ABSTRACT

AN ANALYSIS OF *CHOEROSPONDIAΣ AXILLARIS* “LAPSI” REGARDING PRODUCTION, PRODUCT DEVELOPMENT AND ITS EFFECT ON RURAL LAPSI FARMERS IN NEPAL

This study, conducted in Mudikuwa, Parbat Nepal, addresses the feasibility of *Choerospondias axillaris* (lapsi) as a commodity for production and processing in Nepal, and for import in the United States. Lapsi was identified and characterized based on morphological and physiological features, growing climate, and cultural significance. Lapsi fruit was found to be variable in size, acidity, and brix. The average weight of a lapsi fruit at maturity was found to be 13.17 g. The pH and brix of lapsi fruit was found to be dependent on harvest date. An analysis of processed lapsi products resulted in the identification of the limitations of the processing procedure. Lapsi candy spoiled within 4 months of processing and lapsi pickle did not meet the standard FDA requirement for water activity (0.85). A consumer acceptance test of lapsi pickle in Fresno, CA showed that 80% of the sampled population liked lapsi pickle, which is above the industry standard (75%). Lapsi products can be imported and sold at a profit in the USA, which would create a revenue source for many rural farmers of Nepal; however at the time of writing, manufacturing procedures did not meet industry and government health standards of the US.

Craig Wayne Cole Seber
December 2016
AN ANALYSIS OF *CHOEROSPONDIAΣ AXILLARIS* “LAPSI” REGARDING PRODUCTION, PRODUCT DEVELOPMENT AND ITS EFFECT ON RURAL LAPSI FARMERS IN NEPAL

by

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Plant Science in the Jordan College of Agricultural Sciences and Technology California State University, Fresno December 2016
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Dr. Kriste Sanders,

And all of my teachers inside and outside an academic institution.
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CHAPTER 1: INTRODUCTION

The Peace Corps is a volunteer organization formed by the United States government in 1961. The mission of the Peace Corps is to promote world peace and friendship by providing technical volunteer assistance and allowing volunteers to demonstrate American cultures to the peoples of host countries and explain their host countries’ cultures to American peoples.

The Peace Corps matches the needs of partner countries with the qualifications of volunteers, who will then spend 27 months in their host country. Volunteer activities include food security, business development, teaching, and many others. There were over 70 countries actively hosting Peace Corps volunteers at the time of writing.

In California, California State University Fresno is one of two universities partnering with the Peace Corps to provide volunteer opportunities while earning a degree. The Jordan College of Agricultural Sciences and Technology with the Peace Corps offers a master’s degree in plant science while conducting volunteer service through the Peace Corps Masters International Program.

Research presented in this paper was conducted in Nepal through the Peace Corps Masters International Program at California State University Fresno. The volunteer service was provided from September 2014 to June 2015 in Nepal. The volunteer service was terminated early due to an earthquake, which forced the Peace Corps to evacuate. The Peace Corps has since returned to Nepal, which now has an active volunteer group.

During the Masters International student volunteer service, research was conducted on a native stone fruit tree, *Choerospondias axillaris*. *Choerospondias axillaris* has many common names which include lapsi, hog plum, chanchin.
modoki and many others that are specific to host country and ethnicity. In this thesis, lapsi is used as the common name of *Choerospondias axillaris*.

During the volunteer service, research was conducted through surveying people in lapsi producing areas of Parbat district, Nepal. Lapsi farmers and a food processor specializing in the production of lapsi pickle and candy were routinely met with. Many of the surveys conducted gathered contradictory information from other surveys and research articles.

The research presented in this thesis provides all contradictory information and information with evidence to support or discredit certain claims regarding the cultural significance of lapsi, its production, and marketability.
CHAPTER 2: LITERATURE REVIEW OF CHOEROSPONDIAS AXILLARIES AND OBSERVATIONS

Gestalt

The Anacardiaceae plant family has well known members of economic and agricultural importance. Cashew \((Anacardium occidentale)\), mango \((Mangifera indica)\), pistachio \((Pistacia vera)\), and lapsi \((Choerospondias axillaries)\) belong to the Anacardiaceae family. Lapsi, \((Choerospondias axillaries \text{(Roxb.) B.L. Burtt and A.W. Hill)}\), has also been placed in the genus \text{Poupartia} with species \text{P. fordii} and \text{P. axillaris} (Hill, 253-254). A common misnomer for lapsi is \text{Spondias axillaris} Brodie, Helmy, Brockelman, and Maron et al. (2009) and Bhutia, Suresh, Amar, and Subba (2011), however this is also a synonym for \text{Spondias mombin}, which is similar to lapsi, and in the same family.

Lapsi is a dioecious and deciduous tree, 7.9 – 19.8 m tall. Lapsi trees are reported to be native to Nepal and its range includes Japan, China, India, Bhutan, Thailand and Vietnam (Paudel et al., 2002a). According to Paudel et al. (2002a), lapsi can be heavily branched starting at the base or have a long cylindrical bole without much branching. Shu (2008) stated, its branchlets are dark purple to brown, minutely pubescent to glabrous and lenticellate. The branchlets can terminate into a sparse and airy canopy or dense and thick canopy depending on growth form.

Compared to the observations made by Paudel et al (2002a) and Shu (2008), lapsi trees observed during the years of 2015 and 2016 in Mudikuwa, Nepal exhibited erect growth up to 30.4 m tall (Figure 1). The lower branches of most of the trees observed had been harvested for fire fuel or for construction purposes. The canopy cover was observed to range from 40% to 70%. Branchlets were observed to be red-brown to gray-brown (Figure 2). Juvenile lapsi trunks were
green, lenticlate and smooth (Figure 3). The midribs of juvenile leaves displayed red-brown to red-orange coloration (Figure 4).

Figure 1. A lapsi tree with a cylindrical bole terminating into an airy canopy (left). Figure 2. A grey-brown lapsi branchlet with unripe fruit (right).

Figure 3. Juvenile lapsi trunk with lenticels (left). Figure 4. Juvenile lapsi leaves with red orange midrib and stem (right).
Foliage

Lapsi leaves as described by Shu (2008) are petiolulate, imparipinnately compound with opposite leaflets. The leaf petiole is inflated at the base. The base of the leaflet can be cuneate to round. The leaf can grow 22.8 to 40.6 cm long, with 3-6 leaflets. The leaf can be ovate to ovate-lanceolate or oblong-ovate. The leaflets can be serrate at the base or entirely serrate. The abaxial surface can be glabrous in the vein axils. The leaflets have pinnate venation, which are prominent on the axial and abaxial surfaces. The veins are found in pairs of 8-10.

Gardner, Sidisunthorn, and Anusarnsunthorn (2000) described lapsi leaves as odd-pinnate, with 5-13 pairs of opposite leaflets that are 7-13 cm by 3-5 cm. The leaves are described as narrowly ovate or lanceolate with tapering tips and an oblique base. Lapsi leaves are age dimorphic with the young leaves with scattered teeth and mature leaves without teeth. The leaves have tufts of hairs in axils and no marginal vein.

Lapsi leaves observed in Mudikuwa are petiolate, imparipinately compound with opposite leaflets (Figure 5). The leaf petiole is inflated at the base (Figure 6). The bases of the leaflets are rounded to cuneate with an acuminate leaf apex (Figure 7). Immature leaves have deeply to mildly serrated leaflets (Figure 8). Leaflets on mature fruit producing branches were not serrated (Figure 9). Mature leaf lengths were recorded to grow up to 73.1 cm long, with 13 pairs of leaflets and a terminal leaflet (Figure 10a). The leaflets have lateral venation with minimal sublateral branching (Figure 10b). Venation is prominent on adaxial and abaxial surfaces.

The terminal end of lapsi leaves at the top of young trees showed coloration believed to be the result of anthocyanin accumulation (refer to Figures 4 and 8). The petioles of the leaflets were commonly red or green. The abaxial and adaxial
surfaces of the leaves exhibited minute pubescence along the veins and midribs (refer to Figure 10b). The leaf stems are lenticlate.

Figure 5. A petiolate, imparipinately compound leaf with opposite leaflets

Figure 6. The bases of the leaflets are rounded to cuneate with an acuminate leaf apex (left).
Figure 7. Deeply to mildly serrated leaflets measuring more than 8 cm long (right).
Figure 8. Serrated lapsi leaves

Figure 9. A mature lapsi leaf. Mature lapsi leaves are not serrated.
Figure 10a. An immature lapsi leaf measuring over 64 cm (25.6 in).

Figure 10b. The abaxial surface of a lapsi leaf. It is minutely pubescent with parallel venation.
Inflorescence

Male inflorescences can be 9.6- 25.6 cm long, and minutely pubescent to glabrous. Lapsi flowers have minute subtending bracts. The male calyx can be minutely pubescent to glabrous. Its petals are oblong, 0.22- 0.27 cm long. The petals are recurved at anthesis with brown veins. The stamens are equal to the petals in length. The anthers are oblong about 0.1 cm long. Female flowers are solitary in the axils of distal leaves and are larger than male flowers (Shu 2008).

Gardner et al. (2000) stated that lapsi flowers are 0.4-0.5 cm and dark red. The male flowers are found in branched clusters at the end of twigs and upper leaf axils. Bisexual flowers are found in leaf axils in groups of 2-3. The calyx is less than 2 mm and has 5 lobes. The female flowers are dark red-purple, smooth on outer surface and glandular-hairy on the inside. Lapsi flowers from February to March and to a lesser degree April and May.

Personal observations of male and female inflorescences were not observed during the study. Paudel et al. (2002a) stated lapsi develops its inflorescences between March and April. Interviews with farmers and producers suggest the duration of flowering is about 2 weeks long.

Fruit Characteristics

Lapsi fruit ranges in mass from 8 to 18 g (Paudel, Pieber, Klumpp, & Laimer, 2003) (Figures 27a, and b, Figure 12 right, and Figure 13). Lai, Guo, and Xiao (2014) found the fruit mass to be within the range described by Paudel et al. (2003), which was 8.04g + 1.09g, and by Paudel et al. (2002a) who found the mass of lapsi fruit to range from 58 to 118 fruits per kg with an average of 88 fruits per kg. This (88 fruits per kg) is an average of 11.37 g per fruit. According to Chen et al. (2001), the weight of lapsi fruit was 9.5g+1.11g.
Observations of the average weight of lapsi fruit varied between trees, and time. The average weight of lapsi fruit from 4 trees was found to be 13.17 g. These trees were classified by their owners as large fruit.

Fruit and Seed

The fruit produced by female lapsi trees are drupes (Figure 11). Lapsi fruit can be ellipsoidal, obovate-ellipsoidal or spherical (Figure 12). The fruit is green until maturity at which point it turns yellow.

Lapsi fruits observed in Mudikuwa ranged in length from 2.5 cm to 3.1 cm which was in the range stated by Shu (2008) and Gardner (2000) (Figure 13). The endocarp of lapsi fruit contains 5 seeds enclosed in a woody mesocarp capsule (Figure 14). Each seed is isolated from the others by woody septa. Inside the endocarp box, the seeds are fused to the mesocarp at their bases. The superior portions of the seeds are unattached and free inside the cavities of the stone (Hill, 1937).

Observations of the internal structures of the seed stone allowed for the identification of attachment sites of the seed to the seed stone. The seed was observed attached to the center column of the seed stone, to the posterior wall of the seed stone (Figure 15) and to the woody septa inside the seed stone (Figure 16). The seeds were observed as being attached along longitudinal surfaces at the broad or narrow section of the seeds.

Germination

During the germination of lapsi seeds, longitudinal slits at the apices of the woody mesocarp separate due to cell expansion of the hypocotyl (Figure 17). The separated seed cavity becomes a pore for the embryo to grow out from (Figure 18) (Hill, 1937). The hypocotyl loop emerges from the pore first, bringing the radical
out second. The hypocotl loop then breeches the soil surface followed by the cotyledons (Figure 19). The cotyledons appear to push the hypocotyl as they begin to grow.

Figure 11. An immature green lapsi fruit (left).
Figure 12. Mature yellow lapsi fruits of varying shapes (right).

Figure 13. An immature lapsi fruit dissected to see the seed stone. The fruit measures 3.2cm long (left).
Figure 14. A seed stone dissected to see 5 chambers and 5 woody septa. Two of the chambers have dissected seeds in them (right).
Figure 15. An interior view of a dissected seed stone and the posterior wall of the seed stone with detached seed (left).
Figure 16. The hallow cavity where the seed was attached to the woody septa inside the seed stone (right).

Figure 17. Lapsi seed stone with 5 pores (left).
Figure 18. A lapsi seedling emerging from a pore (middle).
Figure 19. Three lapsi seedlings breaching the soil surface (right).

Wood Anatomy

Gupta and Agarwal (2008) found the wood of *Choerospondias axillaris* to be ring porous. Growth rings were distinguishable by differences in vessel diameter and fiber wall thickness. Early wood vessels were found to be solitary and in multiples of 2 to 4 with an average diameter of 185 \( \mu m \). Late wood vessels were classified as small with an average diameter of 100 \( \mu m \). Vessel-ray pits were found to be simple or with reduced borders. *Choerospondias axillaris* fibers were found to be septate with an average length and diameter of 1,155 \( \mu m \) and 18 \( \mu m \).
respectively. The average ray length was found to be 406 µm and composed of procumbent cells with 1 to 2 rows of square marginal cells. Radial canals were identified as having 1 to 2 layers of partly lignified epithelial cells. Internal crystals were not found by Gupta and Agarwal (2008), however; unconfirmed reports in Gupta and Agarwal (2008) did find internal crystals in the wood.

**Bark**

Gardner et al. (2000) described the outer bark of lapsi as dark grey or red-brown and the inner bark as red. The bark is also described as cracked, and peeling in vertical flakes.

The external bark characteristics were identified as steel gray with vertical fissures approximately 1 cm to 2.5 cm wide and 5 mm deep (Figure 20). Fissuring was greatest on old growth (Figure 21). Young growth is not fissured (Figure 22). The internal coloration of the bark was orange red to burgundy (Figure 23). The internal structure was smooth and solid.

**Climate**

In Nepal, the areas in and around the Kathmandu valley have been identified as high intensity production areas for lapsi. Based on the climatic data recorded by weather online, the Koppen Climate Classification system classified the Kathmandu valley as a temperate, dry climate with the warmest month above 22 degrees C (Cwa). A “C” type climate is classified as humid mesothermal (Kattel, 2008). Specifications of the C type climate include Cwa, Cwb, Cfa and Cfb, which were also present in the Kathmandu valley.

There is not a direct conversion from the Koppen Climate Classification ranking to the USDA’s hardiness zones. The hardiness zone for which lapsi grows and produces fruit was estimated by known plants often associated with lapsi and
Figure 20. Longitudinal fissures in lapsi bark are 2 cm wide and 5 mm deep (left).
Figure 21. An old lapsi tree heavily fissured (right). Note the removed branches.

Figure 22. A young lapsi tree that has not begun to fissure (left).
Figure 23. Shaved off bark revealing orang red coloration and smooth wood underneath (right).
were observed growing next to lapsi. Coffee (*Coffea arabica*), banana (*Musa sp*), papaya (*Carica papaya*), onions (*Allium sp*), garlic (*Allium sp*), potatoes (*Solanum sp*), corn (*Zea mays*), and millet (*Pennisetum sp*) were observed growing in the vicinities of lapsi. Plants in this list are associated with hardiness zones 3 through 10.

**Elevation and Biomes**

Lapsi has been recorded at elevations between 849.7 m to 1899.8 m above sea level (Paudel et al., 2002a; Paudel et al., 2003). The elevation of the mid mountain region of Nepal is 792.4 m to 2399.9 m (Devkota, 2015). The biomes that lapsi trees are commonly associated with in Nepal are mixed mountain systems. The biomes, which lapsi have been identified are the mixed broadleaved forests and evergreen mixed forests (International Centre for Integrated Mountain Development, 2008).

**Ecoregion**

The ecoregions associated with the range of lapsi in Nepal are Himalayan subtropical broadleaf forests, Himalayan subtropical pine forests, Western Himalayan broadleaf forests and Eastern Himalayan broadleaf forests. These regions range in elevation from 487.6 m to 1005.8 m, 999.7 m to 1999.7 m, 1493.5 m to 2590.8 m, 2011.6 m to 2987.0 m respectively (Category: Ecoregions of Nepal 2013).

**Fruit Abscission and ecology**

Similar to some of the other plants found in the same ecoregion, lapsi fruits abscise from the trees beginning late October (Figure 24a). The majority of fruits abscise in December (Figure 24b), but trees may hold fruits until early January.
Many types of frugivores such as, such as: lar gibbon \((Hylobates lar)\), sambar deer \((Rusa unicolor)\), sun bear \((Helarctos malayanus)\) and red muntjac \((Muntiacus muntjak)\) consume lapsi fruits (Brodie et al. 2009 and Lai et al. 2014).

Figure 24a. A lapsi tree in December after its leaves shed. The fruits on this tree were harvested a week after the photo was taken (left). Figure 24b. A lapsi tree in December after leaf and fruit abscission (right). Note the lower branches are removed.

Fruits can be cached or consumed and regurgitated. Seeds deposited in full sun to 30% canopy cover have the greatest germination rate (Brodie et al. 2009). Seeds deposited under lapsi tree canopies can germinate and survive but survival was greatest between 11% and 30% canopy cover that was not lapsi. The seeds typically take up to 2 months to germinate (Brodie et al. 2009 and Napier & Robbins, 1989). Germination generally occurs around March and April. The percentage of viable seeds older than 1 year tends to decrease.
Observations of seed germination are similar to Brodie et al. (2009) and Napier and Robbins (1989). The majority of seed germination occurs within the first month and can continue for more than 3 months. Germination was greatest in full sun and saturated soil in March. Germination trials in a greenhouse with white wash windows, (white latex paint to water 1:4), and with an average temperature of 25 degrees C, and saturated soil with periods of drying produced about 50% germination. When the trial was moved outside into full sun the other 50% of the seeds germinated.

Growth Season

Established trees and seedlings grow from February to November-December, at which time leaves begin to abscise. The majority of the growing season coincides with monsoon season, May-June to September. Lapsi trees begin to lose their leaves beginning mid to late November with the majority of leaf drop occurring early to mid-December. Trees may hold on to their leaves up to January. Dormancy lasts until February when bud break occurs. Flowers develop soon after bud break and continue for about 2 weeks. Flowering only occurs after 7 to 10 years of growth (Paudel, 2003). Some lapsi trees have been reported growing for over 150 years (Paudel et al., 2003).

Growing Conditions

Lapsi grows best in full sun and saturated soil (Brodie et al. 2009; and Lai et al. 2014). Lapsi fruits grown in the shade tend to have a greater incidence of pathogen infection. A lapsi farmer said in an interview that lapsi grows best in well-drained soil. Farmers do not actively manipulate lapsi’s growing environment or provide inputs for quality fruit production. The majority of the growing season
occurs during monsoon season which is characterized by overcast light conditions and heavy rain fall, and temperatures around 25 degrees C.

**Horticultural and Propagation Practices**

Prior studies and field observations have shown horticultural practices such as irrigation, fertilization, or pruning, were not utilized (Paudel et al., 2003). Lapsi trees that were pruned are believed to have been pruned for fire wood and not production. Lapsi producers in Mudikuwa said they actively managed their lapsi trees by applying composted manure to them. However no observations were made of farmers applying nutrient amendments to lapsi trees.

Lapsi is propagated primary by seed. There are no known stratification or scarification requirements for lapsi seed propagation. Observations of seeds that were consumed by ruminant animals appeared to germinate sooner than nondigested seeds. Tests to verify this observation were not preformed. A seed viability trial was conducted using 2,3,5-triphenyl-2-tetrazolium chloride (Figures 25 a, b, c, d). See results. Dried seeds are biable for 9 months to 1 year (Brodie et al. 2009, Gautam 1997, and Napier & Robbins 1989)

According to Paudel et al. (2003), lapsi can be vegetatively propagated by chip budding, grafting, propagation of hardwood and softwood cuttings and by tissue culture.

Chip budding performed during the first 3 weeks of February was found to have a success rate of up to 93% (Paudel et al., 2003). Side grafting performed during the same times in February had a success rate of 7%. Hard wood cutting treated with Seradix-B3 had a 7% survival rate in open field conditions and under a cloning dome (Paudel et al., 2003). Soft wood cuttings had a success rate of 40% when treated with 2000 ppm IBA and propagated in perlite medium (Paudel et al., 2003).
Figure 25a. lapsi seeds, (57), submerged in a 10% solution of 2,3,5-triphenyl-2-tetrazolium chloride (top left).
Figures 25b, c, d. Lapsi radicles were stained red after 16 hours of soaking in solution of 2,3,5-triphenyl-2-tetrazolium chloride (top right, bottom left, and bottom right).

Compared to Paudel et al. (2003), observations of bud grafts preformed in February 2015 had a 0% success rate by October 2015 (Figure 26). The lack of bud take could be contributed improper technique.

Lapsi can be micro-propagated through bud tissue (Paudel et al., 2003). Sterile cultures are propagated in vitro with Driver and Kuniyuki medium and 1mg/l of benzyl-aminopurine (BAP). The success and further details of the study on micropropagation of lapsi were not published.
Figure 26. Failed bud grafting attempts. 
*Note:* The lapsi seedling on the far left had the graft material die and the graft tape became unraveled. The lapsi seedling in the center and far right developed abnormal growths from the graft tape around the stalk and the bud graft died.

Figure 27a. A 50 pound sack of lapsi fruit from Mudikuwa, Parbat. Fruit ranged in size from 8 to 18 g (left).

Figure 27b. Immature lapsi fruit being sold in Thamel, Kathmandu in December (right).
Cultural Importance of Lapsi

Lapsi has received scientific attention due in part to its importance in Nepali culture. According to Paudel et al. (2002a), Paudel et al. (2003), Upadhya et al. (2013) and Gautam (1997), lapsi is important in different aspects of life for Nepali people and others. Lapsi is reported to be consumed during religious ceremonies for its symbolic significance. It is used for medicine, and as a business commodity. Its wood is used for fuel and construction. Its forage is occasionally used to feed livestock and its fruits are commonly consumed.

Observations and interviews conducted in Nepal regarding the cultural significance of lapsi to Nepali people resulted in the identification of lapsi only being important as a food and lumber source. People stated they had no recollection of it being important culturally or for religious ceremonies. At the time of writing a procedure to turn lapsi seeds into buttons and beads was being developed.

According to Paudel et al. (2002a) and Paudel (2003), lapsi is said to be important to many Nepali people and people of the Hindu faith. Lapsi fruits are used in Hindu rituals, Newari feasts, festivals and celebrations. In Hinduism, the fruits are used as offerings to the Gods and Goddesses (Chhetri & Gauchan, 2007) and are grown on many religious sites in the Kathmandu valley.

Lapsi was not observed during religious activities or at temples, stupas or pagodas. During explorations of the largest temples in Kathmandu, including Swayamunath, lapsi trees were not discovered. Lapsi may have some cultural significance to Newari people. A traditional feast for Newari people contains lapsi soup, which is believed to aid in digestion and “purify the elements” (Bajracharya, 2015).
The 2 primary festivals in Nepal are Dashain and Tihar. These festivals occur in October, which also coincides with the harvest of lapsi according to (Paudel et al., 2002a), which further stated that during these festivals lapsi is commonly consumed, sold and traded.

Observations of Dashain and Tihar in Mudikuwa did not include the trade or consumption of lapsi. During Dashain and Tihar lapsi fruits were still immature. All of the known trees in the area had not been harvested during these festivals.

Secondary Metabolites

Lapsi sap contains many compounds, some of which have medical applications. One protease has been found to treat secondary burns (Upadhyay, 2013). Extracts of lapsi have been found to have antiviral properties and have been used to treat herpes simplex virus (Jo et al. 2005). Flavonoid and phenolic extracts, quercetin and gallic acid respectively, of lapsi fruit have been used as a medicine for cardiovascular diseases (Wang, Gao, Zhou, Cai, & Yao 2008). Quercetin has also been shown to reduce the development of neurodegenerative diseases (Bentz, 2009).
2.1 Production of Lapsi Fruit in Nepal

Lapsi trees have been recorded growing from the eastern districts to the far western districts in the hill region to the mountainous region of Nepal (Paudel et al., 2003). Paudel (2003) discovered 301 village development committees in 29 hill districts actively growing lapsi. He estimated over 40,000 mature female trees are being cultivated and more than 450,000 trees have been planted for cultivation in 2001. However, these estimates were not verified. It is unclear if these numbers represent only on farm cultivation of lapsi trees or if wild forest grown lapsi trees were considered in the estimation. The sex of the 450,000 planted trees was not evident. In 2015 assuming 0 mortality, there would be about 265,000 mature and producing female trees if 50% of the planted population were female.

If 265,000 mature female lapsi trees were in production, a conservative estimation for yearly yield would be 53,000,000 kg of lapsi fruit. Yields of this magnitude have not been observed in the markets of Kathmandu, Pokhara, Kusma, or Mudikuwa.

In Sanga, as reported by Gautam, (2004), there are on average 12 to 29 lapsi trees per farming household. Sanga is a high intensity production area (Paudel et al., 2003). In medium intensity production areas such as the district of Parbat, lapsi production was observed to be, on average, less than 1 tree per farming household. In these areas some lapsi trees were shared by villagers. Interviews with villagers suggest more lapsi trees are in forested areas.

In Mudikuwa, ward number 5, 4 trees were identified. One mature tree was identified on abandoned property. An immature tree was identified in the back yard of a villager’s home. The other 2 trees were mature and belonged to residents outside the village. Observations of lapsi production and interviews with farmers
resulted in an estimated average yield per tree of 200 kg. The average weight of the fruit at maturity was estimated at 13 g.

**Farmer Demographics**

Eight farmers were interviewed in Mudikuwa and the surrounding area. One school was identified that had lapsi on its property. The school’s principal was interviewed for the information about the lapsi on the school grounds. The information is presented in Table 1.

Table 1. Profit from Lapsi and Demographic Information on Lapsi Farmers in Mudikuwa, Nepal.

<table>
<thead>
<tr>
<th>NPR/Kg*</th>
<th>Age</th>
<th>Gender</th>
<th># of trees</th>
<th># of mature trees</th>
<th>Kg fruit/tree</th>
<th>Ethnic ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>38</td>
<td>Male</td>
<td>15</td>
<td>3</td>
<td>100-250</td>
<td>Brahmin</td>
</tr>
<tr>
<td>15</td>
<td>33</td>
<td>Female</td>
<td>1</td>
<td>1</td>
<td>400</td>
<td>Brahmin</td>
</tr>
<tr>
<td>15</td>
<td>school</td>
<td>Neutral</td>
<td>6</td>
<td>6</td>
<td>25-100</td>
<td>Neutral</td>
</tr>
<tr>
<td>15</td>
<td>50</td>
<td>Male</td>
<td>100</td>
<td>55</td>
<td>200</td>
<td>Brahmin</td>
</tr>
<tr>
<td>15</td>
<td>49</td>
<td>Male</td>
<td>34</td>
<td>9</td>
<td>200</td>
<td>Brahmin</td>
</tr>
<tr>
<td>15</td>
<td>70</td>
<td>Female</td>
<td>3</td>
<td>3</td>
<td>200-300</td>
<td>Chhetri</td>
</tr>
<tr>
<td>15</td>
<td>Not given</td>
<td>Male</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>Not given</td>
</tr>
<tr>
<td>No sell</td>
<td>45</td>
<td>Male</td>
<td>2</td>
<td>1</td>
<td>100-150</td>
<td>Brahmin</td>
</tr>
</tbody>
</table>

*NPR is the Nepali Rupee (currency)*

The principal of the school noted the low yield of the trees was due to the children harvesting the fruit during recess. All of the farmers interviewed, except for one, stated they are purely subsistence farmers. Their only source of income comes from selling their lapsi once a year. This equates to an average annual salary of $30 per tree.
The cause of the unequal ownership among the ethnic groups is unclear. It is possible that the demographic range of Mudikuwa is weighted heavily towards a higher concentration of Brahmin individuals. Observations of ethnic groups in Mudikuwa revealed primarily Brahmin families and to a lesser degree other groups including Chhetri, Gurung and Dalit families.

According to the Nepali governments’ reports on housing and populations in 2012, there were 1869 people living in 467 households in Mudikuwa. According to an earlier report by the Nepali government’s Housing and Population Census, there are more than 8 different ethnic groups in Mudikuwa (Table 2).

<table>
<thead>
<tr>
<th>Caste</th>
<th># of households</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chhetri</td>
<td>214</td>
</tr>
<tr>
<td>Brahman</td>
<td>1228</td>
</tr>
<tr>
<td>Musalman</td>
<td>18</td>
</tr>
<tr>
<td>Kami</td>
<td>118</td>
</tr>
<tr>
<td>Gurung</td>
<td>11</td>
</tr>
<tr>
<td>Damai/ Bholli</td>
<td>20</td>
</tr>
<tr>
<td>Sarki</td>
<td>221</td>
</tr>
<tr>
<td>Bote</td>
<td>14</td>
</tr>
<tr>
<td>Others</td>
<td>25</td>
</tr>
<tr>
<td>Total</td>
<td>1869</td>
</tr>
</tbody>
</table>

The sampled population is relatively consistent with the population of Mudikuwa, Parbat. Mudikuwa is composed of approximately 65% Brahmin people and 11% Chhetri people. The population percentage of the lapsi tree
owners who were surveyed are 75% Brahmin and 12.5% Chhetri. The other castes were not represented in the survey, possibly due to the small sample size.

**On Farm Production**

Many lapsi trees are grown on the margins of un-irrigated farms (Gautam, 2004; Paudel, 2003). This is a common practice because harvesting lapsi is perceived to be damaging to crops on the farm. These observations are consistent with observations of cropping systems made in Mudikuwa, Parbat. Lapsi trees are grown on the margins of farms. During the lapsi harvest, the farms were fallow (Figure 28 and 31a). This could be due to the farms crop rotation schedule. Chhetri and Gauchan (2007) noted the harvest of lapsi did not coincide with critical farming practices.

![Figure 28. Two lapsi trees, one in the foreground and one in the background, grown on the edges of terraced farm lands. This photo was taken in September.](image)
**Land Preparations for Planting**

Observed land preparations in Nepal consists of spreading composted cow manure on fallow land, then tilling the soil with an ox powered shovel plow. When a single plant is being planted, an appropriate sized hole is dug, about 2 handfuls of composted cow manure is dropped in to the hole, then the plant is applied directly to the compost or a layer of soil is added above the manure and the plant is planted. An average size farm in Mudikuwa is about 1/8th an acre to 1/4th an acre. Lapsi seeds, seedlings and to a lesser extent grafted plants are the primary planting materials (Paudel et al., 2003; Gautam, 1997; Paudel, 2003).

**Seed and Seed Bed Preparation for Propagation**

When lapsi seeds are being planted for commercial production, they are planted in a seed bed (Gautam, 1997). Ripe fruits are buried a meter deep then dug up after 2 to 4 weeks. The rotted flesh is rubbed off the seed stone with sand then washed with water and allowed to dry.

A seed bed is prepared by layering a rectangular hole with 5 cm of gravel then covering the gravel with 2.5cm of soil then 7.5 cm of sieved top soil. The seeds are planted 2.5 to 5 cm apart and watered 2 times a day.

Observations of seed and seed bed preparations in Mudikuwa were similar to those described by Gautam (1997) but the seeds were not buried. Rotten fruits were collected and cleaned of decayed tissue so only the seed stone remained. Seed stones were cleaned by rubbing the pulp off with soil and washing with water. The seed stones were then planted on terraced farmland (Figure 29a). The seedlings were transplanted as needed (Figure 29b). Seeds were observed germinating over 60 days after planting.
Population of Lapsi Trees in Mudikuwa

Interviews and observations of lapsi cultivation in Mudikuwa, Parbat revealed on farm production of 0 to 100 trees. Eight farmers were identified as owning lapsi trees. Of the 8 farmers interviewed, the farmer claiming to have 100 lapsi trees did not have time to show his trees and thus it is unconfirmed. The largest observed number of trees owned by a farmer was 4. In most instances of a farmer having multiple trees, the trees were planted on different plots of land.

There was not an observed pattern of distribution of lapsi trees. The trees were spread out and clumped together. The spacing of trees ranged from about 3.6 m to opposite sides of the properties. There were no observations made relating to irrigation or amendment additions. Trunk scars indicated the trees were pruned; however this was probably for firewood and not for fruit production. These observations are congruent with those made by (Paudel et al., 2003).
Factors Affecting Fruit Quality

Lapsi is a climacteric fruit. It can be harvested unripe or ripe. The fruit quality is extremely variable. The genetic diversity of the trees, elevation, light availability, and water availability are factors affecting fruit quality (Paudel et al., 2002a; Paudel et al., 2003; Gautam, 2004; Brodie et al., 2009) (observations of fruit quality are presented in). Lapsi is harvested by hitting the branches with a pole (Figure 30), climbing trees and shaking the limbs, throwing rocks or sticks at the fruit, or letting the fruit fall naturally to the ground and picking them up (Figure 31a and b).

Figure 30. A Nepali man knocking lapsi fruit off a branch with a bamboo pole, while keeping himself from falling.

Limitations to Production

There are many limitations to production of and access to lapsi fruit. Many farmers do not want to grow lapsi because of the 7 to 10 year waiting period before the first fruit harvest. Nepali farmers also consider the potential of lapsi trees to be non-bearing males before they invest the land area to lapsi production. Resource poor farmers have to wait for a subsidy or handouts before they are
willing to plant lapsi. If farmers have access to planting materials, grafted trees or seeds, they may not possess the knowledge needed for lapsi production.

Figure 31a. A Nepali man picking up fruit from a fallow farm (left). Figure 31b. Fallen lapsi fruit hidden in the foliage (right).

Insect and disease incidence on lapsi fruit have been determined to account for 10-12% of fruit damage (Paudel et al., 2002a). Observed pests of lapsi include lepidopterans (Figure 32) and fungal pathogen(s) (Figure 33 a, b) such as *Colletotrichum sp* (Paudel et al., 2002a). Other observations of pest damage includes partially masticated leaves and mounded soil along the trunk of the tree (Figure 34). The pest(s) responsible for the damage were not identified. Trees growing at higher elevations and under the canopy of other trees have greater pest incidence, up to 40%. In such cases premature fruit drop and leaf drop have been recorded (Paudel et al., 2002a).

In an interview with a lapsi grower, it was mentioned that one of his trees experienced leaf drop in the beginning of the lapsi season, between April and September. He did not know the cause but the owner of the lapsi processing facility contributed it to a hail storm. The other trees in the surrounding areas did
not lose their leaves, which may indicate the variation of tolerance to cold weather. The estimated yield of the tree was 200 kg, which was the same estimations given to the other trees in the area. Leaf drop early in the growing season may not affect yield (personal correspondence, Bhushel, 2015).

Figure 32. A juvenile lepidopteran on a lapsi petiole reaching towards the internode

Incidences of leaf damage were recorded. Observations of leaf consumption were made. A juvenile lepidopteran was found on the axis of a lapsi leaf. The leaf showed signs of herbivory consistent with the chewing and cutting mouthparts of juvenile lepidopterans.

Lapsi fruits are eaten by many animals (Brodie et al. 2009; Lai et al. 2014; Chhetri & Gauchan 2007). Due to poaching and habitat destruction, many of
these animals pose only minor threats to fruit production. Observational accounts of consumption of lapsi fruit by squirrels and deer are numerous. A deer routinely ate the fallen fruit in the study area. The deer was identified by its scat, tracks and regurgitated piles of seeds.

Figure 33a. A pathogen seeping from a wound in a lapsi tree (left). Figure 33b. An immature lapsi fruit with a pathogen growing on the skin (right). The pathogen does not affect the fruit quality.

Figure 34. Mud was built up along the trunk of this lapsi tree. The pest is believed to be a termite but was not identified.
The majority of forest grown lapsi fruits are sold in to markets. For the fruit to get to markets, road access needs to be available. Some production areas, such as those in the far west, do not have road access (Kunwar et al. 2012). For the fruit and processed lapsi to enter foreign markets transportation and policy barriers need to be overcome.

At the time of writing, Nepal was experiencing a deficit in fuel for cooking and for transportation. The deficit was observed to be the result of trade restrictions by the Indian government. The reasons for the restrictions, as suggested by Nepali news and some Nepali people, were due to the ratification of Nepal’s constitution and increased tension in border cities and towns in the Terai.
2.2 Lapsi Fruit Processing

Processing facilities purchase lapsi fruits from collection centers or directly from farmers. The owner of a processing facility claimed he purchases 1 kg of fruit from local growers for 15 Nepalese rupees. At the time of the interview (2015), 105 Nepalese rupees were worth about $1.00. In 1997 the fruits from one lapsi tree were worth 800 Nepalese rupees or about $14 (Gautam 1997), which is equivalent to about $0.07 per kg.

Processing facilities turn the raw fruit into products such as sweet candy (Figure 35 a, b), sweet and sour candy, spicy candy, spiced pickled fruit in oil (Figure 36), jam, chutney, and a powdered tea additive (Figure 37). The seed stones are turned into beads, burned as fire fuel, and sold for planting (Gautam, 1997; Chhetri & Gauchan 2007; Paudel et al., 2002a).

Figure 35a. Lapsi candy split in half (left).
Figure 35b. A large pile of lapsi candy before it is packaged (right).

The Process of Making Sweet Lapsi Candy in Mudikuwa

Fresh fruits are washed and placed in a pot with clean water on a stove. The fruits are boiled for about an hour to cause them to expand enough to cause their skins to split. After the fruits’ skins have split, they are strained from the
Figure 36. A large package and a small package of lapsi pickle. Figure 37. Lapsi skins being sun dried. After the skins are dried, they will be ground into a powder for tea.

water and allowed to cool for 15 minutes. After the fruits have cooled thoroughly, the skins are removed by hand. The skins are placed in the sun to dry and the fruits are placed in a mixer for further processing. The mixer separates the pulp from the seed stone, which takes 10 to 15 minutes. The seed stones are picked from the pulp and sugar is added up to a 1 to 1 ratio of sugar to pulp (wt:wt), and mixed with the pulp in the mixer. The pulp is divided into approximately 1 g units and placed on a drying board, which is placed in the sun with the lapsi skins. After 2 to 3 hours the fruits are placed in a solar oven for 2 to 3 days depending on light availability. When the candies reach a certain firmness, which is checked by feel, they are removed from the solar oven and coated with powdered sugar. The candies are weighed into 100 g increments and packaged.

**The Process of Making Lapsi Pickle in Mudikuwa**

Fresh fruits are washed and placed in a pot with clean water on a stove. The fruits are boiled for about an hour to cause them to expand enough to cause their skins to split. After the fruits’ skins have split, they are strained from the water and allowed to cool for 15 minutes. After the fruits have cooled thoroughly, the skins are removed by hand. The skins are placed in the sun to dry. As the
skins are being removed, a pot is filled with the appropriate amount of mustard oil and brought to a simmer. Fenugreek is added to the oil. The Fenugreek is cooked until it turns red, which takes about 3 minutes. Black cumin is added to the mixture and cooked for 3 minutes. Fennel is added to the mixture then asafetida, turmeric, black and pink salt are added immediately after. Onion is then added and stirred. Lapsi is added to the mixture. The mixture is thoroughly stirred. As the mixture is being stirred, sugar and chili powder are added. The cooking pot is then taken off the oven and allowed to cool overnight. The lapsi pickle is then ladled into 500 g increments and packaged.

**Requirements for Lapsi Processing**

Processing facilities require many inputs in order to operate as a business. Processors require reliable access to fruit for their business. They also require the additives to their food, such as sugar, salt, mustard oil and spices such as coriander, cumin, cloves, cardamom, chilies and pepper (Chhetri & Gauchan, 2007). The added materials can increase the food weight by 30 to 100% for pickles and candies respectively.

The processors need fuel and equipment to cook and prepare the fruits. They need packaging materials such as plastic bags, labels, jars, scales and sealing machines. They also require workers unless they are doing the work themselves. The lapsi facility in Mudikuwa hires 1 to 2 employees during processing operations and may receive volunteers from the organization World Wide Opportunities on Organic Farms (WWOOF), which facilitates the placement of volunteers on farms. Family members also assist in production and transport of products.
Barriers to Beginning Processing Facilities and Current Facilities

The barriers to starting a lapsi processing facility include access to land for a facility, costs of building a facility and purchasing equipment and lapsi fruit, access to reliable electricity, optimal weather conditions for lapsi growth and operating the solar oven, road access, transportation from point of purchase of lapsi fruit to point of sell of processed lapsi products and knowledge of how to operate the equipment, process lapsi and run a business.

At the time of writing The Community Food Processing Facility in Mudikuwa was beginning to come up with innovative solutions to the issue of road access. Ideas were being developed, which included a water sluice that took advantage of existing irrigation channels, and zip lines.
2.3 Economic Importance of Lapsi in Nepal

Even with all the obstacles preventing laspi from entering the market, an approximation of over $650,000 worth of lapsi fruit and lapsi products, such as: candy, powdered skins and pickles, chutney, and jam are sold in Kathmandu annually (Paudel et al., 2003; Paudel 2003; Chhetri & Gauchan 2007). The original source of this estimate was not available for review. The actual number may vary significantly.

Lapsi is recognized as having great potential as a cash generating commodity. The income that could be acquired from the selling of fruit can be used to alleviate the necessity of sustenance food production (Paudel et al., 2002a). The annual income generated from lapsi has a positive impact on poverty alleviation of rural farmers (Chhetri & Gauchan, 2007).

Interviews with lapsi farmers in Mudikuwa and the surrounding villages have led to a better understanding of Parbhats’ economic situation. All the farmers acknowledged they do not earn or receive money from outside sources. The majority said they do not receive any monetary income except from the sale of lapsi. Two farmers were able to produce enough food for themselves and to sell in local market places.

Farmers can sell their fruit to vendors at market centers, collection centers or to processors. Processors can sell the whole fruit to vendors at market centers or process it (Chhetri & Gauchan, 2007). Processing food is a value adding process that increases the total market value of the commodity. Processors have to purchase ingredients, packaging materials, labor and transportation to markets. This brings value to industries and commodities other than lapsi.
Lapsi is increasing in value and popularity. The market potential of lapsi as of 1997, was stated as being “high” (Gautam, 1997). Prior to the 1970’s lapsi was relatively unknown to countries where it was not grown.

Interviews with Nepali people have revealed that only in the past 10 to 20 years has lapsi become popular in Nepal. Within this time the value of lapsi has increased enough for it to become economically important. Interviews with people from India, China, and Japan have revealed that lapsi is still a relatively unknown commodity outside Nepal and Bhutan.

The barriers of lapsi entering the international market place are listed.

**Obstacles to Commercializing Lapsi in USA**

The greatest obstacles to the immediate commercialization of lapsi fruit are the laws and regulations surrounding the exportation of fruit from Nepal. As it stands, Animal Plant Health Inspection Services (APHIS) is required to conduct phytosanitary research regarding lapsi and its potential to harbor pests and diseases that could harm agricultural production in USA (out lined in greater detail in Laws and Regulations).

Consumer awareness is the second greatest obstacle for commercializing lapsi. The market for lapsi in United States has not been developed. Consumers of lapsi represent a relatively small and sparse population of Nepali and Bhutanese people. Other groups of people who may consume lapsi are identified in Target Audience.

Fruit quality, uniformity and availability are considered to be the third greatest obstacle to commercializing lapsi. Uniform fruits that free of blemishes are the most sought after due to their perceived superiority. At the time of writing, lapsi is only available from December to February. In order to develop a
consumer base, lapsi needs to be available year round unless marketing and promotions are strong enough to label it as a seasonal commodity similar to pumpkins (*Cucurbit sp.*).

Costs are identified as the fourth greatest barrier to commercialization. Shipping (air freight) can be more expensive than the cost of the raw product. The costs associated with product transportation to the shipping facility can be more than ½ or the cost of the commodity, depending on where it is being shipped from. Marketing and advertising costs associated with educating consumers are substantial.
2.4 Exporting Capabilities

Many trade networks may exist for bringing lapsi to international markets. At the time of writing, 1 known network pathway was possible for bringing lapsi into United States of America. The other identified pathways are given for comparison. The barriers to utilizing the identified pathways are also identified. The required amount of time for transport is documented. The other identified pathways were not deemed possible at the time of writing due to many factors including trade restrictions.

The majority of the lapsi fruits produced within Nepal are consumed within Nepal; however there is potential for the fruit and fruit products to be sold in international markets (Paudel et al., 2002a; Paudel, Eder, Paar, & Pieber, 2002b; Paudel 2003, and Chhetri & Gauchan, 2007). Whole lapsi fruits are restricted from import into the USA by the Food and Drug Administration. Lapsi has been sent from Nepal to Germany and Denmark for market analysis (Gautam, 1997). The results of the market analysis have not been published.

The trade route from farmer to foreign market is not well defined and can take many shapes depending on factors.

Factors Affecting Trade Networks

Trade networks are affected by market values including costs of lapsi and road access. Low market values can influence producers to not sell their lapsi. Collection centers support trade networks by connecting farmers with resources and market distributors. Processors may purchase lapsi directly from farmers or collection centers. Processors are the largest raw fruit buyers. Traders may connect farmers to processors or sell fruit directly to consumers. Laws associated with business can restrict the potential pool of consumers. Nepali law requires a
formal procedure for consumers outside Nepal, which includes the payment of the products before they are allowed to ship, which is beneficial to the distributor but adds risk to the consumer. These factors are also identified by (Poudel, 2003).

Farmers have been observed delivering lapsi fruit directly to the processor in Mudikuwa. Workers of the processing facility have been observed picking up lapsi fruit from farmers. In each instance the fruits were carried on the back of the transporter in a large woven bamboo basket. The filled weight of the basket with lapsi fruits is about 50 kg. Observed transportation time from farmer to processor in Mudikuwa varies from a 30 minutes to 1 hour.

From the processing facility in Mudikuwa, Parbat to the market in Kusma, Parbat, the transport of goods takes about 1 hour by bus. Bus time frequently changes depending on the season, road condition, number of passengers, and the condition of the bus. From Kusma, Parbat to Pokhara by bus takes 3-4 hours. From Pokhara to Kathmandu by bus takes about 8 hours. The entire trip from Mudikuwa to Kathmandu can be done in a 24 hour period but is normally split into 2-day trips with one night being spent in Pokhara.

In Pokhara, lapsi can be flown into Kathmandu, which takes about 20 to 30 minutes, but may take longer depending on delays. If this route is taken, the lapsi fruits and or products can be in Kathmandu within 4 hours from its origin in Mudikuwa. From Kathmandu the lapsi products can be flown to ports in California, USA, which takes 3 to 7 business days (including customs) (UPS correspondence), or to other ports in neighboring countries, which allow shipping to American ports. From Kathmandu, air freights stop in China. The amount of time air freights spend in China is dependent on unknown factors.
Time Requirement from the Kathmandu Airport to Shipping Ports

From the Kathmandu airport, it takes 4 hours and 30 minutes to travel, by plane, to the Hong Kong airport. If the final destination is better accessed through the Tokyo airport, it takes 10 hours to reach Tokyo from Kathmandu by plane. Mumbai is the closest major port from Kathmandu being 2 hours and 50 minutes away.

A cost estimate could not be provided due to the factors affecting shipping costs. Shipping from south East Asia and East Asia takes 30 to 32 days (personal correspondence Collado, 2015).

The largest freight port in California is in Long Beach. Other large ports on the west coast are the ports of Portland Or., and Seattle Wa. Other ports in California include Eureka, Richmond, Oakland, San Francisco, Redwood City, Hueneme, Los Angeles and San Diego. From any of these ports the lapsi products can be trucked or freighted to a market place or cold storage.

Length of time in Nepali customs

Nepali customs required about 3 days to inspect and clear a lapsi shipment in quarantine. The food products, such as lapsi candy, lapsi pickle, lapsi dust and coffee, in quarantine met phytosanitary regulations and were shipped to China. The shipment was then transferred to The United States.

Length of Time in United States Customs

United States customs required one day to inspect and clear the shipment of lapsi. The FDA put a hold on the shipment for 5 days. The FDA inspects the cargo for contamination and to make sure processed food products are complying with label requirements.
2.5 Food Science

A general assessment of the nutritional value and quality of lapsi fruit can be provided. However, due to the genetic variation within the population and the environmental conditions that affect growth and development, a detailed analysis for lapsi fruit, that holds true through all population variants, cannot be provided (Paudel et al., 2002a). The qualities of Mudikuwa grown lapsi fruits were analyzed. The results are provided in the results section.

Fruits are generally classified as: large or small, early maturing or late maturing, sweet or sour, high pulp content or low pulp content (Paudel et al., 2002a; and Paudel 2003). However many of these traits can be attributed to environmental characteristics (Paudel et al., 2002a) and nutrient and water availability (Tekin, Guzel, & Ibrikci, 1995).

Plants grown in higher elevations, on north facing slopes tend to be late maturing trees. This may be due to the delayed accumulation of growing degree days. The variation observed by farmers may also be contributed to nutrient and water availability (Tekin et al, 1995). Pest incidence and premature leaf drop may affect fruit quality, but observations suggest they do not.

Paudel et al. (2002), harvested fruits from trees between altitudes 849.7 m and 1699.8 m in various climatic conditions. The author notes a significant variance between pulp content of fruit between trees and between study areas. The fruit from the study had a pulp content rang of 23-45% with an average of 37.6%. The peel content ranged from 18-33% with an average of 22.8% and was not significantly different between sites. Seed weight comprised 20-38% of the fruit weight with an average of 22.8% and was not significantly different between sites. These values were obtained through processing, which included boiling the
fruit resulting in an estimated loss of 5.3% and 7% while separating pulp, peel and stone.

Observations of fruit processing are inconsistent with the results presented by (Paudel et al., 2002b). Processing fruit through boiling in water led to an addition of weight to the fruit. However in some instances when the fruits were over cooked, some sugars leached from the fruit into the water. This loss was measured and determined to be negligible.

The total soluble solids (TSS) and titratable acid as found by Paudel et al., (2002) ranged between 4 and 10% with an average of 6.22%. There was notable significant variation of the value of TSS in fruit from trees of the same site and at the date of harvest. The total titratable acid ranged from 2.46 to 4.97 (g/L) with an average of 3.53 (g/L). These values were significantly different between sites and trees. There was no correlation between total titratable acid and total soluble solids.

Paudel et al. (2002a), notes the pulp content of lapsi ranged from 23% to 45%. The weight of the peel ranged from 18% to 33%. The stone weight ranged from 18% to 33% of the total weight of the fruit. The average weight of the stone was 27% of the total mass. The articles by Paudel et al. (2002a) and Paudel et al. (2002b) cited Paudel (2001) (dissertation unavailable). It is unclear if Paudel et al. (2002a) and Paudel et al. (2002b) are rewritten bodies of Paudel 2001 or are original papers.

Paudel et al. (2002a) stated lapsi as having a water content of 83%. Evidence suggests, mature lapsi fruits cannot be juiced. In Paudel et al. (2002a) the total sugar content of pulp and peel was 3.4%. The total acid content of pulp and peel was 6.8%. These values fell outside the range of the values presented by
The total amino acid content of lapsi peel and pulp was found to be 317mg per 100g sample (Paudel et al., 2002b).

The nutrient content of lapsi fruit varied between trees; according to Paudel et al. (2002b) the value of potassium ranged from 327 to 428 mg per 100g. Calcium ranged from 47 to 65 mg per 100g. Magnesium ranged from 29 to 41 mg per 100g. The average of 6 trees had a potassium, sodium, calcium, magnesium, copper, iron and zinc content of 355.16mg per 100g, 2.05mg per 100g, 57mg of per 100g, 34.6mg per 100g, 0.07mg per 100g, 0.10mg per 100g, and 0.08mg per 100g respectively.

Chen et al. (2001), identified the stone weight of lapsi as 26.3% of the total weight of the fruit. The weight of the fruit was 9.5+-1.11g with a coefficient of variation of 11.8 g. The total sugar, titratable acid, protein, crude fiber, and crude fat was 3%, 1.7%, 2.7%, 1.9%, 0.6% respectively. The phosphorous, potassium, calcium, magnesium, iron, sodium, zinc and copper contents were 0.1%, 1.6%, 0.7%, 0.2%, 0.2%, 130.6 µg per g, 28.3 µg per g and 30.9 µg per g respectively. These values were taken from a population of 18 trees and had high variation between trees.

Bhutia et al. (2011) identified the fat, protein and soluble solid contents as 0.05%, 4.11%, and 9.9% respectively. Rai, Sharma, and Tamang (2005) identified the moisture, fat, and protein contents as 84.8% +1.2, 0.9% +0.3%, 2.2% +0.4%. Lapsi was found to have a sodium, potassium and calcium content of 5.0 +0.1mg /100g, 639.3mg +42mg/ 100g, and 202.1 +0.3mg / 100g respectively.

Table 3 compares the authors’ findings.

Lapsi candy, as stated by the lapsi food processor in Mudikuwa, has a shelf life of over 1 year. Lapsi pickle is said to have a shelf life of 2 years. Observations of the actual shelf life of lapsi candy is less than 4 months. All of
the lapsi candy samples shipped to United States of America spoiled within 3 months. At the time of writing, the lapsi pickle has not shown signs of spoilage.

Table 3. A Comparison of the Lapsi Nutrient Qualities Found by Different Authors.

<table>
<thead>
<tr>
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<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude fat %</td>
<td>0.05</td>
<td>0.60</td>
<td>-</td>
<td>0.90</td>
<td>0.52</td>
</tr>
<tr>
<td>Crude protein %</td>
<td>4.11</td>
<td>2.70</td>
<td>-</td>
<td>2.20</td>
<td>3.00</td>
</tr>
<tr>
<td>TSS %</td>
<td>9.99</td>
<td>3.00</td>
<td>6.22</td>
<td>-</td>
<td>6.37</td>
</tr>
<tr>
<td>Titratabile acidity g/l</td>
<td>-</td>
<td>1.70</td>
<td>3.53</td>
<td>-</td>
<td>2.62</td>
</tr>
<tr>
<td>K %</td>
<td>-</td>
<td>1.60</td>
<td>0.35</td>
<td>0.64</td>
<td>0.86</td>
</tr>
<tr>
<td>Ca %</td>
<td>-</td>
<td>0.70</td>
<td>0.06</td>
<td>0.20</td>
<td>0.32</td>
</tr>
<tr>
<td>Mg %</td>
<td>-</td>
<td>0.20</td>
<td>0.03</td>
<td>-</td>
<td>0.12</td>
</tr>
<tr>
<td>Fe %</td>
<td>-</td>
<td>0.20</td>
<td>0.00</td>
<td>-</td>
<td>0.10</td>
</tr>
<tr>
<td>Na %</td>
<td>-</td>
<td>0.13</td>
<td>0.00</td>
<td>0.01</td>
<td>0.05</td>
</tr>
<tr>
<td>Zn %</td>
<td>-</td>
<td>0.00</td>
<td>0.00</td>
<td>-</td>
<td>0.00</td>
</tr>
<tr>
<td>Cu%</td>
<td>-</td>
<td>0.00</td>
<td>0.00</td>
<td>-</td>
<td>0.00</td>
</tr>
</tbody>
</table>

The pH and water activity (aw) of the lapsi candy and lapsi pickle were analyzed. The analysis were conducted in order to determine the cause of the spoilage and to confirm or deny the production procedures were acceptable. The null hypothesis for the pH of the candy and pickle were, the pH is greater than 4.5. The alternate hypothesizes were, the pH is less than or equal to 4.5. The null hypothesis for the water activity of the candy and pickle were, aw is greater than 0.85. The alternate hypothesizes were: aw is less than or equal to 0.85. The results are reported in the results section.
2.6 Market Analysis (Market Potential)

An experiment was conducted to test the consumer acceptance of lapsi pickle. The null hypothesis of the experiment was less than 75% of the people surveyed would like or dislike lapsi pickle slightly to extremely. The null hypothesis was greater than or equal to 75% of the people surveyed would like lapsi pickle slightly to extremely. Three quartiles of likability was stated as the alternate hypothesis because that is the industry standard for sensory analysis. The procedure for the Consumer Acceptance Test is outlined in the procedure section.

**Market Analysis of Fruit**

The USDA July 2015 consumer price index (CPI) Forecast by Levin and Kuhns (n.d.) indicates there is a 3.0% 20 year historical average increase in the retail value of fruits and vegetables. In 2016 the values of fruits and vegetables are forecasted to increase by 2 to 3%. The values of fresh fruits are forecasted to increase by 2.5 to 3.5%. The values of processed fruits are forecasted to increase by 1.5 to 2.5%. The value of sugar and sweets are forecasted to increase by 2.0 to 3.0% (Levin & Kuhns, n.d.).

The results of studies on the buying habits and demographics of consumers of organic foods are varied (Greene, 2002). However, the commonalities of the conclusions garnered by the studies are that consumers prefer organic food, and they are willing to pay higher prices for it. In 2012, $28 billion of organic products were sold in the United States (Greene, n.d.). Sales of organic commodities account for over 4 percent of the total U.S. food sales. At the time of writing, the USDA does not keep or produce official statistics on organic food sales (Greene, 20 n.d.). However the information it presents on organic food
comes from Agricultural Marketing Service, Market News and “other data sources.”

A multi-level price point analysis for lapsi pickle and candy could not be conducted in the American market. Due to concerns of best manufacturing practices, consumer awareness, and spoilage retailers were unwilling to put lapsi products on their shelves.
2.7 Target Audience

In 2014, the U.S. population was 318.9 million (United States Census Bureau, 2015). According to Lin, Varyam, Allshouse, and Cromartie. (2003) 50% of the population eats fruit at home and 11% eat fruit away from home. However the standard deviation of this descriptive statistic is 50% and 31% respectively. When people eat fruit at home the average consumption quantity is 81.26 g per day. When people eat fruit away from home their average consumption is 7.57 g per day.

The United States’ average national exotic fruit consumption is 15.08 g per day (Lin et al. 2003). Americans earning greater than 300% above the poverty line consume 18.43 +/- 2.54 g of tropical fruit per day. Children of normal weight, overweight, and obese consume 16.52 +/- 1.16 g, 20.30 +/- 5.56 g, 17.14 +/- 2.87 g of fruit per day respectively. People identified as black, Hispanic and other consume 23.18 +/- 4.28 g, 24.03 +/- 2.56 g, 20.07 +/- 3.00 g of fruit per day respectively.

The people who would be most likely to have knowledge of lapsi include people in the range of where lapsi grows. This includes Japanese (population 841,824), Chinese (population 3,535,382), Asian Indian (population 2,918,807), Bhutanese (population 18,814), Thai (population 182,872), and Vietnamese (population 1,632,717) people (Hoeffel, Rastogi, Kim, and Shahid 2012). Though they may have knowledge of lapsi, they may not know that it is edible. Buzby, Wells, Axtman, and Mickey (2009) stated that consumers do not purchase products they do not have knowledge about. These population statistics do not represent the total population for the people in their group, only the population of people who responded to the survey administered for the census.
Hoeffel et al. (2012) showed the largest proportion of Asians living in the U.S. resides in the west. California has an Asian population of 5,556,592, which is 14.9% of the total population. The largest groups of Asians by percent of their population and may have knowledge of lapsi that live in California include: Asian Indian 18.5%, Chinese 36.2%, Japanese 32.8%, and Vietnamese 37.3%. These groups in addition to “True Believers” and “Enlightened Environmentalists” represent the initial target audience.

According to the companies Spins and IRI LLC (not reviewed) True Believers are believe providing their bodies with organic and natural products is the best way to attain a healthy body. Their consumption habits are motivated by health. They are also described as consumers that enjoy new products. They are defined by their educational level, age, and income (college, 40 years old and $65,000/ year respectively). Enlightened Environmentalists are described as being concerned with environmental issues and reducing their impact on the environment. They are defined by educational level, age, and income (graduate school, 57 years old, and $57,000/ year respectively).

True believers and enlightened environmentalists have been shown to have a higher interest in natural and organic foods. These 2 groups account for approximately half of all natural and organic sales. (Lin et al. 2003).

Asian American households, as defined by Shirley, Tsai, and Tan, (2006), have an average yearly income of $58,943 which is almost 300% above of the poverty line for a 2 person household. The information garnered by this paper comes from the 2003 consumer expenditure survey, which according to Bee Meyer. Sullivan (2012) may lead to biased and misleading results. Asian households, (70.2%), reported purchasing fruits compared to 62.4% for other households. Asian households spend on average $5.32 per week on fresh fruits
and $2.22 per week on processed fruit, compared to $3.22 and $2.08 respectively for other households.

The Gibson Farm Market on the California State University Fresno’s campus was selected for a product demonstration and Consumer Acceptance Test of lapsi pickle. As of 2012, Gibson Farm Market has a client base of 45-60 year olds (23.4%), and people who self-identified as being greater than 60 years old (22.8%).

Of the people who shop at the Gibson Farm Market, 68.2% are female. The majority of the customers (37%) have a household size of 2. The majority of the customers, 23.4% and 22.2%, spend between $15.00-19.99 and greater than $20.00 at the Gibson Farm Market per visit respectively. Of the customer base, 26.8% shop at the Gibson Farm Market once a week, and 35.9% shop there monthly (Dr. Dennis Ferris, unpublished data). The Gibson Farm Market was determined to be appropriate for a demonstration of lapsi pickle because of its clientele base.
2.8 Laws and Regulations

The importation of a raw commodity into the United States requires the commodity to be approved by Plant Protection and Quarantine (PPQ). In order to be approved by PPQ a commodity must first pass phytosanitary certification by Animal and Plant Health Inspection Service (APHIS). A commodity that has not been approved for import into the United States must submit a Commodity Import Request to (APHIS) in accordance with 7 C.F.R. § 319.5. The report may be submitted to APHIS formally, by letter, or informally during bilateral discussions between the United States and the exporting country. The request for importation can be made by any official in the countries National Plant Protection Organization (NPPO). At the time of writing, Nepal's NPPO officer is Dilli Ram Sharma.

The importation of lapsi fruit into the United States depends on 2 primary and 3 secondary considerations:

Primary and Secondary Considerations for the Import of Raw Lapsi Fruit

If Nepal’s national plant protection officer (NPPO) supports and prioritizes lapsi exportation, the process can be streamlined. The process is also dependent on whether APHIS prioritizes lapsi’s current import regulation (CIR) and pest risk assessment. If both Nepal’s NPPO and APHIS support and prioritize lapsi exportation, the time required to gain import permits can be reduced. However, APHIS assesses about 20 import commodities each year and lapsi from Nepal would be competing against other larger countries with commodities that may be imported in greater quantities. APHIS generally determines the prioritization of commodity import requests in the fall of each year and sets the schedule for such commodity evaluations at that time. APHIS assessments generally take about 9
months to conclude. After that, the assessment and the commodity are submitted to the proposed rule-making processes which requires time for receiving and addressing comments. Given these considerations, ultimate APHIS permission for unprocessed lapsi to enter the United States can require 1.5 years to 7 years (personal correspondence Priddy, 2015).

The importation of processed commodities requires the food manufacturing facility to be registered with the United States Department of Agriculture (USDA) and “prior notice” given to the USDA. A customs broker is required for products to clear customs. Most importing companies offer broker services for a fee. An individual may also act as his or her own broker.
2.9 Production Capabilities and Associated Costs

Observations and interviews in Mudikuwa Parbat, have allowed for the identification of prices of lapsi and lapsi products. One kg of raw lapsi fruit being sold to a fruit processor is 15 rupees or about $0.15. The retail cost, in and around Mudikuwa Parbat, for 100 g of processed lapsi candy is 35 rupees or about $0.35 and about 0.55 rupees for 250 g of lapsi pickle, which is 13.8 rupees below the average market prices of lapsi pickle. This is consistent with information obtained through an interview with the owner of the processing facility (Thaneswor Bushal), who stated the value of lapsi increases as it enters larger markets in urban areas.

The higher cost of lapsi fruit in large cities ($0.50 to $0.80 per kg) in 2015 compared to 1997, which was about $0.3 per kg, may be an indicator of increased market demand of the fruit. According to Poudel (2003), fresh fruit sold in Kathmandu during October was 10 rupees per kg but in February and March one kg sold for 40 rupees per kg in 2003.

Observations were recorded of lapsi vendors in Thamal in Kathmandu. In December lapsi vendors were selling their lapsi for 50-80 rupees ($0.50-$0.80) per kg of raw fruit. The price of the fruit could represent costs associated with being the “middle women” (no men were observed selling lapsi in Kathmandu) and a desire to make a profit.

A processor in Mudikuwa Parbat processes about 907.1 kg of lapsi fruit a year. The factory hires 1 to 2 people during lapsi season, which is about 6 months long. Gautam, K. H. (2004) has also reported the need for 1 laborer for 6 months during lapsi season, but fails to state the intensity of the output of the processing factory. Factories will have different outputs depending on different factors.
Factors Affecting Outputs of Factories

Factory output is dependent on a few requirements. The primary factor is access to lapsi fruit without competition from other factories. This includes being situated in or next to a large production area and having road access to receive lapsi and deliver processed products. The market values of lapsi fruit and processed lapsi products, which includes costs of materials such as ingredients and fire fuel, are factors affecting production.

Observations of the amount lapsi actually processed allow for the estimation of output to be about 5,987.4 to 6,350.2 kg. This figure is consistent with the number of trees identified in and around Mudikuwa, if the actual yield of each tree identified in the area surrounding the processing facility was greater than or equal to 200 kg of fruit per tree per year.

In the village Sanga located in Kavrepalanchowk district, a reportedly high lapsi production area, there are about 80 processors (Chhetri & Gauchan 2007). There are 3 other districts that have similar production rates (Paudel et al., 2003; Paudel et al., 2002a). There are 5 districts that are reported as having medium production rates, which parbat is in. there are 19 reported low intensity production districts (Paudel et al., 2003; Paudel et al., 2002a).
2.10 Economics of Lapsi Business in USA

The wholesale cost of one 250 g package of lapsi pickle in 2015 was $0.42. The cost of one 100 g package of lapsi candy was $0.19. Packaging for 1,200 packages of lapsi pickle and 3,000 packages of lapsi candy cost $198 and $200 respectively. The cost of shipment from Kathmandu, Nepal to Fresno, California, USA was $2,891 (Table 1).

<table>
<thead>
<tr>
<th>Subject</th>
<th>Lapsi pickle cost</th>
<th>Lapsi candy cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost per unit units</td>
<td>$0.42</td>
<td>$0.19</td>
</tr>
<tr>
<td>Number of units</td>
<td>1,200</td>
<td>3,000</td>
</tr>
<tr>
<td>Transport costs</td>
<td>$1,445.50</td>
<td>$1,445.50</td>
</tr>
<tr>
<td>Labels</td>
<td>$198.00</td>
<td>$200.00</td>
</tr>
<tr>
<td>Total cost</td>
<td>$2,147.50</td>
<td>$2,215.50</td>
</tr>
</tbody>
</table>

A single and multi-level price determination could not be calculated.

Grocery stores, outdoor food markets and food trucks in Fresno, California were hesitant to sell lapsi pickle or provide vendor space for the sale of lapsi pickle.

Interviews with shop owners identified their hesitations for reselling lapsi pickle. Their reluctant nature was due to the packaging of the lapsi pickle, which is plastic. They perceived plastic packaging as inferior to glass. Shop owners believed the product was too expensive. A value was not placed on the product by the shop owners but it is believed that anything less than 1 dollar would be acceptable. All of the shop owners interviewed did not know what the product was and therefore believed their customers would not know what it is or want it. A few shop owners said it looked unappealing, but it does not look very different from mango chutney, which was sold in their stores. The store owners believed
foreign produced products carry too much risk, but the majority of their products are produced in a county or countries outside the USA.
CHAPTER 3: PROCEDURE AND METHODS

Sampling began on 9/25/2015. Three trees were initially selected on 09/25/2014 to take part in the study. The trees were selected based on proximity to the processing facility and perceived quality of their fruit. After the first sample was taken, a fourth tree was included into the sample population on 10/03/2015. The area surrounding the lapsi trees were planted with millet.

Fruit was stored in a mud brick house that had an average temperature of 18.35 degrees C with a range of 11.1 to 26.5 degrees C. Fresh fruit was tested within one hour of harvesting. The frequency of fruit harvest was no less than once every other week and no more than once every week. Some harvesting dates were missed due to holidays, weather and the unavailability of the farmers.

To ensure the fruits that were collected were from that days sampling, the fields surrounding the trees were searched for previously fallen fruits. Blankets were laid down to collect the harvested fruit. Lapsi fruit was harvested by shaking the trees, hitting the branches with long sticks and throwing sticks at the fruits. Generally, 10 to 20 fruit were taken from each tree.

The procedure for measuring pH was taken from Guidelines for pH Measurement in Conservation by Season (Tse, 2007).

Stored Fruit Procedure

On 9/25/2015, trees in the study site were labeled: tree 1, tree 2 and tree 3. From tree 1, 14 fruits were collected. From tree 2, 8 fruits were collected. From tree 3, 18 fruits were collected. The fruits were washed with tap water, pictures of the fruits were taken and the fruits were weighed. Two fruits from each tree were chosen at random. The fruits were processed for brix and pH.
The fruit pulp was removed from the seed stone by cutting off the mesocarp with a knife. The mesocarp slices were blended in a small blender. Approximately 5 ml of fluid was extracted and tested for brix and pH. Each sample was processed independently of the others and the instruments were cleaned in-between processing.

On 10/09/15, the remaining fruits from each of the 9/25/2015 samples were analyzed. The fruits were processed by rubbing off the exocarp and mesocarp with a stainless steel grater then pressing the gratings in a stainless steel garlic press. The solutions were analyzed for pH and brix. Each sample was processed independently of the others and the instruments were cleaned in-between processing.

The containers holding the 10/9/15 samples were needed by the owner of processing facility. The containers were taken and the samples in them were put into a single container. Every effort was made to separate the samples into their original groups. Due to the uncertainty of the samples origins, they were processed in the same manner as the collective samples.

On 10/23/2015, 2 fruits from each sampling population from 10/15/2015 were chosen at random and processed. The fruits were held in a brick and mud building with slight ventilation. A pH probe was used to measure the temperature, which was recorded at 21.4 degrees C.

The fruits were processed by rubbing off the exocarp and mesocarp with a stainless steel grater then pressing the gratings in a stainless steel garlic press. The solutions were analyzed for pH and brix. Each sample was processed independently of the others and the instruments were cleaned in-between processing.
On 11/6/2015, 2 fruits from each of the sampling populations that were harvested on 10/15/2015 were chosen at random and processed. The temperature of the room, measured by pH probe, was recorded at 20.2 degrees C. The samples 1, 2, 3, and 4 were processed separately by boiling in 40ml, 40ml, 80ml, and 70ml of water respectively for 10 minutes. The exocarps were removed and discarded. The mesocarp was separated from the endocarp by hand and analyzed. The mesocarp of samples 1, 2, 3, and 4 were analyzed for brix % and pH after water had been added to the samples. The water the samples were boiled in was analyzed for brix % and pH.

On 11/18/2015, 2 fruits from each of the sampling populations that were harvested on 10/15/2015 were chosen at random and processed. The temperature of the room, measured by pH probe, was recorded at 18.9 degrees C. The fruits were boiled for 5 to 7 minutes. The exocarps were removed and discarded. The mesocarps were removed by hand and analyzed for brix % and pH. The water the samples were boiled in was analyzed for brix % and pH.

On 12/4/2015, 2 fruits from each of the sampling populations that were harvested on 12/01/2015 were chosen at random and processed. The temperature of the room, measured by pH probe, was recorded at 17.4 degrees C. The fruits were boiled for 5 to 7 minutes. The exocarps were removed and discarded. The mesocarps were removed by hand and analyzed for brix % and pH. The water that the samples were boiled in was analyzed for brix % and pH.

**Fresh Fruit Procedure**

On 10/03/2015 a fourth tree was added to the sampling population. The fourth tree was labeled tree 4. From tree 1, 11 fruits were harvested. From tree 2,
16 fruits were harvested. From tree 3 13 fruits were harvested. From tree 4, 14 fruits were harvested. The samples were washed, photographed and weighed.

The fruits were processed by rubbing off the exocarp and mesocarp with a stainless steel grater then pressing the gratings in a stainless steel garlic press. The solutions were analyzed for pH and brix. Each sample was processed independently of the others and the instruments were cleaned in-between processing.

On 10/15/2015 20 fruits from each of the 4 sampling trees were taken. From the samples, 10 fruits were chosen at random to be collectively analyzed. Of the 10 fruits chosen at random 2 fruits from each sample were randomly selected to be analyzed by rubbing off the exocarp and mesocarp with a stainless steel grater then pressing the gratings in a stainless steel garlic press. The solutions were analyzed for pH and brix. Each sample was processed independently of the others and the instruments were cleaned in-between processing. This was done to determine if there is difference in processing methods.

The remaining 8 fruits in the sample from tree 1 were boiled in 20 ml of tap water for 20 min. The exocarps of the fruits were separated from the mesocarps by pinching one side of the fruit. The mesocarps were separated from the endocarp by rubbing the fruit in hand. The pH and brix of the boiled water were taken. The pH and brix of the mesocarps were taken. The endocarps and the exocarps were mixed in the boiled water and the pH and brix were analyzed.

The remaining 8 fruits in the samples from tree 2, tree 3, and tree 4 were boiled in an unmeasured amount of water, estimated to be between 30 and 40 ml, for 4 min 4min and 8 min respectively. The exocarps of the fruits were separated from the mesocarps by pinching one side of the fruit. The mesocarps were separated from the endocarp by rubbing the fruit in hand. The pH and brix of the
boiled water were taken. The pH and brix of the mesocarps were taken. The endocarps and the exocarps were mixed in the boiled water and the pH and brix were analyzed.

In all the samples from 10/15/2015, the fruits were not washed before analysis. A rain storm occurred the night before the samples were collected. The samples were presumed clean by the rain. In-between processing of all the samples, the equipment was cleaned.

On 10/29/2015, 13, 15, 14, and 14 fruits were collected from sample trees 1, 2, 3, and 4 respectively. Each sample was analyzed by boiling in 100ml of water for 5 minutes. The exocarp of the fruits were removed and discarded. The mesocarps were removed by hand. Water was added to the mesocarp in a measuring cup to aid in analysis. The samples were analyzed for brix % and pH. The water the samples were boiled in was analyzed for brix % and pH. After each sample was analyzed the instruments were cleaned.

On 11/11/15, 16, 10, 16, and 16 fruits were collected form sample trees 1, 2, 3, and 4 respectively. Each sample was analyzed by boiling in 100ml of water for 7 minutes. The exocarp of the fruits were removed and discarded. The mesocarps were removed by hand. Water was added to sample 1 to aid in analysis but was not added to the other 3 samples. Samples were analyzed for brix % and pH. The water the samples were boiled in was analyzed for brix and pH. After each sample was analyzed the instruments were cleaned.

On 12/01/15, 10 fruits from each sampling tree were collected. Each sample was boiled for 5 to 7 minutes. The exocarps of the fruits were removed and discarded. The mesocarps of the fruits were separated from the endocarp stone by hand. The mesocarps were analyzed for brix % and pH. The water the
samples were boiled in was analyzed for brix % and pH. After each sample was analyzed the instruments were cleaned.

On 12/12/15, 13, 10, 12, and 10 fruits were collected from sampling trees 1, 2, 3, and 4 respectively. Samples from trees 1, 2, 3, and 4 were boiled in 260, 200, 280, and 270 milliliters of water respectively. The exocarps of the fruits were removed by hand and discarded. The mesocarps were removed from the endocarp stone by hand. The mesocarps were analyzed for brix % and pH. The water the fruits were cooked in was analyzed for brix % and pH. The instruments were cleaned after each use.

Consumer Acceptance Test Procedure

A booth was constructed at the Gibson Farm Market. A stack of consent forms and questionnaires (Appendix 1) were placed at the start of the table. A gallon water dispenser and cups were placed next to the consent forms and questionnaires. Lapsi pickles were placed into serving cups on a serving tray with a lid next to the water dispenser. Spoons and napkins were placed next to the serving tray.

Customers of the Gibson Farm Market were asked to volunteer for the Consumer Acceptance Test. The customers that agreed to participate were then asked to sign the consent form. After the consent form was signed the volunteers were asked to take a drink of water. The lid to the lapsi pickle serving container was then removed. The volunteer was asked to take any sample they wanted. After eating the sample the volunteers were given instructions on how to fill out the survey.
2,3,5-Triphenyl-2-Tetrazolium

Seeds were separated from their seed stone by grinding the tops and bottoms flat then pinching the seed apart with hoof nippers. A 10% 2,3,5-triphenyl-2- tetrazolium (tetrazolium) was made by weighing 10 g increments of tetrazolium and adding it to 100 milliliter increments of water. The 10% solution was then added to plastic cups. Seeds were split down their longitudinal axis and placed in the solution. The seeds were allowed to soak in the tetrazolium bath for 24 hours. After 24 hours the seeds were analyzed for color.

pH Lapsi Candy

A slurry of lapsi candy was made by applying 200 ml to 300 g of lapsi candy. A pH probe was then standardized using a 2 point check with a known pH solutions, pH 7 and 4. Samples were drawn from the lapi slurry and analyzed for pH. The pH probe was cleaned between each sample.

pH Lapsi Pickle

Packages of lapsi pickle were opened and sectioned into 3 parts. A pH probe was then standardized using a 2 point check with a known pH solutions, pH 7 and 4. Samples were drawn from the parts and analyzed for pH. The pH probe was cleaned between each sample.

Water Activity of Lapsi Candy

Packages of spoiled lapsi candy were opened. One piece of candy was placed in a sample cup then placed inside a model CX-2 water activity meter from Aqua Lab. The procedure was repeated 14 times.
Water Activity of Lapsi Candy

Packages of lapsi pickle were opened. Pieces of pickle were scraped from their seeds and placed in a sample cup then placed inside a model CX-2 water activity meter from Aqua Lab. The procedure was repeated 3 times.
CHAPTER 4: RESULTS

Collections of unripe to ripe lapsi fruit from 4 trees on October 3 in Mudikuwa were weighed. The average weight per fruit for trees 1, 2, 3 and 4 were: 10.64g, 13.19g, 11.69g, and 17.14g respectively. The range of the weights of the fruits from trees 1, 2, 3 and 4 were: 7g to 12g, 9g to 16g, 8g to 13g and 10g to 20g. Trees 2, 3, and 4 were classified as large sweet fruit by the owner of the lapsi processing facility and tree 1 was classified as small and undesirable. The trees were estimated to yield 3 to 5 quintal, by the owner of the lapsi processing facility, which is approximately 300kg to 500kg. The owner of the trees estimated the yield to be approximately 200kg.

**pH and Brix of Fresh and Stored Lapsi Fruit**

All ANOVA and Model Summery tables were produced by SPSS and imported as figures. They are referred to as figures in the proceedings.

The data on brix for fresh lapsi fruit was analyzed using SPSS. The data were analyzed using a linear regression analysis. At a 0.05 confidence interval, brix is significantly correlated to the amount of time the fruit is left on the tree. The R value was found to be 0.912. The R Square value was found to be 0.832. The P value was found to be 0.011 (Figures 38a and 38b).

The data on brix for stored lapsi fruit was analyzed using SPSS. The data were analyzed using a linear regression analysis. At a 0.05 confidence interval, brix is not significantly correlated to the amount of time the fruit was in storage. The R value was found to be 0.847. The R Square value was found to be 0.717. The p value was found to be 0.153 (Figures 39a and 39b).

The data on the pH of fresh lapsi fruit was analyzed using SPSS. The data were analyzed using a linear regression analysis. At a 0.05 confidence interval,
pH is significantly correlated to the amount of time the fruit is left on the tree. The R value was found to be 0.906. The R Square value was found to be 0.821. The p value was found to be 0.013 (Figures 40a and 40b).

Model Summary

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adj R Square</th>
<th>Std Error of Estimate</th>
<th>Change Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R Square Change</td>
</tr>
<tr>
<td>1</td>
<td>0.912</td>
<td>0.832</td>
<td>0.790</td>
<td>1.52038</td>
<td>832 19.858 1 4 0.011</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), weeks

ANOVA \(^3\)

<table>
<thead>
<tr>
<th>Model</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
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<td>4.958</td>
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<tr>
<td>Residual</td>
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<td>4</td>
<td>2.311</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>5</td>
<td>55.149</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. Dependent Variable: brix

b. Predictors: (Constant), weeks

Figure 38a. A model summary of the brix measurement of the fresh fruit analyzed (top)
Figure 38b. The ANOVA figure of the fresh fruit analyzed for brix (bottom).

Model Summary

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adj R Square</th>
<th>Std Error of Estimate</th>
<th>Change Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R Square Change</td>
</tr>
<tr>
<td>1</td>
<td>0.847</td>
<td>0.717</td>
<td>0.776</td>
<td>0.6902</td>
<td>717 5.069 1 2 0.153</td>
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</tbody>
</table>

a. Predictors: (Constant), weeks

ANOVA \(^2\)

<table>
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<tr>
<th>Model</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Regression</td>
<td>1</td>
<td>4.013</td>
<td>5.069</td>
<td>.153 (^b)</td>
</tr>
<tr>
<td>Residual</td>
<td></td>
<td>2</td>
<td>.792</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>3</td>
<td>5.597</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. Dependent Variable: brix

b. Predictors: (Constant), weeks

Figure 39a. A model summary of the brix values of the stored lapsi fruit (top).
Figure 39b. The ANOVA figure of the brix values of the stored lapsi fruit (bottom).
The data on stored lapsi fruit pH were analyzed using SPSS. The data were analyzed using a linear regression analysis. At a 0.05 confidence interval, the pH of the stored fruit is not significantly correlated to the amount of time the fruit was stored. The R value was found to be 0.288. The R Square value was found to be 0.083. The p value was found to be 0.712 (Figures 41 a and 41 b).

The data on the weight of fresh lapsi fruit were analyzed using SPSS. The data were analyzed using a linear regression analysis. At a 0.05 confidence interval, the weight is not significantly correlated to the amount of time the fruit was allowed to mature. The R value was found to be 0.522. The R Square value was found to be 0.272. The p value was found to be 0.1 (Figures 42 a, b, and c).

Figure 41a. A model summary of the pH values of stored lapsi fruit.
Figure 41b. The ANOVA figure of the values of pH of stored lapsi fruit.

<table>
<thead>
<tr>
<th>Model</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
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<td>.002</td>
<td>.180</td>
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<tr>
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<td>Residual</td>
<td>.025</td>
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<td>.013</td>
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<td></td>
<td>Total</td>
<td>.027</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

a. Dependent Variable: pH

b. Predictors: (Constant), weeks

Figure 42a. A model summary of the weight of fresh fruit.

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std. Error of the Estimate</th>
<th>Change Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>.372</td>
<td>.191</td>
<td>47509</td>
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</tr>
</tbody>
</table>

a. Predictors: (Constant), sample date

Figure 42b. The ANOVA figure of the weight of fresh lapsi fruit.

<table>
<thead>
<tr>
<th>Model</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Regression</td>
<td>.759</td>
<td>1</td>
<td>.759</td>
<td>3.363</td>
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<tr>
<td></td>
<td>Residual</td>
<td>2.031</td>
<td>9</td>
<td>.226</td>
<td></td>
</tr>
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<td></td>
<td>Total</td>
<td>2.791</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. Dependent Variable: weight

b. Predictors: (Constant), sample date

2,3,5-Triphenyl-2-Tetrazolium Chloride

The viability results were not analyzed using statistical software. The results of the viability test showed 100% viability. Seeds consumed by frugivores germinated a month earlier than non-digested seeds.

Consumer Acceptance Test

Based on the data collected from the Consumer Acceptance Test at the Gibson Farm Market, lapsi pickle is liked by 80% of the tested population.
Figure 42c. The graph of the weights of the lapsi fruits by time sampled.

**pH of Lapsi Candy and Pickle**

The average pH of the lapsi candy was found to be 2.89 with a range of 2.87 to 2.93. The average pH of the lapsi pickle was found to be 2.64 with a range of 2.58 to 2.74.

**Water Activity of Lapsi Candy and Pickle**

The average water activity of lapsi candy was found to be 0.700 with a range of 0.672 to 0.717. The average water activity of lapsi pickle was found to be 0.853 with a range of 0.85 to 0.858
4.1 Discussion

During the first 3 months of Peace Corps training, Peace Corps trainees learn cultural etiquette and gain language proficiency specific to their host country. After the end of training Peace Corps trainees become volunteers and are sent to their host families. At this point of service the language proficiency of the author was tested by a certified language examiner. The author received an intermediate-mid level proficiency grade.

Intermediate-mid level proficiency in language is considered average fluency. Average fluency may not be considered adequate in conducting surveys due to the subtleties in communication that are not understood by the foreign speaker. Although every effort was made to understand the surveys information may have been “lost in translation”.

Due to the awkwardness in cultural etiquette by the interviewer and lack of sufficient language skills, interviewees may have answered interview questions with disdain and thus provided inaccurate information. This may be a reason for some of the discrepancies between published literatures and the results in this paper.

Throughout this paper some authors are cited multiple times. This is due to the limited amount of information and publications available and relating to lapsi, lapsi fruit production and processing, and lapsi marketing. Some authors have more than one publication on the topics presented in this paper and are thus cited more heavily.
CHAPTER 5: CONCLUSION

Based on a Consumer Acceptance Test, lapsi pickle has an 80% likeability factor in the consumer population at Gibson Farm Market. The measured water activity from random samples of lapsi pickle were at or above the 0.85 threshold of acceptable levels set forth in the Code of Federal Regulation Standards for Hot Fill Hold processing. The current best production procedures for lapsi pickle does not meet FDA regulation, 21 CFR 113.3(e) (1) (ii), to destroy vegetative cells of microorganisms of pathogenic or spoilage concern and are deemed unfit for human consumption due to the lack of commercial sterility.

Lapsi candy was not found to be an acceptable product for American consumers because its shelf life is too short. Even though the pH and water activity are within the range deemed safe by the USDA, spoilage occurred within 4 months. Identification of the spoilage organism was not identified but is believed to be a yeast. The pathway of spoilage was not identified, but is believed to be the result of best production practices, which are believed to be not commercially sterile and in violation of FDA code 21 CFR 113.40(i).

The brix of fresh lapsi fruit has a high correlation to the amount of time it is left on the tree. The brix increased as time increased. The amount of variance that can be accounted for is 83%. The pH of fresh lapsi fruit has a high correlation to the amount of time it is left on the tree. The pH decreased as time increased. The amount of variance that can be accounted for is 82%.

Lapsi seeds were found to be 100% viable. Warm, wet and sunny environmental conditions are required for growth. Growth was observed in USDA hardiness zone 9b and in Cw in the koppen climate classification system.
REFERENCES


APPENDIX: CONSENT FORM
CALIFORNIA STATE UNIVERSITY, FRESNO
DEPARTMENT OF PLANT SCIENCE

CONSENT TO PARTICIPATE IN THE FOLLOWING STUDY

I, (please print)_____________________________________________ hereby willingly and voluntarily consent to participate as a subject in the research project entitled “An Analysis of Choerospondias axillaris “Lapsi” Regarding Production, Product Development and its Effect on Rural Lapsi Farmers in Nepal” conducted by Craig Seber, masters candidate in Plant Science at the California State University, Fresno. The California State University, Fresno Committee on the Protection of Human Subjects has reviewed and approved the procedures for this research, which is determined to be of minimal risk to participants.

I understand the procedures for participating in the project are as follows:

I will taste a sample of lapsi pickle (recipe appears below) and record my results on an accompanying score sheet. To the best of my knowledge, I have no known allergies to any of the ingredients listed in the recipe.

I understand that my name will be kept confidential and the consent form will be saved for 1 year.

I understand that my participation in this study does not in any way affect my relationship with California State University, Fresno.

I understand that I may quit or decline to participate in the study at any time.

The lapsi pickle contains the following ingredients:
Lapsi Fruit
Mustard Oil
Sugar
Salt
Chili Powder
Fennel
Black Cumin
Turmeric
Fenugreek
Allium hypsistum

I fully understand the terms of my consent and agree to participate in the study.

Signed ___________________________________________________________
Consumer Acceptance Test

Name ________________________                         Date ___________________

Type of Sample:  Lapsi Pickle

- Please rinse your mouth before starting.
- Evaluate the product in front of you by looking at it and tasting it.
- Considering ALL characteristics (APPEARANCE, FLAVOR, and PUNGENCY)
  indicate your overall opinion by checking one box [ 4 ].

\[ \begin{array}{cccccccc}
\text{Dislike} & \text{Dislike} & \text{Dislike} & \text{Dislike} & \text{Neither} & \text{Like} & \text{Like} & \text{Like} \\
\text{Extremely} & \text{Very Much} & \text{Moderately} & \text{Slightly} & \text{like nor dislike} & \text{Slightly} & \text{Moderately} & \text{Very Much} & \text{Extremely}
\end{array} \]

Comments: Please indicate WHAT in particular you liked or disliked about this product.

(USE WORDS NOT SENTENCES).

LIKED

________________________
________________________
________________________

DISLIKED

________________________
________________________
________________________
Fresno State

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Craig Wayne Cole Seber

Type full name as it appears on submission

October 31, 2016

Date