0E-05	6.7E-05	6.3E-05	5.6E-05	4.9E-05	4.1E-05	3.1E-05	2.1E-05	1.0E-05	0.0E+00
127	174.77	7.1E-05	6.9E-05	6.6E-05	6.2E-05	5.6E-05	4.9E-05	4.0E-05	3.1E-05	2.1E-05	1.0E-05	0.0E+00
128	176.15	7.0E-05	6.9E-05	6.6E-05	6.1E-05	5.5E-05	4.8E-05	4.0E-05	3.1E-05	2.1E-05	1.0E-05	0.0E+00
129	177.52	6.9E-05	6.8E-05	6.5E-05	6.1E-05	5.5E-05	4.8E-05	3.9E-05	3.0E-05	2.0E-05	1.0E-05	0.0E+00
130	178.90	6.9E-05	6.7E-05	6.4E-05	6.0E-05	5.4E-05	4.7E-05	3.9E-05	3.0E-05	2.0E-05	9.9E-06	0.0E+00
131	180.27	6.8E-05	6.6E-05	6.4E-05	5.9E-05	5.4E-05	4.7E-05	3.8E-05	3.0E-05	2.0E-05	9.8E-06	0.0E+00
132	181.65	6.7E-05	6.6E-05	6.3E-05	5.9E-05	5.3E-05	4.6E-05	3.8E-05	2.9E-05	2.0E-05	9.7E-06	0.0E+00
133	183.03	6.6E-05	6.5E-05	6.2E-05	5.8E-05	5.2E-05	4.6E-05	3.8E-05	2.9E-05	1.9E-05	9.6E-06	0.0E+00
134	184.40	6.6E-05	6.4E-05	6.2E-05	5.7E-05	5.2E-05	4.5E-05	3.7E-05	2.9E-05	1.9E-05	9.5E-06	0.0E+00
135	185.78	6.5E-05	6.4E-05	6.1E-05	5.7E-05	5.1E-05	4.5E-05	3.7E-05	2.8E-05	1.9E-05	9.4E-06	0.0E+00
136	187.15	6.4E-05	6.3E-05	6.0E-05	5.6E-05	5.1E-05	4.4E-05	3.6E-05	2.8E-05	1.9E-05	9.3E-06	0.0E+00
137	188.53	6.4E-05	6.2E-05	6.0E-05	5.6E-05	5.0E-05	4.4E-05	3.6E-05	2.8E-05	1.9E-05	9.2E-06	0.0E+00
138	189.91	6.3E-05	6.2E-05	5.9E-05	5.5E-05	5.0E-05	4.3E-05	3.6E-05	2.7E-05	1.8E-05	9.1E-06	0.0E+00
139	191.28	6.2E-05	6.1E-05	5.8E-05	5.4E-05	4.9E-05	4.3E-05	3.5E-05	2.7E-05	1.8E-05	9.0E-06	0.0E+00
140	192.66	6.2E-05	6.0E-05	5.8E-05	5.4E-05	4.9E-05	4.2E-05	3.5E-05	2.7E-05	1.8E-05	8.9E-06	0.0E+00
141	194.04	6.1E-05	6.0E-05	5.7E-05	5.3E-05	4.8E-05	4.2E-05	3.5E-05	2.6E-05	1.8E-05	8.8E-06	0.0E+00

Table 7.10 Continued

142	195.41	6.0E-05	5.9E-05	5.7E-05	5.3E-05	4.8E-05	4.1E-05	3.4E-05	2.6E-05	1.8E-05	8.7E-06	0.0E+00
143	196.79	6.0E-05	5.8E-05	5.6E-05	5.2E-05	4.7E-05	4.1E-05	3.4E-05	2.6E-05	1.7E-05	8.6E-06	0.0E+00
144	198.16	5.9E-05	5.8E-05	5.5E-05	5.1E-05	4.6E-05	4.0E-05	3.3E-05	2.6E-05	1.7E-05	8.5E-06	0.0E+00
145	199.54	5.8E-05	5.7E-05	5.5E-05	5.1E-05	4.6E-05	4.0E-05	3.3E-05	2.5E-05	1.7E-05	8.4E-06	0.0E+00
146	200.92	5.8E-05	5.7E-05	5.4E-05	5.0E-05	4.6E-05	4.0E-05	3.3E-05	2.5E-05	1.7E-05	8.3E-06	0.0E+00
147	202.29	5.7E-05	5.6E-05	5.4E-05	5.0E-05	4.5E-05	3.9E-05	3.2E-05	2.5E-05	1.7E-05	8.2E-06	0.0E+00
148	203.67	5.7E-05	5.5E-05	5.3E-05	4.9E-05	4.5E-05	3.9E-05	3.2E-05	2.5E-05	1.7E-05	8.1E-06	0.0E+00
149	205.04	5.6E-05	5.5E-05	5.2E-05	4.9E-05	4.4E-05	3.8E-05	3.2E-05	2.4E-05	1.6E-05	8.0E-06	0.0E+00
150	206.42	5.5E-05	5.4E-05	5.2E-05	4.8E-05	4.4E-05	3.8E-05	3.1E-05	2.4E-05	1.6E-05	7.9E-06	0.0E+00
151	207.80	5.5E-05	5.4E-05	5.1E-05	4.8E-05	4.3E-05	3.7E-05	3.1E-05	2.4E-05	1.6E-05	7.9E-06	0.0E+00
152	209.17	5.4E-05	5.3E-05	5.1E-05	4.7E-05	4.3E-05	3.7E-05	3.1E-05	2.4E-05	1.6E-05	7.8E-06	0.0E+00
153	210.55	5.4E-05	5.3E-05	5.0E-05	4.7E-05	4.2E-05	3.7E-05	3.0E-05	2.3E-05	1.6E-05	7.7E-06	0.0E+00
154	211.93	5.3E-05	5.2E-05	5.0E-05	4.6E-05	4.2E-05	3.6E-05	3.0E-05	2.3E-05	1.5E-05	7.6E-06	0.0E+00
155	213.30	5.2E-05	5.1E-05	4.9E-05	4.6E-05	4.1E-05	3.6E-05	3.0E-05	2.3E-05	1.5E-05	7.5E-06	0.0E+00
156	214.68	5.2E-05	5.1E-05	4.9E-05	4.5E-05	4.1E-05	3.6E-05	2.9E-05	2.3E-05	1.5E-05	7.4E-06	0.0E+00
157	216.05	5.1E-05	5.0E-05	4.8E-05	4.5E-05	4.0E-05	3.5E-05	2.9E-05	2.2E-05	1.5E-05	7.4E-06	0.0E+00
158	217.43	5.1E-05	5.0E-05	4.8E-05	4.4E-05	4.0E-05	3.5E-05	2.9E-05	2.2E-05	1.5E-05	7.3E-06	0.0E+00
159	218.81	5.0E-05	4.9E-05	4.7E-05	4.4E-05	4.0E-05	3.4E-05	2.8E-05	2.2E-05	1.5E-05	7.2E-06	0.0E+00
160	220.18	5.0E-05	4.9E-05	4.7E-05	4.3E-05	3.9E-05	3.4E-05	2.8E-05	2.2E-05	1.5E-05	7.1E-06	0.0E+00
161	221.56	4.9E-05	4.8E-05	4.6E-05	4.3E-05	3.9E-05	3.4E-05	2.8E-05	2.1E-05	1.4E-05	7.0E-06	0.0E+00
162	222.93	4.9E-05	4.8E-05	4.6E-05	4.2E-05	3.8E-05	3.3E-05	2.8E-05	2.1E-05	1.4E-05	7.0E-06	0.0E+00
163	224.31	4.8E-05	4.7E-05	4.5E-05	4.2E-05	3.8E-05	3.3E-05	2.7E-05	2.1E-05	1.4E-05	6.9E-06	0.0E+00
164	225.69	4.8E-05	4.7E-05	4.5E-05	4.2E-05	3.7E-05	3.3E-05	2.7E-05	2.1E-05	1.4E-05	6.8E-06	0.0E+00
165	227.06	4.7E-05	4.6E-05	4.4E-05	4.1E-05	3.7E-05	3.2E-05	2.7E-05	2.0E-05	1.4E-05	6.7E-06	0.0E+00
166	228.44	4.7E-05	4.6E-05	4.4E-05	4.1E-05	3.7E-05	3.2E-05	2.6E-05	2.0E-05	1.4E-05	6.7E-06	0.0E+00
167	229.82	4.6E-05	4.5E-05	4.3E-05	4.0E-05	3.6E-05	3.2E-05	2.6E-05	2.0E-05	1.3E-05	6.6E-06	0.0E+00
168	231.19	4.6E-05	4.5E-05	4.3E-05	4.0E-05	3.6E-05	3.1E-05	2.6E-05	2.0E-05	1.3E-05	6.5E-06	0.0E+00
169	232.57	4.5E-05	4.4E-05	4.2E-05	3.9E-05	3.6E-05	3.1E-05	2.6E-05	2.0E-05	1.3E-05	6.4E-06	0.0E+00
170	233.94	4.5E-05	4.4E-05	4.2E-05	3.9E-05	3.5E-05	3.1E-05	2.5E-05	1.9E-05	1.3E-05	6.4E-06	0.0E+00
171	235.32	4.4E-05	4.3E-05	4.1E-05	3.9E-05	3.5E-05	3.0E-05	2.5E-05	1.9E-05	1.3E-05	6.3E-06	0.0E+00
172	236.70	4.4E-05	4.3E-05	4.1E-05	3.8E-05	3.4E-05	3.0E-05	2.5E-05	1.9E-05	1.3E-05	6.2E-06	0.0E+00
173	238.07	4.3E-05	4.2E-05	4.1E-05	3.8E-05	3.4E-05	3.0E-05	2.4E-05	1.9E-05	1.3E-05	6.2E-06	0.0E+00
174	239.45	4.3E-05	4.2E-05	4.0E-05	3.7E-05	3.4E-05	2.9E-05	2.4E-05	1.9E-05	1.2E-05	6.1E-06	0.0E+00
175	240.82	4.2E-05	4.2E-05	4.0E-05	3.7E-05	3.3E-05	2.9E-05	2.4E-05	1.8E-05	1.2E-05	6.0E-06	0.0E+00
176	242.20	4.2E-05	4.1E-05	3.9E-05	3.7E-05	3.3E-05	2.9E-05	2.4E-05	1.8E-05	1.2E-05	6.0E-06	0.0E+00
177	243.58	4.2E-05	4.1E-05	3.9E-05	3.6E-05	3.3E-05	2.8E-05	2.3E-05	1.8E-05	1.2E-05	5.9E-06	0.0E+00
178	244.95	4.1E-05	4.0E-05	3.8E-05	3.6E-05	3.2E-05	2.8E-05	2.3E-05	1.8E-05	1.2E-05	5.8E-06	0.0E+00
179	246.33	4.1E-05	4.0E-05	3.8E-05	3.5E-05	3.2E-05	2.8E-05	2.3E-05	1.8E-05	1.2E-05	5.8E-06	0.0E+00
180	247.71	4.0E-05	3.9E-05	3.8E-05	3.5E-05	3.2E-05	2.7E-05	2.3E-05	1.7E-05	1.2E-05	5.7E-06	0.0E+00
181	249.08	4.0E-05	3.9E-05	3.7E-05	3.5E-05	3.1E-05	2.7E-05	2.2E-05	1.7E-05	1.2E-05	5.7E-06	0.0E+00
182	250.46	3.9E-05	3.9E-05	3.7E-05	3.4E-05	3.1E-05	2.7E-05	2.2E-05	1.7E-05	1.1E-05	5.6E-06	0.0E+00
183	251.83	3.9E-05	3.8E-05	3.6E-05	3.4E-05	3.1E-05	2.7E-05	2.2E-05	1.7E-05	1.1E-05	5.5E-06	0.0E+00
184	253.21	3.9E-05	3.8E-05	3.6E-05	3.4E-05	3.0E-05	2.6E-05	2.2E-05	1.7E-05	1.1E-05	5.5E-06	0.0E+00
185	254.59	3.8E-05	3.7E-05	3.6E-05	3.3E-05	3.0E-05	2.6E-05	2.1E-05	1.6E-05	1.1E-05	5.4E-06	0.0E+00
186	255.96	3.8E-05	3.7E-05	3.5E-05	3.3E-05	3.0E-05	2.6E-05	2.1E-05	1.6E-05	1.1E-05	5.4E-06	0.0E+00
187	257.34	3.7E-05	3.7E-05	3.5E-05	3.2E-05	2.9E-05	2.5E-05	2.1E-05	1.6E-05	1.1E-05	5.3E-06	0.0E+00
188	258.71	3.7E-05	3.6E-05	3.5E-05	3.2E-05	2.9E-05	2.5E-05	2.1E-05	1.6E-05	1.1E-05	5.2E-06	0.0E+00
189	260.09	3.7E-05	3.6E-05	3.4E-05	3.2E-05	2.9E-05	2.5E-05	2.1E-05	1.6E-05	1.1E-05	5.2E-06	0.0E+00
190	261.47	3.6E-05	3.5E-05	3.4E-05	3.1E-05	2.8E-05	2.5E-05	2.0E-05	1.6E-05	1.0E-05	5.1E-06	0.0E+00
191	262.84	3.6E-05	3.5E-05	3.3E-05	3.1E-05	2.8E-05	2.4E-05	2.0E-05	1.5E-05	1.0E-05	5.1E-06	0.0E+00
192	264.22	3.5E-05	3.5E-05	3.3E-05	3.1E-05	2.8E-05	2.4E-05	2.0E-05	1.5E-05	1.0E-05	5.0E-06	0.0E+00
193	265.59	3.5E-05	3.4E-05	3.3E-05	3.0E-05	2.7E-05	2.4E-05	2.0E-05	1.5E-05	1.0E-05	5.0E-06	0.0E+00
194	266.97	3.5E-05	3.4E-05	3.2E-05	3.0E-05	2.7E-05	2.4E-05	2.0E-05	1.5E-05	1.0E-05	4.9E-06	0.0E+00
195	268.35	3.4E-05	3.4E-05	3.2E-05	3.0E-05	2.7E-05	2.3E-05	1.9E-05	1.5E-05	9.9E-06	4.9E-06	0.0E+00
196	269.72	3.4E-05	3.3E-05	3.2E-05	3.0E-05	2.7E-05	2.3E-05	1.9E-05	1.5E-05	9.8E-06	4.8E-06	0.0E+00
197	271.10	3.4E-05	3.3E-05	3.1E-05	2.9E-05	2.6E-05	2.3E-05	1.9E-05	1.4E-05	9.7E-06	4.8E-06	0.0E+00
198	272.48	3.3E-05	3.3E-05	3.1E-05	2.9E-05	2.6E-05	2.3E-05	1.9E-05	1.4E-05	9.6E-06	4.7E-06	0.0E+00
199	273.85	3.3E-05	3.2E-05	3.1E-05	2.9E-05	2.6E-05	2.2E-05	1.9E-05	1.4E-05	9.5E-06	4.7E-06	0.0E+00

Table 7.10 Continued

200	275.23	3.3E-05	3.2E-05	3.0E-05	2.8E-05	2.6E-05	2.2E-05	1.8E-05	1.4E-05	9.4E-06	4.6E-06	0.0E+00
201	276.60	3.2E-05	3.1E-05	3.0E-05	2.8E-05	2.5E-05	2.2E-05	1.8E-05	1.4E-05	9.3E-06	4.6E-06	0.0E+00
202	277.98	3.2E-05	3.1E-05	3.0E-05	2.8E-05	2.5E-05	2.2E-05	1.8E-05	1.4E-05	9.2E-06	4.5E-06	0.0E+00
203	279.36	3.2E-05	3.1E-05	2.9E-05	2.7E-05	2.5E-05	2.1E-05	1.8E-05	1.4E-05	9.1E-06	4.5E-06	0.0E+00
204	280.73	3.1E-05	3.1E-05	2.9E-05	2.7E-05	2.4E-05	2.1E-05	1.8E-05	1.3E-05	9.0E-06	4.4E-06	0.0E+00
205	282.11	3.1E-05	3.0E-05	2.9E-05	2.7E-05	2.4E-05	2.1E-05	1.7E-05	1.3E-05	8.9E-06	4.4E-06	0.0E+00
206	283.48	3.1E-05	3.0E-05	2.9E-05	2.7E-05	2.4E-05	2.1E-05	1.7E-05	1.3E-05	8.8E-06	4.3E-06	0.0E+00
207	284.86	3.0E-05	3.0E-05	2.8E-05	2.6E-05	2.4E-05	2.1E-05	1.7E-05	1.3E-05	8.7E-06	4.3E-06	0.0E+00
208	286.24	3.0E-05	2.9E-05	2.8E-05	2.6E-05	2.3E-05	2.0E-05	1.7E-05	1.3E-05	8.7E-06	4.2E-06	0.0E+00
209	287.61	3.0E-05	2.9E-05	2.8E-05	2.6E-05	2.3E-05	2.0E-05	1.7E-05	1.3E-05	8.6E-06	4.2E-06	0.0E+00
210	288.99	2.9E-05	2.9E-05	2.7E-05	2.5E-05	2.3E-05	2.0E-05	1.6E-05	1.3E-05	8.5E-06	4.1E-06	0.0E+00
211	290.37	2.9E-05	2.8E-05	2.7E-05	2.5E-05	2.3E-05	2.0E-05	1.6E-05	1.2E-05	8.4E-06	4.1E-06	0.0E+00
212	291.74	2.9E-05	2.8E-05	2.7E-05	2.5E-05	2.2E-05	2.0E-05	1.6E-05	1.2E-05	8.3E-06	4.0E-06	0.0E+00
213	293.12	2.8E-05	2.8E-05	2.6E-05	2.5E-05	2.2E-05	1.9E-05	1.6E-05	1.2E-05	8.2E-06	4.0E-06	0.0E+00
214	294.49	2.8E-05	2.7E-05	2.6E-05	2.4E-05	2.2E-05	1.9E-05	1.6E-05	1.2E-05	8.1E-06	4.0E-06	0.0E+00
215	295.87	2.8E-05	2.7E-05	2.6E-05	2.4E-05	2.2E-05	1.9E-05	1.6E-05	1.2E-05	8.0E-06	3.9E-06	0.0E+00
216	297.25	2.7E-05	2.7E-05	2.6E-05	2.4E-05	2.2E-05	1.9E-05	1.5E-05	1.2E-05	7.9E-06	3.9E-06	0.0E+00
217	298.62	2.7E-05	2.7E-05	2.5E-05	2.4E-05	2.1E-05	1.8E-05	1.5E-05	1.2E-05	7.9E-06	3.8E-06	0.0E+00
218	300.00	2.7E-05	2.6E-05	2.5E-05	2.3E-05	2.1E-05	1.8E-05	1.5E-05	1.2E-05	7.8E-06	3.8E-06	0.0E+00
219	301.37	2.7E-05	2.6E-05	2.5E-05	2.3E-05	2.1E-05	1.8E-05	1.5E-05	1.1E-05	7.7E-06	3.8E-06	0.0E+00
220	302.75	2.6E-05	2.6E-05	2.5E-05	2.3E-05	2.1E-05	1.8E-05	1.5E-05	1.1E-05	7.6E-06	3.7E-06	0.0E+00
221	304.13	2.6E-05	2.5E-05	2.4E-05	2.3E-05	2.0E-05	1.8E-05	1.5E-05	1.1E-05	7.5E-06	3.7E-06	0.0E+00
222	305.50	2.6E-05	2.5E-05	2.4E-05	2.2E-05	2.0E-05	1.8E-05	1.4E-05	1.1E-05	7.4E-06	3.6E-06	0.0E+00
223	306.88	2.5E-05	2.5E-05	2.4E-05	2.2E-05	2.0E-05	1.7E-05	1.4E-05	1.1E-05	7.4E-06	3.6E-06	0.0E+00
224	308.26	2.5E-05	2.5E-05	2.4E-05	2.2E-05	2.0E-05	1.7E-05	1.4E-05	1.1E-05	7.3E-06	3.6E-06	0.0E+00
225	309.63	2.5E-05	2.4E-05	2.3E-05	2.2E-05	2.0E-05	1.7E-05	1.4E-05	1.1E-05	7.2E-06	3.5E-06	0.0E+00
226	311.01	2.5E-05	2.4E-05	2.3E-05	2.1E-05	1.9E-05	1.7E-05	1.4E-05	1.1E-05	7.1E-06	3.5E-06	0.0E+00
227	312.38	2.4E-05	2.4E-05	2.3E-05	2.1E-05	1.9E-05	1.7E-05	1.4E-05	1.1E-05	7.1E-06	3.4E-06	0.0E+00
228	313.76	2.4E-05	2.4E-05	2.3E-05	2.1E-05	1.9E-05	1.6E-05	1.4E-05	1.0E-05	7.0E-06	3.4E-06	0.0E+00
229	315.14	2.4E-05	2.3E-05	2.2E-05	2.1E-05	1.9E-05	1.6E-05	1.3E-05	1.0E-05	6.9E-06	3.4E-06	0.0E+00
230	316.51	2.4E-05	2.3E-05	2.2E-05	2.1E-05	1.9E-05	1.6E-05	1.3E-05	1.0E-05	6.8E-06	3.3E-06	0.0E+00
231	317.89	2.3E-05	2.3E-05	2.2E-05	2.0E-05	1.8E-05	1.6E-05	1.3E-05	1.0E-05	6.8E-06	3.3E-06	0.0E+00
232	319.26	2.3E-05	2.3E-05	2.2E-05	2.0E-05	1.8E-05	1.6E-05	1.3E-05	1.0E-05	6.7E-06	3.3E-06	0.0E+00
233	320.64	2.3E-05	2.2E-05	2.1E-05	2.0E-05	1.8E-05	1.6E-05	1.3E-05	9.9E-06	6.6E-06	3.2E-06	0.0E+00
234	322.02	2.3E-05	2.2E-05	2.1E-05	2.0E-05	1.8E-05	1.5E-05	1.3E-05	9.8E-06	6.6E-06	3.2E-06	0.0E+00
235	323.39	2.2E-05	2.2E-05	2.1E-05	1.9E-05	1.8E-05	1.5E-05	1.3E-05	9.7E-06	6.5E-06	3.2E-06	0.0E+00
236	324.77	2.2E-05	2.2E-05	2.1E-05	1.9E-05	1.7E-05	1.5E-05	1.2E-05	9.6E-06	6.4E-06	3.1E-06	0.0E+00
237	326.15	2.2E-05	2.1E-05	2.1E-05	1.9E-05	1.7E-05	1.5E-05	1.2E-05	9.5E-06	6.3E-06	3.1E-06	0.0E+00
238	327.52	2.2E-05	2.1E-05	2.0E-05	1.9E-05	1.7E-05	1.5E-05	1.2E-05	9.4E-06	6.3E-06	3.1E-06	0.0E+00
239	328.90	2.2E-05	2.1E-05	2.0E-05	1.9E-05	1.7E-05	1.5E-05	1.2E-05	9.3E-06	6.2E-06	3.0E-06	0.0E+00
240	330.27	2.1E-05	2.1E-05	2.0E-05	1.8E-05	1.7E-05	1.4E-05	1.2E-05	9.2E-06	6.1E-06	3.0E-06	0.0E+00
241	331.65	2.1E-05	2.1E-05	2.0E-05	1.8E-05	1.6E-05	1.4E-05	1.2E-05	9.1E-06	6.1E-06	3.0E-06	0.0E+00
242	333.03	2.1E-05	2.0E-05	1.9E-05	1.8E-05	1.6E-05	1.4E-05	1.2E-05	9.0E-06	6.0E-06	2.9E-06	0.0E+00
243	334.40	2.1E-05	2.0E-05	1.9E-05	1.8E-05	1.6E-05	1.4E-05	1.2E-05	8.9E-06	6.0E-06	2.9E-06	0.0E+00
244	335.78	2.0E-05	2.0E-05	1.9E-05	1.8E-05	1.6E-05	1.4E-05	1.1E-05	8.8E-06	5.9E-06	2.9E-06	0.0E+00
245	337.15	2.0E-05	2.0E-05	1.9E-05	1.8E-05	1.6E-05	1.4E-05	1.1E-05	8.7E-06	5.8E-06	2.8E-06	0.0E+00
246	338.53	2.0E-05	2.0E-05	1.9E-05	1.7E-05	1.6E-05	1.4E-05	1.1E-05	8.6E-06	5.8E-06	2.8E-06	0.0E+00
247	339.91	2.0E-05	1.9E-05	1.8E-05	1.7E-05	1.5E-05	1.3E-05	1.1E-05	8.5E-06	5.7E-06	2.8E-06	0.0E+00
248	341.28	2.0E-05	1.9E-05	1.8E-05	1.7E-05	1.5E-05	1.3E-05	1.1E-05	8.4E-06	5.6E-06	2.8E-06	0.0E+00
249	342.66	1.9E-05	1.9E-05	1.8E-05	1.7E-05	1.5E-05	1.3E-05	1.1E-05	8.3E-06	5.6E-06	2.7E-06	0.0E+00
250	344.03	1.9E-05	1.9E-05	1.8E-05	1.7E-05	1.5E-05	1.3E-05	1.1E-05	8.2E-06	5.5E-06	2.7E-06	0.0E+00
251	345.41	1.9E-05	1.9E-05	1.8E-05	1.6E-05	1.5E-05	1.3E-05	1.1E-05	8.1E-06	5.5E-06	2.7E-06	0.0E+00
252	346.79	1.9E-05	1.8E-05	1.8E-05	1.6E-05	1.5E-05	1.3E-05	1.1E-05	8.1E-06	5.4E-06	2.6E-06	0.0E+00
253	348.16	1.9E-05	1.8E-05	1.7E-05	1.6E-05	1.5E-05	1.3E-05	1.0E-05	8.0E-06	5.4E-06	2.6E-06	0.0E+00
254	349.54	1.8E-05	1.8E-05	1.7E-05	1.6E-05	1.4E-05	1.2E-05	1.0E-05	7.9E-06	5.3E-06	2.6E-06	0.0E+00

Appendix 7.12: Model Output for *Salmonella* Concentration Profile

Excel formula used to calculate the *Salmonella* concentration at t = 1.03 s and x = 0.005 m. (i.e. cell D5):

D5 =Concentration(D$3,dx,$A5,'*Salmonella*

Location'!$C$5:$IV$258,$C$5:$C$258)*(1/MASTER!$B$9)

Table 7.11: Predicted *Salmonella* concentration profile generated by Excel, given the input variables listed in Table 4.1.

Salmonella Concentration Profile												
	i =>	0	1	2	3	4	5	6	7	8	9	10
j		0	0.005	0.01	0.015	0.02	0.025	0.03	0.035	0.04	0.045	0.05
0	0	# Entering cells/cm^3										
1	1.03	18139	16196	0	0	0	0	0	0	0	0	0
2	2.06	18139	32392	0	0	0	0	0	0	0	0	0
3	3.10	13775	44690	0	0	0	0	0	0	0	0	0
4	4.13	13612	56844	0	0	0	0	0	0	0	0	0
5	5.16	11524	67134	0	0	0	0	0	0	0	0	0
6	6.19	11351	77268	0	0	0	0	0	0	0	0	0
7	7.22	10101	70092	16196	0	0	0	0	0	0	0	0
8	8.26	9938	78965	16196	0	0	0	0	0	0	0	0
9	9.29	9099	70893	32392	0	0	0	0	0	0	0	0
10	10.32	8949	78884	32392	0	0	0	0	0	0	0	0
11	11.35	8345	74036	44690	0	0	0	0	0	0	0	0
12	12.39	8208	81364	44690	0	0	0	0	0	0	0	0
13	13.42	7750	76131	56844	0	0	0	0	0	0	0	0
14	14.45	7626	72650	67134	0	0	0	0	0	0	0	0
15	15.48	7267	79138	67134	0	0	0	0	0	0	0	0
16	16.51	7152	75389	77268	0	0	0	0	0	0	0	0
17	17.55	6863	72498	86287	0	0	0	0	0	0	0	0
18	18.58	6758	78532	86287	0	0	0	0	0	0	0	0
19	19.61	6519	75479	95161	0	0	0	0	0	0	0	0
20	20.64	6423	73090	87089	16196	0	0	0	0	0	0	0
21	21.67	6222	78645	87089	16196	0	0	0	0	0	0	0
22	22.71	6133	76131	95080	16196	0	0	0	0	0	0	0
23	23.74	5962	74003	86335	32392	0	0	0	0	0	0	0
24	24.77	5879	79253	86335	32392	0	0	0	0	0	0	0
25	25.80	5732	77042	81364	44690	0	0	0	0	0	0	0
26	26.83	5654	75170	88284	44690	0	0	0	0	0	0	0
27	27.87	5525	73295	82939	56844	0	0	0	0	0	0	0
28	28.90	5453	78164	82939	56844	0	0	0	0	0	0	0
29	29.93	5339	76442	89427	56844	0	0	0	0	0	0	0
30	30.96	5270	74762	85524	67134	0	0	0	0	0	0	0
31	32.00	5168	79376	85524	67134	0	0	0	0	0	0	0
32	33.03	5104	77806	81517	77268	0	0	0	0	0	0	0
33	34.06	5012	76247	87551	77268	0	0	0	0	0	0	0

Table 7.11 Continued

34	35.09	4951	74847	84352	86287	0	0	0	0	0	0	0
35	36.12	4867	79192	84352	86287	0	0	0	0	0	0	0
36	37.16	4809	77751	81214	95161	0	0	0	0	0	0	0
37	38.19	4732	76421	78645	103285	0	0	0	0	0	0	0
38	39.22	4676	75120	84121	103285	0	0	0	0	0	0	0
39	40.25	4606	73909	81454	95080	16196	0	0	0	0	0	0
40	41.28	4552	77973	81454	95080	16196	0	0	0	0	0	0
41	42.32	4486	76729	79253	102530	16196	0	0	0	0	0	0
42	43.35	4434	75570	84370	86335	32392	0	0	0	0	0	0
43	44.38	4373	74426	82090	93663	32392	0	0	0	0	0	0
44	45.41	4322	78285	82090	93663	32392	0	0	0	0	0	0
45	46.44	4265	77160	80103	88284	44690	0	0	0	0	0	0
46	47.48	4216	76056	84972	88284	44690	0	0	0	0	0	0
47	48.51	4162	75005	82930	95093	44690	0	0	0	0	0	0
48	49.54	4115	78679	76442	89427	56844	0	0	0	0	0	0
49	50.57	4063	77601	81148	89427	56844	0	0	0	0	0	0
50	51.61	4017	76573	79376	95813	56844	0	0	0	0	0	0
51	52.64	3968	75559	83934	85524	67134	0	0	0	0	0	0
52	53.67	3923	74587	82281	91651	67134	0	0	0	0	0	0
53	54.70	3876	78048	82281	91651	67134	0	0	0	0	0	0
54	55.73	3833	77050	80667	87551	77268	0	0	0	0	0	0
55	56.77	3788	76086	79192	93372	77268	0	0	0	0	0	0
56	57.80	3746	75137	83486	84352	86287	0	0	0	0	0	0
57	58.83	3702	78442	77751	90087	86287	0	0	0	0	0	0
58	59.86	3661	77486	81976	90087	86287	0	0	0	0	0	0
59	60.89	3619	76542	80596	86770	95161	0	0	0	0	0	0
60	61.93	3579	75625	84708	86770	95161	0	0	0	0	0	0
61	62.96	3538	78784	79232	84121	103285	0	0	0	0	0	0
62	63.99	3499	77844	77973	89445	103285	0	0	0	0	0	0
63	65.02	3460	76927	81978	89445	103285	0	0	0	0	0	0
64	66.05	3422	76023	80687	86704	111275	0	0	0	0	0	0
65	67.09	3383	75140	84592	86704	95080	16196	0	0	0	0	0
66	68.12	3346	78127	79474	84370	102530	16196	0	0	0	0	0
67	69.15	3309	77222	78285	89419	102530	16196	0	0	0	0	0
68	70.18	3273	76336	82093	89419	102530	16196	0	0	0	0	0
69	71.22	3236	75461	80925	87024	109859	16196	0	0	0	0	0
70	72.25	3201	78320	80925	87024	93663	32392	0	0	0	0	0
71	73.28	3166	77430	79772	84972	100583	32392	0	0	0	0	0
72	74.31	3131	76552	83446	84972	100583	32392	0	0	0	0	0
73	75.34	3097	75690	82307	82930	107392	32392	0	0	0	0	0
74	76.38	3063	78425	77601	87636	95093	44690	0	0	0	0	0
75	77.41	3030	77543	81188	87636	95093	44690	0	0	0	0	0
76	78.44	2997	76676	80116	85763	101581	44690	0	0	0	0	0
77	79.47	2964	75819	83619	85763	101581	44690	0	0	0	0	0
78	80.50	2932	78437	79062	83934	95813	56844	0	0	0	0	0
79	81.54	2900	77565	82523	83934	95813	56844	0	0	0	0	0
80	82.57	2869	76704	81470	88409	95813	56844	0	0	0	0	0
81	83.60	2837	75856	80432	86701	101941	56844	0	0	0	0	0
82	84.63	2807	78362	80432	86701	91651	67134	0	0	0	0	0
83	85.66	2776	77497	79430	85013	97685	67134	0	0	0	0	0
84	86.70	2746	76643	82736	85013	97685	67134	0	0	0	0	0
85	87.73	2717	75800	81711	83486	103506	67134	0	0	0	0	0
86	88.76	2687	78200	81711	83486	93372	77268	0	0	0	0	0
87	89.79	2658	77342	80717	87711	93372	77268	0	0	0	0	0
88	90.83	2630	76495	79737	86151	99106	77268	0	0	0	0	0
89	91.86	2601	78817	79737	86151	99106	77268	0	0	0	0	0

Table 7.11 Continued

90	92.89	2573	77955	78784	84708	95643	86287	0	0	0	0	0
91	93.92	2545	77104	81908	84708	95643	86287	0	0	0	0	0
92	94.95	2518	76263	80933	88772	95643	86287	0	0	0	0	0
93	95.99	2491	78487	80933	83296	92246	95161	0	0	0	0	0
94	97.02	2464	77632	79982	87301	92246	95161	0	0	0	0	0
95	98.05	2438	76788	83003	81978	97569	95161	0	0	0	0	0
96	99.08	2411	75953	82032	85937	97569	95161	0	0	0	0	0
97	100.11	2385	78083	82032	85937	89445	103285	0	0	0	0	0
98	101.15	2360	77236	81082	84592	94694	103285	0	0	0	0	0
99	102.18	2334	76398	80144	88451	94694	103285	0	0	0	0	0
100	103.21	2309	78460	80144	83334	99812	103285	0	0	0	0	0
101	104.24	2285	77610	79226	87142	91821	111275	0	0	0	0	0
102	105.27	2260	76769	82084	87142	91821	111275	0	0	0	0	0
103	106.31	2236	78766	78320	85858	96870	111275	0	0	0	0	0
104	107.34	2212	77914	81146	85858	96870	111275	0	0	0	0	0
105	108.37	2188	77072	80226	84641	94352	118726	0	0	0	0	0
106	109.40	2165	76239	82991	84641	94352	118726	0	0	0	0	0
107	110.44	2141	78151	79317	88314	94352	118726	0	0	0	0	0
108	111.47	2118	77308	82052	83446	91892	126055	0	0	0	0	0
109	112.50	2096	76474	81130	87074	91892	126055	0	0	0	0	0
110	113.53	2073	78325	81130	82307	96659	109859	16196	0	0	0	0
111	114.56	2051	77481	80219	85894	96659	109859	16196	0	0	0	0
112	115.60	2029	76646	82865	85894	89739	116779	16196	0	0	0	0
113	116.63	2007	78438	79322	84731	94444	116779	16196	0	0	0	0
114	117.66	1986	77594	81940	84731	94444	116779	16196	0	0	0	0
115	118.69	1965	76759	81026	88234	94444	116779	16196	0	0	0	0
116	119.72	1944	78494	81026	83619	92251	123588	16196	0	0	0	0
117	120.76	1923	77650	80127	87080	92251	123588	16196	0	0	0	0
118	121.79	1902	76815	82660	82523	96808	107392	32392	0	0	0	0
119	122.82	1882	78495	79238	85945	96808	107392	32392	0	0	0	0
120	123.85	1862	77652	81744	85945	90320	113880	32392	0	0	0	0
121	124.88	1842	76818	80841	84852	94795	113880	32392	0	0	0	0
122	125.92	1822	78445	80841	84852	94795	113880	32392	0	0	0	0
123	126.95	1803	77603	79949	88196	94795	113880	32392	0	0	0	0
124	127.98	1784	76770	82374	83776	92829	107967	44690	0	0	0	0
125	129.01	1765	78346	79069	87081	92829	107967	44690	0	0	0	0
126	130.05	1746	77505	81468	87081	92829	107967	44690	0	0	0	0
127	131.08	1727	76674	80573	86004	91047	114095	44690	0	0	0	0
128	132.11	1709	78200	80573	86004	91047	114095	44690	0	0	0	0
129	133.14	1691	77361	79690	84942	95341	114095	44690	0	0	0	0
130	134.17	1673	78855	79690	84942	95341	114095	44690	0	0	0	0
131	135.21	1655	78010	82012	84942	95341	101941	56844	0	0	0	0
132	136.24	1637	77174	81114	83912	93532	107975	56844	0	0	0	0
133	137.27	1620	78620	81114	83912	93532	107975	56844	0	0	0	0
134	138.30	1603	77779	80228	87071	93532	107975	56844	0	0	0	0
135	139.33	1585	76946	82476	82896	97707	107975	56844	0	0	0	0
136	140.37	1569	78347	79352	86020	91886	113796	56844	0	0	0	0
137	141.40	1552	77508	81576	86020	91886	113796	56844	0	0	0	0
138	142.43	1535	78879	78487	84997	95998	103506	67134	0	0	0	0
139	143.46	1519	78035	80687	84997	95998	103506	67134	0	0	0	0
140	144.49	1503	77201	82864	84997	90264	109241	67134	0	0	0	0
141	145.53	1487	78528	79809	83988	94328	109241	67134	0	0	0	0
142	146.56	1471	77689	81962	83988	94328	109241	67134	0	0	0	0
143	147.59	1455	76858	81071	87009	94328	109241	67134	0	0	0	0
144	148.62	1440	78144	81071	83003	92777	114796	67134	0	0	0	0
145	149.66	1425	77309	80190	85991	92777	104662	77268	0	0	0	0

Table 7.11 Continued

146	150.69	1409	78568	80190	85991	92777	104662	77268	0	0	0	0
147	151.72	1395	77729	82274	85991	92777	104662	77268	0	0	0	0
148	152.75	1380	76899	81382	84986	96736	104662	77268	0	0	0	0
149	153.78	1365	78117	81382	84986	91260	110138	77268	0	0	0	0
150	154.82	1351	77283	80499	87908	91260	110138	77268	0	0	0	0
151	155.85	1336	78476	80499	84004	95165	110138	77268	0	0	0	0
152	156.88	1322	77639	82517	84004	95165	110138	77268	0	0	0	0
153	157.91	1308	78807	79628	86893	89841	106442	86287	0	0	0	0
154	158.94	1294	77966	81624	83034	93701	106442	86287	0	0	0	0
155	159.98	1280	77134	80740	85892	93701	106442	86287	0	0	0	0
156	161.01	1267	78265	80740	85892	93701	106442	86287	0	0	0	0
157	162.04	1253	77431	82694	85892	93701	106442	86287	0	0	0	0
158	163.07	1240	78538	79867	84911	92259	111692	86287	0	0	0	0
159	164.10	1227	77701	81800	84911	92259	111692	86287	0	0	0	0
160	165.14	1214	78785	79004	87707	92259	102818	95161	0	0	0	0
161	166.17	1201	77945	80916	83942	96024	102818	95161	0	0	0	0
162	167.20	1188	77114	82808	83942	96024	102818	95161	0	0	0	0
163	168.23	1176	78164	80043	86707	90906	107936	95161	0	0	0	0
164	169.27	1163	77331	81914	86707	90906	107936	95161	0	0	0	0
165	170.30	1151	78359	81914	82991	94622	107936	95161	0	0	0	0
166	171.33	1139	77524	81030	85726	94622	107936	95161	0	0	0	0
167	172.36	1127	78530	81030	85726	94622	107936	95161	0	0	0	0
168	173.39	1115	77694	80156	88431	89574	112985	95161	0	0	0	0
169	174.43	1103	78679	80156	84758	93248	104860	103285	0	0	0	0
170	175.46	1091	77841	81968	84758	93248	104860	103285	0	0	0	0
171	176.49	1080	78805	79292	87433	93248	104860	103285	0	0	0	0
172	177.52	1068	77967	81085	83805	96875	104860	103285	0	0	0	0
173	178.55	1057	78910	81085	83805	91942	109793	103285	0	0	0	0
174	179.59	1046	78071	80211	86452	91942	109793	103285	0	0	0	0
175	180.62	1035	77240	81966	86452	91942	109793	103285	0	0	0	0
176	181.65	1024	78154	81966	82865	95529	101803	111275	0	0	0	0
177	182.68	1013	77323	81083	85483	95529	101803	111275	0	0	0	0
178	183.71	1002	78218	81083	85483	90660	106672	111275	0	0	0	0
179	184.75	992	77386	82800	85483	90660	106672	111275	0	0	0	0
180	185.78	981	78262	80211	84530	94203	106672	111275	0	0	0	0
181	186.81	971	77430	81910	84530	94203	106672	111275	0	0	0	0
182	187.84	960	78288	81910	84530	94203	106672	111275	0	0	0	0
183	188.88	950	77456	81029	87091	94203	106672	111275	0	0	0	0
184	189.91	940	78295	81029	87091	89437	111438	111275	0	0	0	0
185	190.94	930	77463	82691	83588	92940	103987	118726	0	0	0	0
186	191.97	920	78285	80158	86121	92940	103987	118726	0	0	0	0
187	193.00	911	77453	81803	86121	92940	103987	118726	0	0	0	0
188	194.04	901	78258	81803	86121	92940	103987	118726	0	0	0	0
189	195.07	892	77427	80924	85166	96401	103987	118726	0	0	0	0
190	196.10	882	78214	80924	85166	91695	108693	118726	0	0	0	0
191	197.13	873	77384	82534	85166	91695	108693	118726	0	0	0	0
192	198.16	864	78155	80055	87645	91695	108693	118726	0	0	0	0
193	199.20	854	78918	80055	84223	95117	108693	118726	0	0	0	0
194	200.23	845	78080	81647	84223	95117	101365	126055	0	0	0	0
195	201.26	836	78827	79195	86675	95117	101365	126055	0	0	0	0
196	202.29	828	77990	80771	86675	90502	105979	126055	0	0	0	0
197	203.32	819	78721	80771	86675	90502	105979	126055	0	0	0	0
198	204.36	810	77886	82330	83293	93884	105979	126055	0	0	0	0
199	205.39	802	78601	79904	85719	93884	105979	126055	0	0	0	0
200	206.42	793	77767	81447	85719	93884	105979	126055	0	0	0	0
201	207.45	785	78468	81447	85719	93884	105979	126055	0	0	0	0

Table 7.11 Continued

202	208.49	777	77636	80573	88118	93884	105979	126055	0	0	0	0
203	209.52	768	78322	80573	84774	92672	110536	126055	0	0	0	0
204	210.55	760	77491	82083	84774	92672	103616	132975	0	0	0	0
205	211.58	752	78163	82083	84774	92672	103616	132975	0	0	0	0
206	212.61	744	78827	79709	87147	92672	103616	132975	0	0	0	0
207	213.65	736	77992	81203	87147	92672	103616	132975	0	0	0	0
208	214.68	729	78642	81203	83842	95977	103616	132975	0	0	0	0
209	215.71	721	77808	80332	86190	91502	108091	132975	0	0	0	0
210	216.74	713	78445	80332	86190	91502	108091	132975	0	0	0	0
211	217.77	706	77614	81794	86190	91502	108091	132975	0	0	0	0
212	218.81	698	78237	81794	86190	91502	108091	132975	0	0	0	0
213	219.84	691	78855	79472	85243	94770	108091	132975	0	0	0	0
214	220.87	684	78019	80918	85243	94770	108091	132975	0	0	0	0
215	221.90	677	78623	80918	85243	94770	101283	139783	0	0	0	0
216	222.93	669	77790	82349	85243	94770	101283	139783	0	0	0	0
217	223.97	662	78381	80051	87541	90350	105703	139783	0	0	0	0
218	225.00	655	78966	80051	87541	90350	105703	139783	0	0	0	0
219	226.03	648	78130	81467	84310	93581	105703	139783	0	0	0	0
220	227.06	642	78703	81467	84310	93581	105703	139783	0	0	0	0
221	228.10	635	77869	80595	86582	93581	105703	139783	0	0	0	0
222	229.13	628	78430	80595	86582	93581	105703	139783	0	0	0	0
223	230.16	622	77599	81980	86582	93581	105703	139783	0	0	0	0
224	231.19	615	78149	81980	83387	96776	105703	139783	0	0	0	0
225	232.22	609	78692	79732	85635	92431	110049	139783	0	0	0	0
226	233.26	602	77859	81103	85635	92431	103561	146271	0	0	0	0
227	234.29	596	78391	81103	85635	92431	103561	130076	16196	0	0	0
228	235.32	590	78917	81103	85635	92431	103561	130076	16196	0	0	0
229	236.35	583	78082	80235	87859	92431	103561	130076	16196	0	0	0
230	237.38	577	78597	80235	84700	95590	103561	130076	16196	0	0	0
231	238.42	571	77765	81577	84700	95590	103561	130076	16196	0	0	0
232	239.45	565	78269	81577	84700	95590	103561	130076	16196	0	0	0
233	240.48	559	78769	81577	84700	91296	107854	130076	16196	0	0	0
234	241.51	553	77935	80705	86900	91296	107854	130076	16196	0	0	0
235	242.54	547	78424	80705	86900	91296	107854	130076	16196	0	0	0
236	243.58	542	78907	80705	86900	91296	107854	130076	16196	0	0	0
237	244.61	536	78073	82018	83776	94420	107854	130076	16196	0	0	0
238	245.64	530	78546	79842	85952	94420	107854	130076	16196	0	0	0
239	246.67	525	77715	81141	85952	94420	101468	136462	16196	0	0	0
240	247.71	519	78179	81141	85952	94420	101468	136462	16196	0	0	0
241	248.74	514	78637	81141	85952	94420	101468	136462	16196	0	0	0
242	249.77	508	77805	82427	85952	90195	105693	136462	16196	0	0	0
243	250.80	503	78255	80274	88105	90195	105693	136462	16196	0	0	0
244	251.83	498	78699	80274	85017	93284	105693	136462	16196	0	0	0
245	252.87	492	77867	81546	85017	93284	105693	136462	16196	0	0	0
246	253.90	487	78302	81546	85017	93284	105693	136462	16196	0	0	0
247	254.93	482	78732	81546	85017	93284	105693	136462	16196	0	0	0
248	255.96	477	77900	80675	87146	93284	105693	136462	16196	0	0	0
249	256.99	472	78321	80675	87146	93284	105693	136462	16196	0	0	0
250	258.03	467	78738	80675	87146	93284	105693	136462	16196	0	0	0
251	259.06	462	77906	81920	84091	96339	105693	136462	16196	0	0	0
252	260.09	457	78314	81920	84091	92164	109868	136462	16196	0	0	0
253	261.12	452	78718	79813	86198	92164	103741	142589	16196	0	0	0

Appendix 7.13: Three-Dimensional Graphs of Model Output

The following three-dimensional graphs show the complete profile created by the model for dry basis moisture concentration, effective gap radius, *Darcy's* velocity, marinade velocity, *Salmonella* velocity, *Salmonella* location, and *Salmonella* concentration at every time step.

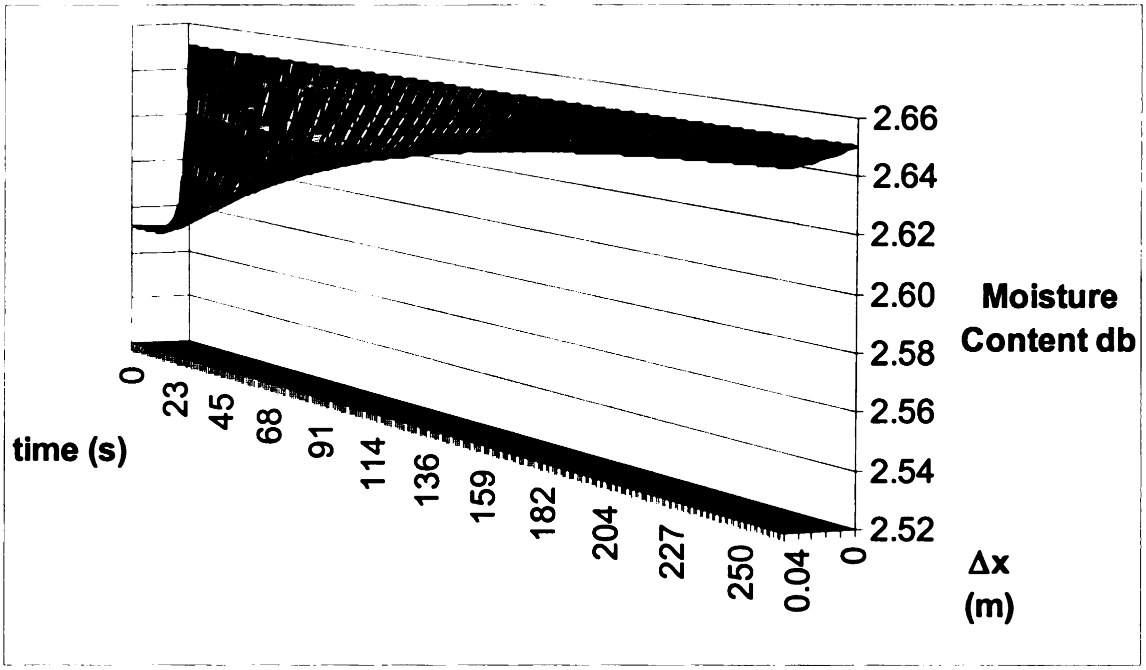

Figure 7.1: Three-dimensional graph of the dry basis moisture content.

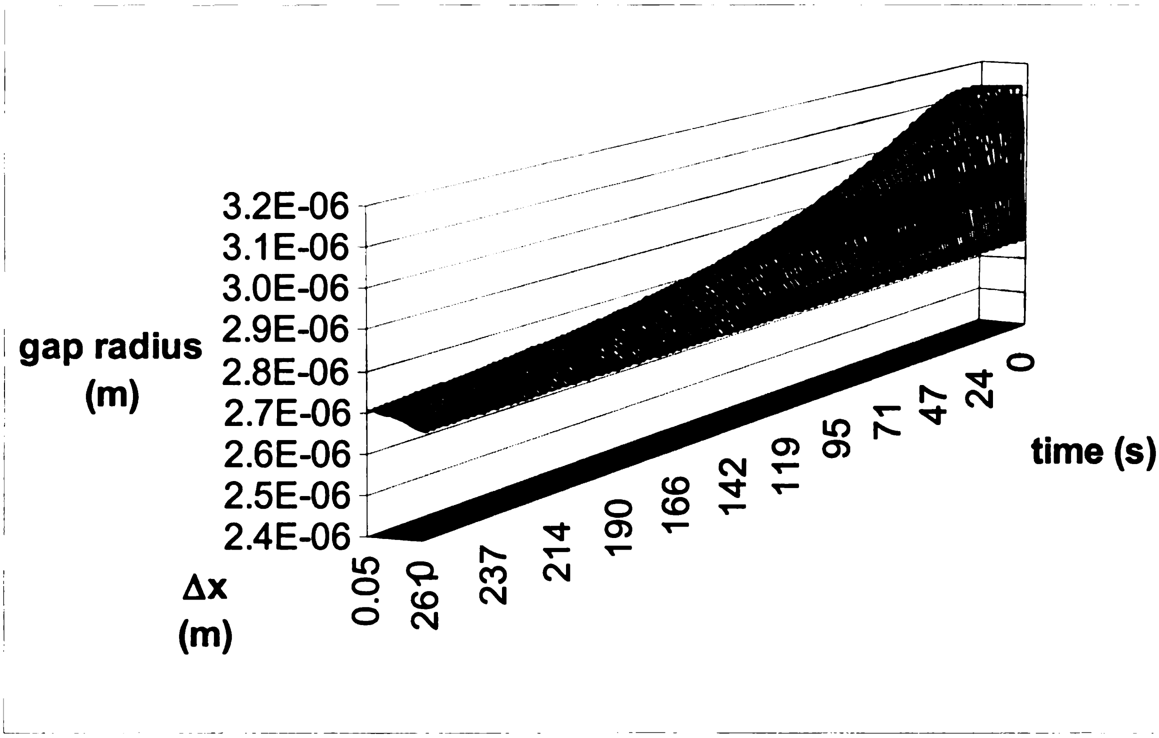

Figure 7.2: Three-dimensional graph of effective gap radius.

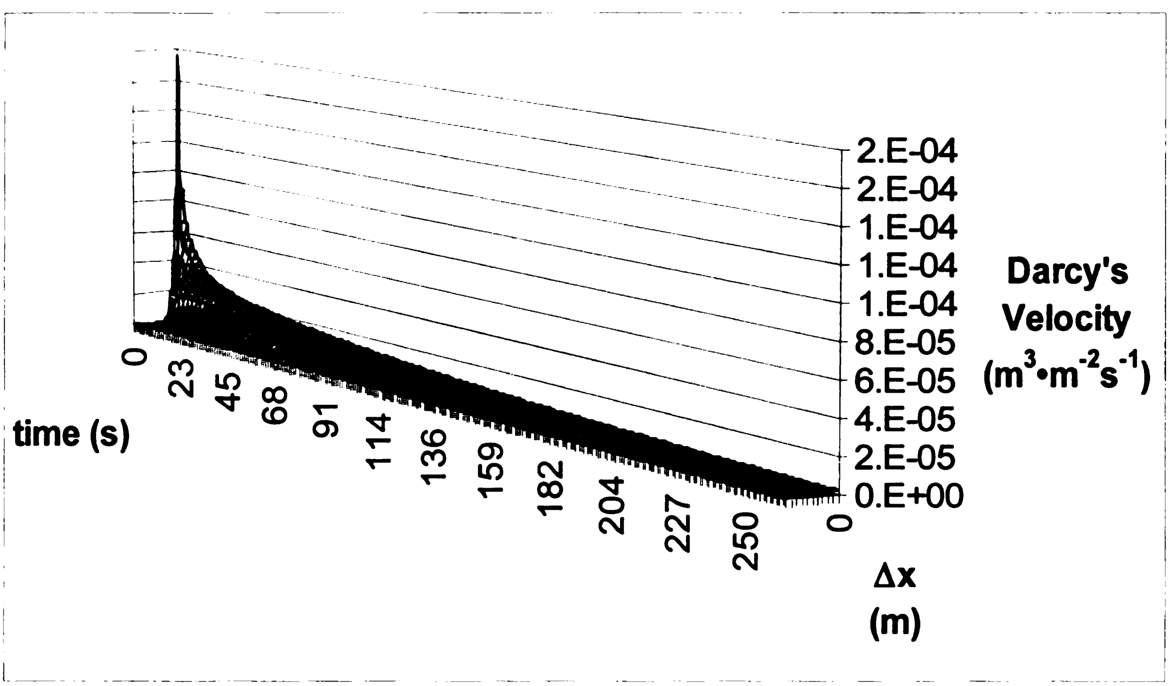

Figure 7.3: Three-dimensional graph of Darcy's velocity.

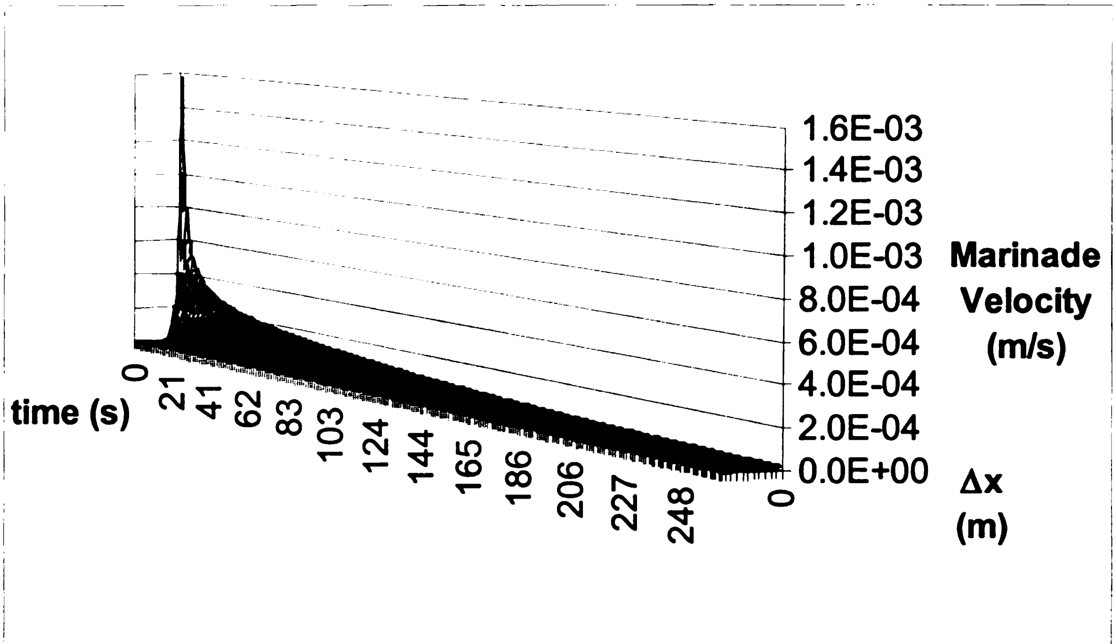

Figure 7.4: Three-dimensional graph of marinade velocity.

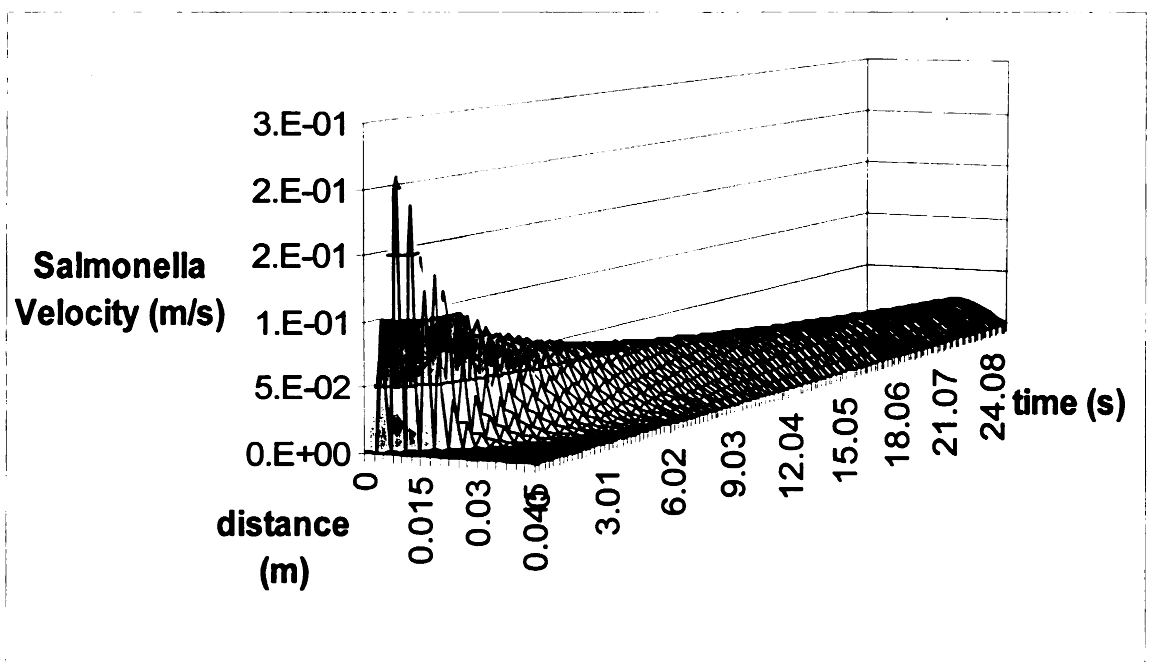

Figure 7.5: Three-dimensional graph of *Salmonella* velocity.

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