Potato J. 33 (1 - 2) : 35-43, 2006

KUFRI SURYA: A NEW HEAT-TOLERANT POTATO VARIETY SUITABLE FOR EARLY PLANTING IN NORTH-WESTERN PLAINS, PENINSULAR INDIA AND PROCESSING INTO FRENCH FRIES AND CHIPS

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ABSTRACT: Kufri Surya is an early maturing, heat tolerant and hopper-burn resistant potato variety with oblong tubers, white smooth skin and pale yellow flesh. This variety is meant for early (September) planting in north-western plains and for *rabi* and *kharif* plantings in peninsular India. It can also be grown in the main crop season in north-western and west-central plains. The total tuber yield of Kufri Surya is at par with high yielding variety Kufri Bahar. This variety yields excellent defect free tubers with high proportion of large (>85mm) tubers suitable for processing into high quality French fries and chips. The reducing sugar content of tubers of this variety is less than 100mg/100g fresh weight and the tuber dry matter content is 20-21% at harvest.

INTRODUCTION

Potato prefers cool climate for optimum tuber yield. This condition is met-with in some seasons, both at low elevations in medium to high latitudes and at high elevations in low latitudes. Bushnell (3) defined 17°C as an optimum temperature for good yield in potatoes. High temperatures delay, impede or even inhibit tuber initiation and affect the distribution of dry matter between tubers and haulms, night temperatures being especially crucial. High temperatures and long days favour assimilate partitioning to the above ground vegetative parts, as a result, above ground bio-mass and plant height is increased and tuber yield is reduced (13, 19, 20). Tuberization is reduced at night temperatures above 18°C (11) and there may not be any tuberization beyond 25°C (3, 10), even though potato plants can tolerate day temperature of about 32°C without significant loss in total biomass production (20). Optimum night temperature during pre-stolon initiation stage has been found to be 15-20°C, while it is 15°C after tuber initiation (12, 17). High night temperatures lead to a reduction in carbon export rate from the leaves (1) and in combination with long days, have an additive effect with the plants partitioning minimum dry matter to the tubers (4, 20). Although photosensitivity of the crop has been tackled to a greater extent by breeding 'so called' day neutral varieties (2), yet there is no variety that can give economical yields under higher temperatures, especially at night temperatures above 20°C. As a result, large parts of peninsular India are unsuitable for potato cultivation. Therefore, to extend potato cultivation to non-traditional areas and seasons, a project was initiated at the Central Potato Research Institute in 1990 to develop potato varieties suitable for plateau regions and for early planting (September) in the north-

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western plains when the temperatures are high.

BACKGROUND

Parents were selected from early bulking high yielding indigenous varieties and heat tolerant lines developed for lowland tropics at the International Potato Centre, Lima Peru. These parents were used in hybridization at Kufri (32°N, 77°E, 2501 AMSL) in Shimla hills. The seedlings were raised at Shimla and screened for heat tolerance, particularly tuberization, in a heated glasshouse according to the technique originally proposed by Sattelmacher (18), and modified for our conditions. Selected seedlings were multiplied at the Central Potato Research Institute Campus (CPRIC) Modipuram (29°N, 76°E, 222 AMSL) for subsequent evaluation. The initial selection of genotypes was based on tuber characteristics *viz.,* shape, eye depth, skin colour, etc. In subsequent generations, the selections were made on the basis of tuber yield under early planting conditions (2nd week of September) when the temperatures were high (**Figure 1**). A number of promising hybrids were identified and finally two hybrids, *viz*., HT/92-621 and HT/92-802 were selected in the year 2000 for evaluation in multi-location trials through All India Co-ordinated Research Project on Potato (AICRP-Potato). These were evaluated at six locations, two in north-western plains (in early planting) and four in peninsular India. Hybrid HT/92-621 consistently performed well at most of the locations for three years. This hybrid, christened as 'Kufri Surya', was accepted for release by "Central Sub-committee on Crop Standards, Notification and Release of Varieties for Horticultural Crops", Ministry of Agriculture and Co-operation, Government of India, New Delhi in October 2005. Kufri Surya is recommended as a heat tolerant variety suitable for early planting in north-western plains, peninsular India and for processing into French fries and chips.

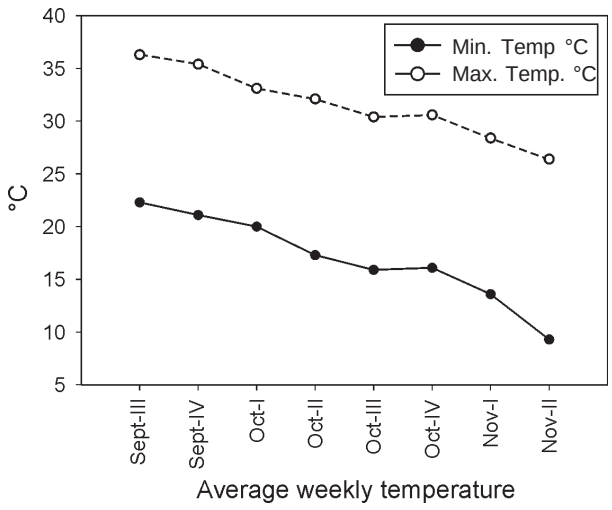

Fig. 1. Maximum and minimum temperature at Modipuram during 2001

Kufri Surya (**Figure 2**) is a selection from the progeny of a cross between Kufri Lauvkar and LT-1, made in 1992. The female parent, Kufri Lauvkar is an early bulking variety especially bred for the plateau region of Maharashtra and the male parent LT-1, is a selection made by the International Potato Centre, Lima, Peru, for lowland tropics. The pedigree of Kufri Surya is as given below:

(USDA40568 x USDA24642) – (Katahdin x Aquila) – LT1
x
(Adina x Sarkov) Kufri Lauvkar
→ HT/92-621 (Kufri Surya)

Variety Description

Habit : Medium tall, erect, semi-compact, vigorous

Stem : Few, thick, green with purple colour lightly scattered throughout, wings highly developed

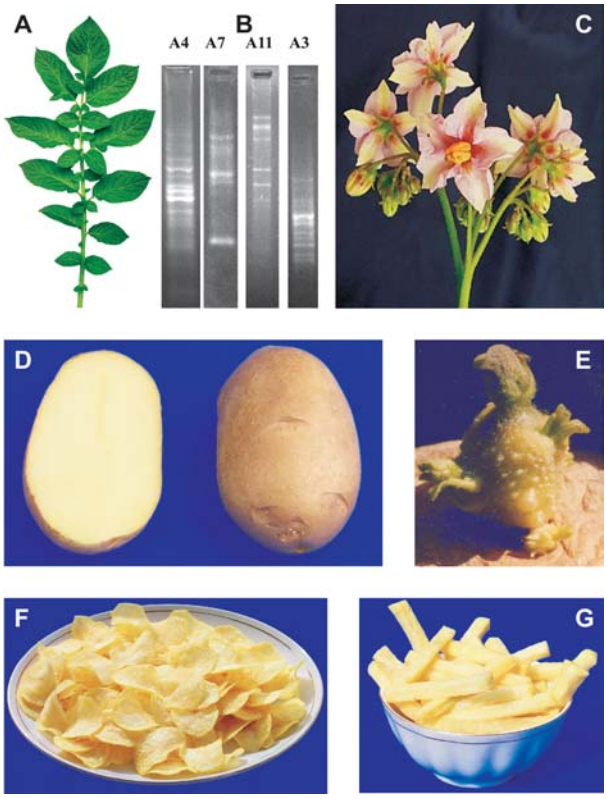

Fig. 2. Characteristics of Kufri Surya : A-leaf, B-DNA fingerprints generated by four random primers, C-flowers, D-Tubers, E-Sprout, F-Chips and G-French fries

Leaf : Open, large, rachis pigmented; leaflets narrow, ovate, smooth, margin entire; folioles many, large; vigorous foliage growth

Foliage colour : Dark green

Tuber : Medium to large, oblong, skin white, smooth, eyes shallow, eyebrows normal, flesh colour pale yellow, dormancy medium, 8-10 weeks

Flower : Light red-purple, shy flowering

Maturity : Early, 75-90 days, good bulker, can be harvested at 60 and 75 days in mid-September planted crop, also a good yielder in main season crop and can be grown for 75-90 days

Reaction to major pests/ diseases under field condition : Highly field resistant to hopper burn, possesses moderate resistance to mite damage and late blight

Reaction to stress : Heat tolerant, can be grown in areas having night temperatures up to 22°C

Agronomic features : Fertilizer responsive, suitable for early planting and can be harvested at 60, 75 or 90 days

Specific gravity : 1.076

Dry matter content : 20-21%

Tuber protein content : 2.5% (soluble proteins)

Reducing sugars content : 71.2 mg/100g fresh weight at 90 day harvest

Cooking quality : Good, cooks well in 30 minutes

Texture : Floury

Yield performance of Kufri Surya

During three years of yield trials in North-western plains under early planting (September), Kufri Surya gave 35 and 48% higher yield than the control varieties Kufri Ashoka and Kufri Bahar, respectively (**Table 1**). During the main potato season at Modipuram (October–January, 90 days crop) Kufri Surya yielded more than 400q/ha which was comparable to other high yielding potato varieties commonly grown in the region

Table 1. Tuber yield (q/ha) of Kufri Surya in early planted crop (2nd fortnight of September) at Modipuram (1997-2000)

Culture/ Variety	*1997-98 (75 days)*	*1998-99 (60 days)*	*1999-2000 (60 days)*	*Average*
HT/92-621 (Kufri Surya)	198	142	119	153
Kufri Bahar	123	94	92	103
Kufri Ashoka	133	97	110	113
CD (0.05)	54	38	25	

Table 2. Tuber yield of Kufri Surya (at 90 days) in main crop season. Modipuram (2001-02)

Genotype	*Tuber yield (q/ha)*	*Late blight incidence (%)*
Kufri Surya	418	5
Kufri Anand	467	<1
Kufri Bahar	423	50
Kufri Chipsona-1	358	10
Kufri Chipsona-2	344	5
Kufri Pukhraj	469	10
Kufri Sutlej	461	5
C.D. (0.05)	85.0	—

Table 3. Tuber yield of Kufri Surya at 60 days, in early planted AICRP trials

Year	*Hybrid/ Control*	*North-western plains Total tuber yield (q/ha)*	
		Jalandhar	*Modipuram*
2003-04	**Kufri Surya**	**118.05**	**136.97**
	Kufri Pukhraj (C)	108.02	92.25
	CD(0.05)	23.48	33.63
2002-03	**Kufri Surya**	**236.7**	**68.5**
	Kufri Pukhraj (C)	238.5	67.7
	CD(0.05)	35.38	9.47
2001-02	**Kufri Surya**	**128.9**	**46.3**
	Kufri Lauvkar (C)	70.22	18.2
	CD(0.05)	20.96	10.58

Where C = Best control

(**Table 2**). Thus, this variety could also be profitably grown during the main season and the produce used for seed, table or for processing purposes. In early planted trials under AICRP, the total tuber yield of Kufri Surya was significantly higher than the best control during 2001-02 crop season at Jalandhar and Modipuram, during 2002-03 at Dharwad and during 2003-04 at Modipuram. In all other years and locations total tuber yield of Kufri Surya was comparable with the best control, although the absolute value of tuber yield was higher than the control in 9 trials and lower than the control in 4 trials (**Tables 3 and 4**). At Bangalore, Kufri Surya gave reasonably good yield among seven hybrids that were tested (**Table 5**). The overall

Table 5. Performance of heat tolerant genotypes at Bangalore (May- August, 1999)

Genotype	Germination %	Yield/plot ($4.8m^2$) kg
Kufri Surya	78	10.5
HT/92-731	64	2.51
HT/92-418	70	0.2
HT/92-499	78	0.21
HT/92-802	30	0.3
HT/92-829	64	1.1
Kufri Jyoti	92	1.1

Table 4. Tuber yield of Kufri Surya at 75 days in AICRP trials in plateau region

Year	*Hybrid/ Control*	*West-central plains Total tuber yield (q/ha)*			
		Chindwara (Rabi)	*Hassan (Kharif)*	*Rajgurunagar (Rabi)*	*Dharwad (Kharif)*
2003-04	**Kufri Surya**	**128.5**	**136.8**	**-**	**60.7**
	Kufri Pukhraj (C)	105.9	153.2	-	32.1
	CD(0.05)	46.64	NS	-	NS
2002-03	**Kufri Surya**	**193.4**	**196.8**	**84.0**	**121.7**
	Kufri Pukhraj (C)	178.3	181.6	56.3	91.5
	CD(0.05)	20.74	36.82	32.06	16.29
2001-02	**Kufri Surya**	**219.9**	**-**	**113.5**	
	Kufri Pukhraj (C)	253.7	-	88.0	
	CD(0.05)	46.23	-	36.33	
2000-01	**Kufri Surya**	**225.9**	**-**	**257.7**	**-**
	Kufri Pukhraj (C)	240.8	-	240.5	—
	CD(0.05)	NS	-	75.62	

Where C = Best control; NS = Non-significant

yield data showed that this variety is at par with the best varieties in main crop season in north-western region, but has added advantage of higher yield in early planting, large tuber size, good keeping quality and suitability for processing.

Heat tolerance of Kufri Surya

Tuberization: Heat tolerance of Kufri Surya was studied along with the variety Kufri Chandramukhi (control) for their ability to form tubers in leaf bud cuttings in plant growth chambers at 24 and 27°C day temperatures in combination with 18, 20, 22, and 24°C night temperatures. Kufri Surya was able to tuberize at all the temperature combinations and good tuberization was observed up to 22°C night temperature. Kufri Chandramukhi showed good tuberization at 18°C only and failed to tuberize at 24°C. The tuber fresh weight was higher at 24°C than at 27°C day temperature in both the varieties (11).

Photosynthetic efficiency: Under heat stress conditions of early planting (mid-September) in north-western plains, Kufri Surya germinated well (>90%) and established a vigorous crop canopy when compared with control cultivar Kufri Ashoka. Measurements of net photosynthesis rate (Pn) during the course of a day in 36-day old crop showed significantly higher Pn (32.3 µmol CO_2 m^{-2} s^{-1}) than Kufri Ashoka (26.8 µmol CO_2 m^{-2} s^{-1}) at 10 am. Even though Pn declined at 12 noon and increased at 2 pm, Kufri Surya (HT/92-621) maintained higher Pn than Kufri Ashoka. Higher Pn in Kufri Surya was accompanied by higher stomatal conductance that was 1.0 s cm^{-1} as against 0.5 s cm^{-1} in Kufri Ashoka at 10 am followed by 0.6 and 0.4 s cm^{-1} at noon and 0.4 and 0.3 s cm^{-1} at 2 pm, respectively. Owing to higher stomatal conductance, the transpiration rate was also higher in Kufri Surya. Higher stomatal conductance in Kufri Surya led to faster evaporative cooling, which is beneficial to the plant during the period of heat stress, resulting in higher rate of photosynthesis and better plant growth (7).

Although laboratory tests proved ability of Kufri Surya to form tubers under higher temperatures, this superiority was not translated into better yield during the AICRP trials at some locations. The results of early planting trials at Modipuram showed that Kufri Surya performed better than other varieties when temperatures were high at planting and during early growth period (mid September planting at Modipuram). However, if early planting is delayed due to rains in mid September, the yield advantage is lost as temperatures become congenial for other varieties as well. Thus, congenial temperatures at the time of planting could be the reason for yield parity in some of the AICRP trials.

Processing quality of Kufri Surya

Kufri Surya had more than 18% tuber dry matter at 60 days harvest and 20% dry matter at 75 days harvest compared to 14-17% for Kufri Bahar and 12-15% for Kufri Ashoka during the three years of trials at Modipuram (**Table 6**). Since this variety had relatively good tuber dry matter even at 60 days, it was checked for processing into chips, during 1998-99 and 1999-2000 crop seasons. The results showed that Kufri Surya consistently produced grade 1 chips (on a scale of 1 to 10, with 1 being the lightest and 10 the darkest colour chips) compared to grade 3.0 and 3.5 for Kufri

Table 6. Per cent tuber dry matter and chip colour of Kufri Surya in early planted (2nd fortnight of September) crop at Modipuram (1997-2000)

Culture/ Variety	*1997-98 (75 days)*	*1998-99 (60 days)*	*1999-2000 (60 days)*	*Average*
Kufri Surya	20.0	18.1 (1)*	18.6 (1)	18.9 (1.0)
Kufri Bahar	16.8	14.0 (3)	16.9 (4)	15.9 (3.5)
Kufri Ashoka	14.8	12.3 (3)	14.1 (3)	13.6 (3.0)

*Figures in parenthesis are chip colour score on a scale of 1-10, 1 being the lightest colour and 10 being the darkest colour.

Ashoka and Kufri Bahar, respectively (**Table 6**). During the month of November, when fresh tubers are not available to processors from anywhere in the country, the early planted crop of Kufri Surya can provide high quality potatoes for processing. At Jalandhar, good quality chips can not be produced from fresh potatoes because of low temperatures during crop maturity. Even under these conditions, Kufri Surya gave chips of 3.75 grade compared to 5.0 for Kufri Chipsona-1. After 75 days of on-farm storage, chip colour of Kufri Surya improved to below 2.0, which is acceptable to the processing industry (9). During the years 2003 and 2004, Kufri Surya (from 90 days main crop at Modipuram) was tested for chips production on an industrial processing line at M/s Frito Lay India Ltd. Sangarur. The variety was found acceptable for processing, based on good specific gravity/ Frito Lay solids, low total potato defects (TPoD), low undesirable colour (UC) and acceptable Hunter colour score (HC) (**Table 7**).

Tubers of Kufri Surya are oblong and medium to large in size; therefore, they were also tested for processing into French fries. Laboratory results were very encouraging. Peeling and trimming losses (assessed manually) in this variety were low being only 9.9% compared to 17.5% for Atlantic. The finished French fry yield from Kufri Surya was the highest among seven commonly used processing varieties (**Table 8**). The French fries obtained were of light colour. Kufri Surya was also tested for French fries production on industrial processing line at M/s Wimpy International for three years (2003-2005). This variety showed good consistency, not only in yield of finished product (32-33%) but also in organoleptic attributes, such as, taste, colour and texture. Other parameters important in deciding processing attributes, *viz.*, tuber dry matter and reducing sugars were also comparable to those in standard processing variety Kufri Chipsona-1 (8). Kufri Surya had 68% processable grade tubers compared to 62% of standard processing variety Kufri Chipsona-1. There was a good proportion of French fry grade tubers (length >85 mm) in Kufri Surya while chip grade tubers' proportion in the total yield was comparable to Kufri Chipsona-1 (**Table 9**). In a two year (2002-04) study at three locations in Gujarat, Kufri Surya gave highest proportion of French fry grade tubers (45-51%) compared to 21-36% for Kufri Chipsona-1, 30-33% for Kufri Anand, 33-40% for Kufri Badshah and 34-48% for Kufri Sutlej (15).

Table 7. Performance of potato varieties in "On-Line testing" for chips production at M/s Frito Lay India Ltd., Sangarur (2003 and 2004)

Cultivar	*Specific gravity*	*Undesi-rable colour*	*Total defects*	*Hunter colour score*
2003				
Kufri Surya	1.070	1.8	35	61
Kufri Chipsona-1	1.074	1.7	27	60
KufriChipsona-2	1.088	4.0	49	60
Kufri Jyoti	1.072	10.0	Not done	Not done
Atlantic	1.088	2.3	36	61
2004	*FL Solids*	*Undesirable colour*	*Total defects (TPoD)*	*Hunter colour score*
Kufri Surya	17.2	10	12.5	57.5
Kufri Chipsona-1	19.9	12	33.7	61.6
Kufri Chipsona-2	21.1	19.2	46.9	62.6
Kufri Jyoti	20.5	26.5	46.9	59.1
Acceptable	**>16.0**	**<5**	**<15**	**>58**

Keeping quality

Kufri Surya has very good keeping quality with long tuber dormancy, low rottage, low weight loss and low sprouting intensity. Tubers of Kufri Surya, Kufri Bahar and Kufri Jyoti from the main crop were stored at room temperature (24-36°C) from mid March to mid May during 2001 and 2002 at Modipuram. After 75 days of storage there was no tuber rottage in Kufri Surya compared to 2-8% in the controls. The weight loss in Kufri Surya

Table 8. Yield and quality of French fries in laboratory tests Modipuram (2005)

Variety/hybrid	*Peeling loss*	*Trimming loss*	*Total loss*	*Finished french fry yield*	*French fry colour*
Kufri Surya	3.7	6.2	9.9	42.5	Light
Atlantic	2.7	14.8	17.5	41.8	Light
Kufri Chipsona-1	3.2	5.7	8.9	36.6	Very light
Kufri Chipsona-2	2.8	8.7	11.5	37.8	Very light
Kufri Jyoti	4.2	11.2	15.4	38.1	Light brown
Kufri Lauvkar	4.5	16.3	20.8	38.4	Light brown
K. Chandramukhi	4.1	13.2	17.3	38.5	Light brown

Table 9. Processing grade yield (q/ha) of Kufri Surya during main crop at Modipuram during 2001-02

Treatments	*Yield of processing grade tubers*			*Yield of non-processing grade tubers*	*Total yield*
	Chip	*French Fry*	*Total*		
Kufri Surya	102.3	108.8	211.1	97.6	308.7
Kufri Chipsona-1	112.7	74.6	187.4	112.9	300.2
SE ±m	8.5	11.8	13.9	12.0	4.2

was also lower, being 9.1% compared to 12-13% in control varieties Kufri Bahar and Kufri Jyoti. At the end of storage period, 73% tubers of Kufri Surya were sprouted compared to 92% of Kufri Bahar and 88% of Kufri Jyoti. Sprouting intensity was also very low in Kufri Surya as indicated by sprout weight of only 0.36g/kg tuber compared to 3.21g/kg tuber for Kufri Bahar and 0.66g/kg for Kufri Jyoti (6). Naidu and Nandekar (14) studied room temperature storage of Kufri Surya, alongwith Kufri Pukhraj and Kufri Lauvkar, during 2002 and 2003 at Chhindwara. After 75 days of storage, Kufri Surya had 54% sprouting (90 and 95% in controls), sprouting intensity of 0.65g/kg tuber (3.8 and 4.5 for controls), the lowest rottage (10.8%) and lowest weight loss (10.5%). In a two-year study (2003 and 2004) at three locations in Gujarat, Kufri Surya showed 2.9% tuber rottage (15% in Kufri Chipsona-1 and 47% in Kufri Sutlej) and 14.9% weight loss (24.7% in Kufri Chipsona-1 and 59% in Kufri Sutlej) after 120 days of storage at room temperature. Due to its excellent keeping quality, Kufri Surya can be stored in heaps at the farm itself and can be supplied to French fry processing industries for up to four months (15).

Reaction to various diseases

Leaf-hoppers causing hopper-burn are a serious problem in early planted potato crop. Kufri Surya (HT/92-621) showed high resistance to hopper-burn and moderate resistance to mite-damage under field conditions, while all commercial varieties were susceptible to both the diseases (16). Kufri Surya also possesses moderate degree of resistance to late blight (5) (**Table 2**).

Agronomic management

The following norms are recommended for Kufri Surya :

Planting time: Second fortnight of September for early planting and 2nd fortnight of October for main planting in the North-western plains; and *rabi* and *kharif* planting seasons in peninsular India.

Seed rate: 30-35 q/ha

Spacing: 60 x 20 cm for early planting and for peninsular India, and 67.5 x 20 cm for main planting season, for maximum processing grade tubers, in North-western plains.

Fertilizer: 180 kg N, 80 kg P and 100 kg K per ha as per standard agronomic recommendations when grown for table purposes and 270 kg N, 80 kg P and 150 kg K per ha when grown for processing purposes. However, these recommendations pertain to north-western plains and crop management for different agro-climatic regions may differ and need to be worked our on location and utilization specific basis.

Usage

Kufri Surya is expected to be the most popular variety for early planting in north-western plains as well as in *rabi* and *kharif* crops in peninsular India. Due to its large tuber size and oblong shape (desired shape for French fries), and high dry matter, it is likely to be accepted as the first French fry variety in the country. This new heat tolerant variety is expected to extend potato cultivation to non-traditional areas and seasons, thus bringing more area under potato cultivation in the country.

ACKNOWLEDGEMENTS

Authors are thankful to the present and past Directors of the Central Potato Research Institute, Shimla for providing facilities and encouragement during the development of this variety. We are thankful to the present and past Project Coordinators of All India Coordinated Research Project on Potato and scientists of Jalandhar, Modipuram, Rajgurunagar, Dharwad and Chhindwara centers for carrying out multi-location trials with this variety. We are thankful to the International Potato Centre, Lima, Peru, for providing the material of LT-1. Thanks are also due to M/s Frito Lay India Ltd., Sangarur and M/s Wimpy International, New Delhi for carrying out on-line tests for chips and French fries production, respectively.

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MS Received: 02.02.2006