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Post-harvest losses in Potato in Nyandarua County

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Introduction

Irish potato is the second most important food crop in Kenya after maize (Kaguongo et al., 2014). Potato production in Kenya is expected to grow, as farmers are being encouraged both by climate shifts and by the government to diversify their production from reliance on maize. Many farmers are opting to grow potato because it is fast-maturing compared to maize and can be used to bridge the gap during shortages of the staple grain (ibid). However, significant barriers exist to more productive and profitable potato cultivation in East Africa, including low quality of seed potato, poor disease and soil fertility management, and high rates of post-harvest losses (Schulte-Geldermann, 2013). Average potato yields in Nyandarua County are 3-4 tonnes per acre per season, well below the 10 tonnes per hectare that can be realised by professional farmers using certified seed and sound agricultural practices (Kaguongo et al., 2014).

The goal of this study is to understand the drivers of post-harvest losses in Irish potato in Nyandarua County. The specific research questions are:

1) What is the level of post-harvest losses in potato in Nyandarua County?
2) At what stage do the majority of losses occur?
3) What are the main drivers of post-harvest loss at each stage?
4) What policy options can be considered to reduce PHL in potato?
5) What is the economic impact of the losses of potato in Nyandarua?

Methods

The population of interest is farmers in Nyandarua who grow and sell Irish potato. Two wards from each of Nyandarua's five constituencies were

randomly selected for the study.1 Potato-growing villages within each of these wards were then identified through discussion with county agricultural officers, and one potato-growing village per ward was randomly selected. These villages were subsequently visited to obtain a list of farmers who grow Irish potato. From these lists, 15 farmers per village were randomly selected as the primary sample and 10 farmers were randomly selected as back-ups in case those on the primary sample list were not available or declined to participate.

Sample size calculations were based on the characterization of post-harvest losses for this crop in a previous study conducted in Nyandarua (Kaguongo et al., 2014). Using a smaller sample of 73 farmers recruited from four sub-counties of Nyandarua, the authors found that 19.4% of potato value was left in the field or lost to damage and rot post-harvest.2 This figure was expected to mask significant variation based on the variety grown. According to the Kaguongo et al. study, 100% of farmers grew Shangi, and approximately 60% also grow another potato variety. By asking about losses by variety, we aimed to characterise the impact of variety on loss. With a sample of 150 farmers, approximately 90 of whom were expected to grow a non-Shangi variety, we expected be able to detect a 17.8 percentage-point difference in proportional losses (10.5% vs. 28.3%) around this mean between Shangi and non-Shangi varieties, with power of 0.8 and alpha of 0.05 (two sided-test).

Intermediaries who collect potato at the farm gate and retailers to whom farmers sold directly were identified by asking farmers to provide contact information for those to whom they sold. Additional retailers were identified through intermediary referrals. The combined target sample size for intermediaries and retailers was 60. The study was conducted in October after the majority of harvests and sales for the long rains 2019 (cropping

[1] The selected wards are as follows: in Kinangop, North Kinangop and Nyakio; in Kipipiri, Kipipiri and Wanjohi; in Ndaragwa, Central and Kiriita; in Ol Jororok, Gathanji and Weru; and in Ol Kalou, Karau and Rurii.

[2] The sub-counties included in that study were Kinangop, Mirangine, Nyandarua North and Ol Kalou.

period of April to September) had been completed. All of the following discussion relates to this completed potato cropping season.

Results

Farmer characteristics and potato production

Data was collected from 150 farmers over the 2019 long rains season, with cropping from April to July/Aug and marketing Aug-Oct. As can be seen in Table 1, just under half of the farmers interviewed were women and the average household size was 4.45 individuals. The majority of farmers (56%) had attained primary education or less. The average area of agricultural land owned is 2.55 acres, 28% of which acres of which was devoted to potatoes during the 2019 long rains season. By far the most frequently produced variety of potato is Shangi. 94 percent of farmers grew this variety while only 11 percent grew a variety other than Shangi. Because there are so few non-Shangi observations, and the number of observations for any specific non-Shangi variety is even fewer, we analyze post-harvest losses for all types of Irish potato grown, rather than comparing across varieties as originally planned. The most common other varieties grown are Kanyoni and Dutch Robjyn. The majority of farmers had finished harvesting potato for the season at the time of the interview and Shangi represented 85% of the harvest. Potato yields in this sample are considerably lower than those shown in county statistics, at just 2.4 tonnes per acre on average, with the median slightly lower at 1.7 tonnes per acre. This could reflect differences between the random sampling methodology used for this study, versus county surveys that may rely on agricultural extension agents to identify farmers.

Table 1: Farmer characteristics and potato production

	Observations	Median	Mean	Std Dev
Age	150	53	52.4	13.2
Female	150	0	0.45	0.50
Education level:				
None / Adult education	150	0	0.05	0.23
Primary (some or completed)	150	1	0.51	0.50
Secondary (some or completed)	150	0	0.33	0.47
Post-secondary	150	0	0.11	0.31
household size	150	5	4.45	1.99
Total land (acres)	150	2	2.55	2.24
Potato land (acres)	150	0.50	0.72	0.81
Prop. planted shangi	150	1	0.94	0.24
Prop. planted other	150	0	0.11	0.31
Shangi harvest (kg)	141	700	1961	3938
Other harvest (kg)	16	255	338	310
Prop. still planning to harvest shangi	141	0	0.02	0.14
Prop. still planning to harvest other	16	0	0.06	0.25
Remaining shangi harvest (kg)	3	140	1821	2970
Remaining other harvest (kg)	1	45	45	0
Shangi yield (kg per acre)	141	1749	2361	2080
Other yield (kg per acre)	16	1116	1484	1159

Variety choice

Table 2 shows the reasons that farmers, intermediaries, and retailers, chose to produce or trade in Shangi, the primary variety grown in Nyandarua. Reasons given by farmers for their choice of the Shangi variety included its high yield, ease of sale, and fast maturation. Availability and ease of sale are the primary reasons for trading in Shangi listed by intermediaries and retailers. Two retailers (10% of the total) identified resistance of the variety to spoilage, and 35% included this among their top three reasons.

Table 2: Reasons for selecting Shangi variety

	Main reason			Top 3 reasons		
	Farmers	Inter-mediaries	Retailers	Farmers	Inter-mediaries	Retailers
Percentage listing reason as:						
Widely Available	44	43	30	64	69	55
Disease resistant	4	0	0	11	0	0
Fast-maturing	13	0	0	46	0	0
Lasts long / resistant to spoilage	1	0	10	06	12	35
Quick cooking	0	2	05	05	21	30
Good flavor	0	2	05	17	31	35
Size	0	0	0	02	0	5
Easy to sell / Preferred at market	14	50	50	37	88	75
Good price	0	0	0	1	0	0
High yielding	21	0	0	52	0	0
Other	03	0	0	10	0	0
Observations	141	42	20	141	42	20

Reported challenges

Table 3 shows the main challenges faced by farmers in potato production. 43 percent of farmers list pests and disease as their main challenge, while 75 percent count this among their top three challenges. The two other most frequently cited challenges are the price of potatoes and access to inputs such as pesticides and fertilizers. Among the other challenges listed, soil quality or lack of soil testing were mentioned by four farmers (3% of the total).

Table 3: Farmer-reported challenges in potato production

	Main challenge	Among top 3 challenges
Percentage listing challenge as:		
Market demand	2	13
Sales price	13	49
Extended bags	3	15
Access to mechanization / machinery in production and harvest	0	1
Pests and Disease	43	75
Inputs (fertilizer, pesticides)	13	44
Access to certified seeds	8	14
Storage	0	1
Post-harvest losses	0	2
No other challenges	0	28
Weather	9	22
Lack of access to quality seed	3	3
Inputs too expensive	3	5
Other (specify)	3	19
Observations	150	150

From Table 4 (next page), it can be seen that none of the farmers in the sample used certified seed, and only 2 percent of farmers used professionally produced clean seed. Instead, almost all farmers interviewed reported using seed they have saved, which is often riddled with soil- and seed-borne diseases after years of recycling seed, resulting in low yields (Forbes et al., 2020). Most farmers (71%) have never bought seed, only bought once, or buy new seed after more than 5 years. This suggests that increasing farmer use of high-quality seed could be an effective way to reduce the prevalence and spread of potato pests and disease transmitted by seed, principally bacterial wilt (BW), potato cyst nematode (PCN), viruses and Rhizoctonia.

Table 4: Seed type and source

	Mean	Std Dev
Seed type:		
Farmer saved	99	12
Clean seed (professionally produced, not certified)	2	14
Certified seed	0	0
Seed source:		
Farmer saved seed	73	45
Neighbor	17	38
Shop / local market	9	28
Potato buyer	1	8
Clean seed producer	1	8
Other	1	12
Frequency of seed purchase:		
Never buys or has only bought once	35	48
Every season	3	18
Every second season	11	31
Every 3 seasons	7	25
Every 4 seasons	4	20
Every 5 seasons	4	20
After more than 5 seasons	36	48
Other	3	16
Observations	150	

Rotation of the potato crop with other crops is the key practice to manage soil-borne pests and diseases. Table 5 shows that 90 percent of farmers rotate their potato crop, with the majority doing this every one to two seasons. Maize was the most frequently planted crop during rotation, followed by vegetables and beans. While farmers rotate, the rotation cycle is insufficient to manage persistent soil-borne diseases and pests such as BW and PCN, which are widespread in Nyandarua (Were et al, 2013). Once these pests and diseases are introduced in the soil, by seed or run-off, 5 to 15 years are needed to eradicate them from the soil (Duceppe et al, 2017; Hayword, 1991)

Table 5: Rotation with other crops

	Mean
Percentage that rotate or leave fallow	90
Observations	150
Number of consecutive seasons planted to potato before rotating:	
1 season	53
2 seasons	40
3 seasons	4
4 seasons	1
More than 4 seasons	2
Number of seasons between potato crop:	
1 season	70
2 seasons	27
3 seasons	2
4 seasons	1
Proportion farmers that rotated with:	
Vegetables	52
Maize	64
Beans	27
Oats	13
Fallow	1
Other	2
Observations	135

The frequency of disease as a challenge to farmers is again apparent in the high proportion (93%) of farmers who state that they observed a disease on their potatoes during the most recent growing season (Table 6). The most frequently observed disease was late blight, indicated by 88% of farmers who noticed a disease. BW was also a common occurrence, with over half of these farmers listing it. While other diseases cause wilting (for example Fusarium, Pectobacterium), most farmers attribute wilting symptoms to BW. 82 percent of farmers sprayed against disease. Of the major diseases reported by farmers, spraying is only effective against late blight, having no effect on BW or PCN. Formulations based on the non-systemic fungicide mancozeb, such as Ridomil, Mistress, and Agromax were by far the most frequently used chemicals.

Table 6: Disease incidence and management

	Observations	Mean
Observed any disease	150	93
Proportion that observed:		
Late blight	139	88
Bacterial wilt (wilting symptoms)	139	58
Other	139	02
Don't know	139	01
Managed any disease	150	82
Proportion that sprayed:		
Mancozeb-based *(all)*	123	86
Mancozeb + Metalaxyl *(Ridomil, Master)*	123	58
Mancozeb + Cymoxanil *(Mistress, Agromax)*	123	33
Chlorothalonil *(Daconil)*	123	1
Propamocarb hydrochloride + fluopicolide *(Infinito)*	123	2
Propineb + cymoxanil *(Milraz)*	123	3
Other	123	21
Don't know	123	7

Pre-harvest practices are described in Table 7. Most farmers (84%) indicated that they prepared their potatoes prior to harvest, either through mechanical dehaulming (that is, cutting off the stems and leaves while leaving the tubers in the ground) or leaving the plants to die back. This pre-harvest step reduces post-harvest losses in potato by causing the skin of the crop to harden. Simply allowing the plants to die back was the most common method of harvest preparation, used by 75% of farmers who prepared their crop for harvest in some way.

Most of the farmers who did not prepare their potato for harvest either were not aware of the benefits (39%) or harvested early to avoid harvesting during rains. Among farmers who engaged in pre-harvest preparation, the average length of time between preparation of the crop and harvest was approximately 16 days.

Table 7: Pre-harvest practices

	Observations	Mean	Std Dev
% prepared potato before harvest	150	84	37
How potato was prepared:			
% mechanical dehaulming (cutting back)[3]	126	26	44
% leave to die back	126	75	44
Reason did not prepare (percentages):			
Don't know how	23	09	29
Harvests early to get high prices	23	04	21
Harvests early to avoid rains	23	17	39
Don't want to incur extra cost	23	09	29
Don't have time	23	09	29
Don't see the benefits	23	39	50
Other reason	23	26	45
Days between preparation and harvest	126	15.6	9.4

[3] The proportions who left to die back and used mechanical dehaulming sum to over 100% because one farmer used both approaches.

Table 8: Harvest conditions and practices

Weather during preparation and harvest (%):	Observations	Mean	Std Dev
Wet	150	36	48
Moderate (not too wet or dry)	150	38	49
Dry	150	26	44
Soil during preparation and harvest (%):			
Wet	150	39	49
Moderate (not too wet or dry)	150	36	48
Dry	150	25	44
Tools used for harvest (%):			
Hands	150	1	12
Fork Jembe	150	91	29
Hoe	150	15	35
Use tools that damage potato	150	89	31
Type of labor used for harvesting (%)			
Family	150	73	44
Casual	150	59	49
Permanent employee	150	1	12
Help from neighbors/relatives	150	1	8
Independent contractor	150	09	28
Days between harvest and sale	101	6.8	8.1
Delayed harvest to find buyer	150	27	44

In Table 8, we describe weather conditions during pre-harvest preparation and the harvest itself. Rains during harvest can lead to spoilage of the crop, but if soil conditions are too dry, this can make digging up potato difficult and lead to mechanical damage. Thus, dry or moderate weather and moderately wet soil are ideal conditions for harvest. Over a third of farmers reported wet weather conditions during the pre- and harvest period, and a quarter indicated dry soil conditions. Most farmers (91%) used a fork jembe to harvest potato, while 15% used a hoe. Very few, just 1% of the sample, used their hands. A large majority (89%) of farmers indicated that the tools they used during harvesting could damage the potatoes. Family labor was used to harvest by 73% of farmers, while 59% hired casual workers, sometimes in combination with family labor. Contractors were used by 9% of farmers, while neighbors and relatives and permanent employees assisted in a few cases. The average duration between harvest and sale of potatoes was 6.8 days, and 27% of farmers indicated that they delayed harvest while they looked for a buyer.

Table 9: Farmer potato losses by activity

		Quantity (kg)…			Value (Ksh)…				% initial value lost in terms of…		
	Obser-vations	at start of activity	lost during activity	with a quality loss	at start of activity	of quantity loss	of quality loss	of total loss	quantity	quality	total losses
Harvest	150	1,807	105	61	29,140	1,572	441	2,013	9	2	11
		(3,640)	(246)	(90)	(59,469)	(3,930)	(1,521)	(4,215)	(13)	(3)	(14)
Storage	148	672	17	4.5	10,334	231	21	252	2	0	2
		(1,020)	(118)	(25.1)	(15,979)	(1,768)	(105)	(1,769)	(6)	(2)	(6)
Transport to buyer/market	11	956	0	0	10,755	0	0	0	0	0	0
		(1,145)			(11,096)						

Table 9 describes the quantity and value of potato losses incurred by farmers, from harvest up to time of sale an average of just under 7 days later.[4] We distinguish between physical or quantity losses and losses in value due to deterioration in quality. The average quantity of all potato varieties that farmers estimated they had in the ground prior to harvest was 1,807 kgs. Farmers' estimated average value of this quantity was 29,140 KSH. The time period immediately before and during harvest was the costliest to farmers in terms of losses. An average of 11% of farmers' estimated pre-harvest value of potatoes was lost – either due to degradation in quality or complete physical loss. In addition, an average of 2% of the pre-storage value was lost during storage. Both harvest and storage losses were primarily physical losses, as opposed to losses in quality.

[4] All but 7 farmers harvested all their potato crop in a single round, and an average of 98.9% of the crop was harvested in the first round. While it is possible that farmers left some potato in the field unharvested, this amount is difficult to quantify and is not included as a post-harvest loss in this analysis.

Table 10: Causes of on-farm quantity losses by activity (%)

	Harvest	Storage
Mechanical damage near/during harvest	10	0
Weather near/during harvest	29	0
Timing of harvest (too late or too early)	01	0
Insect infestation	02	04
Disease	80	78
Heat	0	4
Humidity/moisture	0	13
Poorly packaged	0	17
Sprouting	0	4
Greening	0	4
Don't know	1	0
Observations	101	23

Note: Observations are the number of farmers that experienced a loss in quantity during the activity. Farmers may have listed more than one cause for the loss. No farmers experienced a loss during transport from the field or to the buyer / market. General "rot" is considered a disease.

Table 10 describes the causes of these losses in quantity while Table 11 lists the causes of the quality losses. As expected from the list of challenges described in Table 3, disease is the cause of quantity loss most frequently cited by farmers, both at harvest and during storage. Weather was the next

most frequent cause of quantity loss, while poor packaging was reported as a common cause of losses during storage.

Losses in quality occurred almost exclusively during harvest. Almost all farmers who experienced these losses (98%) blamed mechanical damage. This finding concords with the common report by farmers, shown in Table 8, that tools used for harvesting damage the potato. By far the most frequently used tool and the most likely cause of this damage is the fork jembe. Only 9 of 148 farmers who stored their potato experienced a loss of quality during this time, for which humidity or moisture was the most common cause.

Table 11: Causes of on-farm quality losses by activity

	Harvest	Storage
Mechanical damage around/during harvest	98	0
Weather near/during harvest	08	0
Timing of harvest (too late or too early)	02	0
Insect infestation	02	0
Disease	05	44
Humidity/moisture	0	56
Poorly packaged	0	11
Sprouting	0	33
Greening	0	44
Other	0	22
Observations	124	9

Note: Observations are the number of farmers that experienced a loss in quality during the activity. Farmers may have listed more than one cause for the loss. No farmers experienced a loss during transport from the field or to the buyer / market. General "rot" is considered a disease.

Intermediaries and Retailers

Surveys were conducted with 42 intermediaries and 20 retailers. Classification as retailer versus intermediary was determined based on the type of potato business. Vendors at local markets, retail shops, those conducting both retail and wholesale trade, restaurants, and institutions such as schools or hospitals were classified as retailers, while intermediaries were broker or commission agents and wholesalers. While retailers purchase potatoes from intermediaries, some purchase directly from farmers. The type of businesses represented in the survey, and characteristics of the business operators interviewed, are described in Table 12.

Table 12: Intermediary and retailer characteristics

	Intermediary		Retailer	
	Mean	Std Dev	Mean	Std Dev
Type of business:				
Broker or commission agent	55	50	0	0
Wholesale	45	50	0	0
Retail	0	0	50	51
Both retail and wholesale	0	0	35	49
Restaurant	0	0	15	37
Age	43.07	9.33	44.85	9.84
Female	07	26	35	49
Education level:				
None / Adult education	02	15	0	0
Primary (some or completed)	57	50	50	51
Secondary (some or completed)	29	46	40	50
Post-secondary	12	33	10	31
Observations	42		20	

The majority of retailers are exclusively involved in retail while intermediaries are split with 55% acting as brokers or commission agents and 45% engaging in wholesale trade. A minority of potato intermediaries (34%) and retailers (7%) interviewed were female, in contrast to the 45% of female farmers in the sample. Retailers appear to be slightly more educated than intermediaries with 50% having attained some secondary education compared to 41% of intermediaries.

Similar to farmers, potato intermediaries and retailers in Nyandarua deal predominantly in the Shangi variety. In fact, as shown in Table 13, all intermediaries and retailers interviewed trade in Shangi and only two intermediaries and one retailer trade in other varieties in addition to Shangi.[5]

Table 13: Volume of trade, sources, and customers of potato intermediaries and retailers

	Intermediary		Retailer	
	Mean	Std Dev	Mean	Std Dev
Trade in Shangi (%)	100	0	100	0
Trade in other variety	05	22	05	22
Trade in the last 30 days (Kgs)	65,430	89,586	14,576	19,522
Number of days stored	65	1.38	4.28	6.82
Types of sellers they buy from (%):				
Farmers	83	38	20	41
Brokers	29	46	80	41
Wholesalers	5	22	30	47
Transportation mode to sellers (%):				
On head or back	10	30	10	31
Donkey or ox cart	26	45	15	37
Motorcycle	36	48	40	50
Tractor, pick-up, lorry, or truck	95	22	45	51

[5] One intermediary and the retailer traded in Asante while the second retailer traded in Kombiri.

Public transport / matatu	0	0	5	22
Other	0	0	10	31
Observations	42		20	
Types of buyers they sell to (%):				
Wholesale market	76	43		
Informal restaurant or hotel	14	35		
Formal restaurant or hotel	14	35		
Institution	2	15		
Trader	14	35		
Retailer	14	35		
Other	5	22		
Observations	42			

Note: The type of buyer was not asked for 13 retailers that stated their type of potato business as retail or restaurant. If an intermediary or retailer stated they did not store potato, the number of days is 2 retailers were not asked the number of days they store potatoes.

Intermediaries and retailers differ in terms of their sources of potato. While intermediaries source the majority of their potatoes from farmers, retailers buy mainly from brokers. The majority (76%) of intermediaries sell through wholesale markets, while others supply restaurants, institutions, other traders, and retailers. Intermediaries trade in larger volumes, with an average of 65.4 tonnes traded over the past 30 days, while retailers sold an average of 14.6 tonnes.

Despite these differences, intermediaries and retailers transport potatoes to their buyers using similar modes of transportation. Both mainly use tractors, pick-ups, lorries, or trucks while motorcycles are the next most frequently used form of transportation. Donkeys and ox-carts are also used by over a

quarter of intermediaries and 15% of retailers, while 10% of both types of business carry their wares themselves or hire others to do so.

Table 14 shows that overall, potato losses were relatively low across all activities for both intermediaries and retailers, compared to losses by farmers. Among intermediaries, most losses occurred during transport. Losses at this stage accounted for 1.3% of the pre-transportation value of potato. While only ten intermediaries reported storing potatoes, these lost 0.9% of the value to a loss in quantity at this stage. No losses were incurred during repackaging, which was done by 9 intermediaries.

The activity during which greatest losses were incurred by retailers was storage. Retailers stored potatoes for an average of 4.3 days, in contrast to intermediaries, who kept the commodity for less than a day on average. The 16 retailers who stored potato for any length of time lost an average of 4.8% of their pre-storage value, primarily due to physical (quantity) losses.

Table 14: Losses by intermediaries and retailers

		Quantity (kg)…			Value (Ksh)…			% of initial value lost due to a…		
	Obs.	start of activity	quant lost	quality lost	start of activity	quantity lost	quality loss	of total loss	quant loss	qual loss	quant + qual
Intermediaries											
Transport	39	5,233	25.6	6.4	88,580	625.6	179.5	805	0.5	0.8	1.3
		(5,346)	(82.6)	(40)	(76,861)	(2,167)	(1,129)	(2,392)	(019)	(5.1)	(5.4)
Storage	10	3,623	18.0	0	79,975	348	0	348	0.9	0	0.9
		(3,166)	(36.1)		(68,352)	(716)		(716)	(017)		(1.7)
Repacking	9	4,372	0	0	89,222	0	0	0	0	0	0
		(3,288)			(95,629)						

		Quantity (kg)…			Value (Ksh)…			% of initial value lost due to a…			
	Obs.	start of activity	quant lost	quality lost	start of activity	quantity lost	quality loss	total loss	quan t loss	qual loss	quant + qual
Retailers											
Transport	10	2,971	0	84.0	84,540	0	120	120	0	0.2	0.2
		(3,364)		(229)	(109,528)		(380)	(380)		(0.6)	(0.6)
Storage	16	2,115	189	2.2	43,128	3,011	15.6	3,027	4.7	0	4.8
		(3,701)	(622)	(8.8)	(60,934)	(8,762)	(62.5)	(8,758)	(7.5)	(0.1)	(7.5)
Processing	3	212	6.7	3.3	3,817.3	83.3	4.7	88	1.6	0.2	1.8
		(172)	(11.5)	(5.7)	(1,408)	(144.3)	(8.1)	(145)	(2.8)	(0.3)	(2.7)
Repacking	13	2,085	7.7	1.2	43,162	200	1.3	20	0.4	0	0.4
		(3,766)	(27.7)	(3.9)	(56,726)	(721.1)	(3.1)	(727)	(1.4)	(0.1)	(1.4)

Note: Transportation was asked about in two separate pieces: from farmer/market and to buyer/market. The beginning quantity and value reported here is the average from the first type of transportation that was conducted. The losses in quantity and quality are the total average across both types of transportation. The proportional loss is the average of the intermediary/retailer's average proportional loss across all transportation activities. Meaning that, for each intermediary and retailer, the proportional loss for each transportation activity is calculated separately and then the intermediary/retailer average proportional transportation loss is calculated before averaging across all intermediaries/retailers.

Reasons for potato losses among intermediaries and retailers are described in Table 15. Losses during transport to the buyer or market were mainly ascribed to poor packaging and excess humidity or moisture. These factors were also cited in the cause of losses during storage, at which stage mechanical damage and humidity and moisture also contributed to losses.

Table 15: Intermediary and Retailer: Cause of loss (either quantity or quality) by activity

	Intermediary			Retailer			
	Transport from farm / market	Storage	Transport to buyer / market	Transport from farm / market	Storage	Processing	Repackaging
Poor road quality	1			1			
Poorly packaged			2	2	3		
Disease		1	1				
Heat							2
Humidity/moisture		2	2	1	5		
Sprouting					1		
Greening					1		
Theft			1				
Mechanical damage					3	2	2
Other		2			2		1
Observations	1	3	4	2	8	2	3

Note: Observations are the number of intermediaries and retailers that experienced a loss in quantity during the activity. Intermediaries and retailers may have listed more than one cause for the loss. Only activities (e.g. storage, processing, repackaging) during which at least one intermediary or retailer incurred a loss are listed.

While losses were minimal for both intermediaries and retailers, poor packaging was one of the more frequently stated causes of these losses. Table 16 describes the main types of packaging or container used by potato intermediaries and retailers in the study area. We distinguish between the characteristics of bags used at purchase and sale, and intermediary assessments of bags at these two stages in the table below, since the characteristics important at purchase may differ from those important at sale.

The most common purchase containers used by intermediaries and retailers were woven nylon bags. At purchase from farmers (or in the case of retailers, often from an intermediary), these bags carried on average of 59 kgs of potatoes. None of these bags had holes for aeration. The most frequently cited advantages of these bags are their low cost and wide availability. The main critique is their lack of durability. Additionally, intermediaries were frustrated by a lack of standard bag sizing, which affects the amount of potatoes exchanged for the unit price.

Table 16: Proportion of intermediary and retailer: Purchase and Sales Packaging

	Woven nylon bag (purchase)	Woven nylon bag (sales)	Bucket	Other
Quantity held (KG)	59	72.7	15.7	20
Has holes for aeration	0	09	0	0
Advantages:				
Cheap	34	27	25	50
Easily available	45	36	50	50
Long lasting	2	0	8	0
Can carry a lot	8	27	0	0
Water proof	2	0	0	0
Protects from sunshine	2	0	0	0
Can be easily joined together	2	18	0	0
No advantages	16	0	8	0
Carries few potatoes	5	0	0	0
Easy to pack/transport	15	0	8	0
Sells for a good price	0	0	25	0
Easy to sell and measure	0	9	33	50
Other reason	6	9	08	0

Disadvantages:

Expensive		0	0	0
Does not last long	27	9	25	0
Cannot carry a lot	3	0	0	0
Not water proof	11	0	17	0
Does not protect from sunshine	3	0	8	0
Cannot be easily joined together	0	0	8	0
No disadvantages	27	82	50	100
Bad price for quantity it holds	8	0	0	0
Lack of standard sizing	13	9	8	0
No aeration	3	0	0	0
Damages potatoes	3	0	0	0
Other reason	11	0	8	0
Observations	62	11	12	2

11 of the 42 intermediaries sold their potatoes in a container different than the one in which they were received. These intermediaries repacked potatoes into slightly larger nylon bags, with an average size of 72.7 kgs – this is done to reduce cess charges, which are paid per bag. One of the intermediaries reported that the bags used for potato sales had holes for aeration. The main advantage cited for these bags was wide availability, low cost, and capacity to hold a large volume of potato. Most intermediaries considered there to be no disadvantages.

The most common container used by the retailers interviewed to sell potatoes were buckets with the capacity to carry an average of 15.7 kgs of potato. Four used the same woven bags in which they typically bought potato, and two used other containers. Like most of the woven bags used by intermediaries, these buckets also have no holes for aeration. The advantages cited for buckets were availability, cost, and ease of use for measurement of quantities and for selling. Half of the retailers felt that there was no disadvantage while, a quarter stated that the buckets did not last long.

Losses by value chain stage

In Table 17, we compare the overall losses experienced by farmers, retailers, and intermediaries across activities. As a share of the initial value, farmers experienced the highest losses with 9 percent of the pre-harvest value lost due to a loss in quantity and an additional 3 percent lost in terms of quality. The overall proportional losses for intermediaries was 1 percent while retailers lost 4 percent. If we use the proportional losses for each actor and assume that a value chain is comprised of a farmer, intermediary and retailer[6] we can estimate the total loss across the value chain at 16.4 percent.[7]

[6] Due to the nature of data collection we were able to track potatoes to either the retailer or through three levels of sales, whichever came first. Defining intermediaries based on the type of business, there were 20 farmer, intermediary, retailer chains; and 12 farmer, intermediary, intermediary chains. There were also 11 partial chains where data was collected for the farmer and first intermediary. Given that farmer, intermediary, retailer was the most common type of chain we feel comfortable using this assumption to calculate average losses across the value chain.

[7] A 12% loss after farmer's activities leaves 88% of the beginning value. Intermediaries then lost an additional 1 percent so that 87.1% of the original value was passed on to retailers. Retailers lost 4 percent of this value resulting in 83.6% of the original value remaining (or a loss of 16.4% across all actors) at the end of the retailers' activities.

Table 17: Losses across all activities, by stage of the value chain

	Farmer	Inter-mediary	Retailer
Quantity before first activity (kg)	1,807	4,961	2,369
	(3,640)	(5,242)	(3,828)
Quantity lost across activities (kg)	122	28	157
	(278)	(81)	(557)
Quantity with loss in quality across activities (kg)	66	6	45
	(93)	(39)	(157)
Value before first activity (KSh)	29,140	84,336	56,848
	(59,469)	(75,752)	(90,717)
Total value lost due to a loss in quantity across activities (KSh)	1,800	664	2,552
	(4,300)	(2,101)	(7,859)
Total value lost due to a loss in quality across activities (KSh)	461	167	74
	(1,523)	(1,080)	(271)
Total value lost across activities (KSh)	2,261	830	2,626
	(4,680)	(2,314)	(7,839)
% of the value lost due to a loss in quantity across all activities	9	1	4
% of the value lost due to a loss in quality across all activities	3	1	0
% of the value lost across all activities	12	2	4
Observations	150	42	20

Conclusions

The majority of losses across the potato value chain in Nyandarua, occur during production, both before and during harvest. An estimated 11 percent of the value of the potato crop is lost at this stage. The most frequently stated cause of losses at the farm level is disease. This cause was reported by 80% of farmers who experienced a loss in quantity during harvest, and 78% who experienced storage losses. Even so, 82 percent of farmers sprayed their potato crop against diseases, indicating that spraying is done incorrectly and/or timing needs improvement. Late blight and bacterial wilt were each observed by a majority of farmers. Weather around harvest time was cited as by 29% of farmers who experienced harvest losses. Also related to weather conditions are humidity and moisture, which were blamed by 13% of farmers who experienced storage losses, and heat (4% of farmers). Poor packaging was responsible for another 17% of losses at this stage. Other causes of loss at harvest included mechanical damage (10%), insect infestation (2%), and timing of harvest (1%). Storage losses were also blamed on insects (4%), sprouting (4%) and greening (4%).

Losses at the intermediary and retailer stages were estimated at 1 and 4 percent, respectively. For intermediaries, the majority of losses occurred during transport, while retailers experienced most of their losses during the short storage period of 4.3 days. The main causes of the intermediary losses were poor packaging and humidity / moisture. These were also the main issues for retailers which lead to losses in storage, who additionally had trouble with mechanical damage. The main container used by both retailers and intermediaries were woven nylon bags without holes for aeration. The

main disadvantages of these containers expressed by both retailers and intermediaries is their lack of durability or standard sizing; disadvantages related to post-harvest losses were not mentioned.

Policy recommendations

- Disease is a major driver of losses, but seed distribution systems are underdeveloped (Kaguongo et al. 2014). Counties could provide clean land to support sound crop rotation schemes for seed production as clean land is one of the biggest challenges for seed production.
- Provide training to extension and other relevant staff and institutions in disease management and pesticide application. Develop/distribute extension briefs/disease management guides for farmers.
- Extended bags have negative effects on potato quality (Kaguongo et al. 2014). Permit importation of sisal or other natural fibre bags in standard 50 kg capacity with duty exemption as local supply is either exported or doesn't meet internal demand. This is needed to support enforcement of the National Irish Potato Regulations (Part III, clause 18 on potato packaging stipulating that the basic unit of marketing potato is the 50 kg bag. But can only be enforced if there is access to suitable packaging material.
- With National Potato Council of Kenya, initiate a communication system to warn extension agents and farmers when late blight pressure is high, and the appropriate contact or systemic fungicide to apply.

These recommendations align with the Nyandarua county strategy that has prioritized seed system development, increasing farmer productivity through improved farming practices (including disease management) and improved postharvest management among the strategy objectives. Specifically, the Nyandarua county strategy needs to prioritise:

i) supporting seed businesses to invest in certified seed production through ensuring an enabling environment and access to sufficient areas of clean land,

ii) developing a training program for farmers implemented by ward agricultural officers in partnership with agricultural institutions and projects

iii) advocate to national government to support importation or increase national production of packaging to enforce the 50 kg bag law

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