Bulletin UASVM Animal Science and Biotechnologies, 68(1-2)/2011
Print ISSN 1843-5262; Electronic ISSN 1843-536X

Technological and Economical Considerations for Breeding Terrestrial Snails *Cornu aspersum* (*Helix aspersa* Muller) and *Helix pomatia* as Alternative Animal Protein Source for Human Consumption towards Ecological Protection and Sustainable Development

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Abstract. Farming potential of the most popular edible terrestrial snails, it was investigated within the context of efficient agricultural land use of for maximum animal protein production. The stress induced by climate changes upon the snail's development is a considering factor, therefore snails are tested for fitness. Sel-Plex™ is used as concentrated forage additive in both 2009 and 2010 experiments involving *Cornu aspersum* (*Helix aspersa* Muller) and *Helix pomatia* edible terrestrial snails. Young snails of 4-7 days were tested for crawling speed as fitness component, an expression of vitality and resistance during prolonged heat waves and drought season. Using proper white led based cold lighting sources and high definition highly sensitive video recording equipment snail's activity has been recorded. Snails crawling on graded paper allowed for measuring their speed. Seeing thru the snail's shell due to proper light positioning, heartbeat was counted as well during the crawling. While the heartbeat rate of the snails is relatively high on all snail batches, respectively 97-102 bpm (bits per minute) due to the high temperature, the snails fed with Sel-Plex™ 0.10% have the highest speed, namely 1.5694±0.0504 mm/s followed by the snails fed with Sel-Plex™ 0.04%, averaging 1.4403±0.0323 mm/s respectively. The paper introduces for the first time the concept of "Gain to the Proposed Norm" (GPN), presented as a development indicative, a progress indices towards meeting a predetermined goal target. The yield upon slaughter is a factor that plays a major roll as to recommend *Cornu aspersum* species for farming as opposed to its counterpart *Helix pomatia*.

Keywords: Sel Plex, fitness component, heartbeat rate, crawling speed, economics, gain to the proposed norm

INTRODUCTION

Human's health start with a proper nutrition as to supply the human body with the right amount of protein averaging 70-100 grams per day as reflected in a FAO/WHO/UNU Technical Report No. 935 (2002). According to Avagnina, (2006), snail farming is a very lucrative agricultural activity given the fact that snail's meat provides high levels of protein.

Microelements are also important for human nutrition. Selenium (Se) is of a special interest having high antioxidant properties and essentiality to animals and human beings, describes Golubkina and Papazyan, (2006).

Most of European countries suffer of Se deficiency shows Thorling *et al.,* (1986), deficiency that can be responsible for an increased risk of cardiovascular diseases and several forms of cancer (Navarro-Alarcon, Cabrera-Vique, 2008).

The meat of domestic animals is an important source of Se in human diet, reason for witch feeding edible terrestrial snails with an organic form of Se, namely Sel-Plex™, as additive to concentrated forage has been investigated in order to evaluate its effect upon the

growth, survival rate, prolificacy and the bioaccumulation of selenium. Sel-Plex™ it's a product manufactured and a trademark owned by Alltech, USA, a company that holds the U.S. Patent No. 6,045,834 C1 valid until April 16, 2019 as stated by IPFrontline, (2011).

MATERIALS AND METHODS

A prim part of studies has been carried out during month of September-October 2009 for 38 days in order to observe the behavior, growth pattern and meat quality/chemical composition of the 1-year-old *Helix pomatia* (local species) as opposed to the 1-year old and 3-month old *Cornu aspersum* (*Helix aspersa* Muller). It is important to have knowledge of snail's development and resistance towards the end of the farming season under the specific climate of Cluj County, Crăieşti snail farm, where temperature tend to drop drastically; the data is being presented in *Table 1*.

Tab. 1

Meteorological data recorded during the 38 days experiments, September 3rd –October 11th, 2009

	Temperature	Humidity
maximum	29°C (September 3rd -4th)	99% (October 1st-11th)
minimum	2°C (October 4th)	22% (September 11th-12th)
mean	16°C	64%

All snails distributed in four different batches, one control CF-1(C) and tree experimental batches CF-2(E), CF-3(E), CF-4(E) populated with 40 snails of each species and age, experiment replicated in tandem using four repetitions, using therefore a total of 16 enclosures, each populated with a total of 120 snails.

A second part of the studies was conducted in Băişoara, Cluj County for 91 days from May 29th to August 29, 2010 in order to observe the behavior, survival rate, prolificacy and growth dynamics of the 9-12 month old *Cornu aspersum*. Each of the batches BF-1(C), BF-2(E) and BF-3(E) each of the four repetition in tandem consisted of 40 snails each. The summer of 2010 presented very high temperatures and extreme high humidity for long periods as presented in *Table 2*.

Tab. 2

Meteorological data recorded during the 91 days experiments May 29th–August 29th, 2010

	Temperature	Humidity
maximum	34°C (June 11th -13th)	100% (June 1st- July 31st)
minimum	9°C (June 2nd)	35% (July 17th – 19th)
mean	21°C	84%

Concentrated forage consisting of 60% wheat flour, 20 % corn flour and 20 % calcium carbonate ($CaCo_3$) mix it was used to feed all snails. The control batches did not receive Sel-Plex™ while the experimental batches received Sel-Plex™ as it is shown in Tab. 3 for the 2009 experiments and Tab. 5 for the 2010 experiments. Sel-Plex™ contains 2000-2400 mg Se/Kg (97-99% of organic selenium) as indicated in EFSA Journal (2011).

The weight was registered using an electronic scale AWS ScaleMate-501 Digital Pocket Scale 500 x 0.01 grams evaluating the entire snail group at once.

The young offspring snails of 4-7 days old were examined for crawling speed as a fitness component, indicating the eventual differences given by the different feeding regiments under the extreme weather conditions of summer 2010, *Table 2*.

Using white led based cold lighting and high definition highly sensitive video recording equipment, RICOH CX1 camera, snail's activity has been recorded. Snails crawling

on graded paper were filmed using 30 fps allowed for measuring their speed. Seeing thru the snail's shell due to proper light positioning, the heartbeat was observed as well during the crawling. The snails were sacrificed using a novel technique by being exposed to microwaves. The leg of *Helix pomatia* has been detached using a scissor as seen in *Figure 1*.

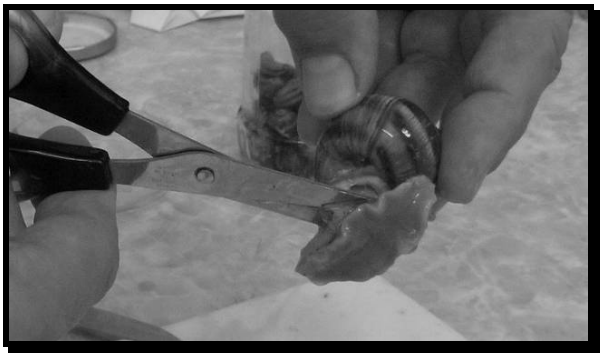

Fig. 1. Detaching the leg of *Helix pomatia*.

In the case of *Cornu aspersum*, the entire meat content has been analyzed for chemical composition since all the meat is consumed by humans, whereas in the case of *Helix pomatia* only the leg is being consumed. The biochemical composition of snails' meat has been determined using the Wendee method. The data was statistically processed using GraphPad 5.03 software.

In order to properly manage natural resources as non-monetary values, agricultural activity has to be bioeconomically efficient, as all human endeavors should be. Snail farming efficiency needs to consider market preferences. As is the case for pigs, being preferred young up to 80-100 kg, not only from the meat's quality but also from the weight gain efficiency, *Cornu aspersum* snails can reach 14-16 grams each, but the consumers prefer the smaller one in the area of 8-10 grams. For a better growth progress evaluation, snails development is expressed by a novel production criteria named "Gain to the Proposed Norm" (GPN), presented as a development indicative, an indices towards meeting a predetermined goal target. GPN(%)=WGx100/(WPN-WI), where WG represents the weight gain, WPN represents the proposed norm weight and WI the initial weight. The complement indices "Remaining Difference to Proposed Norm" (RDPN)(%)=100–GPN.

Product's gross weight obtained from a unit of land, net meat production based on slaughter yield and its protein content are factors that determine the non-monetary value of snail farming, respectively expressed hereby as protein production per square meter. In the case of *Cornu aspersum* slaughter yield (%) $\mathbf{Y}_{sCa}$=Wm x 100/WT where for *Helix pomatia* only the leg is being consumed the slaughter yield (%) is obtained by $\mathbf{Y}_{sHp}$=WL x 100/WT.

RESULTS AND DISCUSSION

The *Cornu aspersum* as imported snail species for the purpose of farming were compared with the local species *Helix pomatia* during 2009 experiments reaching late season when temperature dropped severely. In the presence or not of the additive Sel-Plex^{TM} *Helix pomatia* snails dropped in weight in the control batch as well in the experimental CF-2(E) and CF-3(E) exception being in the case of CF-4(E) were they experience a mean daily increase in weight by a mere 0.004 grams. Under the same conditions, the 1 year old *Cornu aspersum* snails decrease in CF-3(E) and CF-4(E) while registering a 0.145 g/day mean increase in

weight in the presence of Sel-Plex^{TM} 0.02% additive concentration. The 3-month-old *Cornu aspersum* snails shown the highest weight increase in all batches, toping with 0.950 g/day in the CF-2(E) batch as depicted in *Figure 2*.

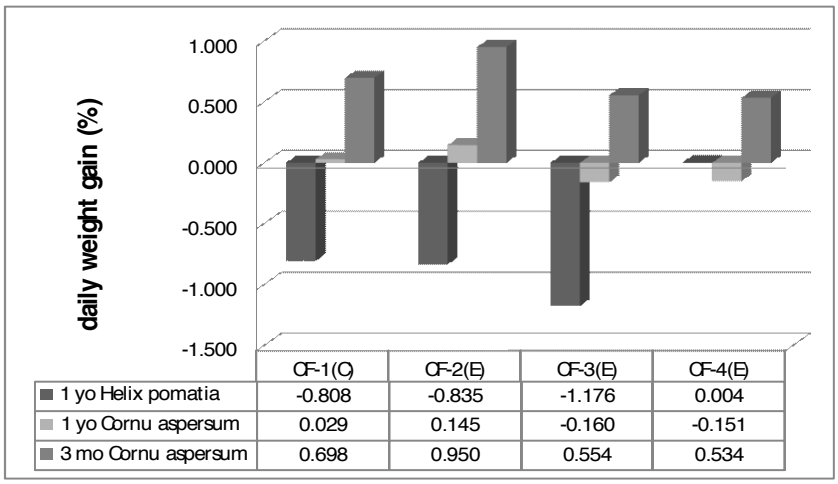

Fig. 2. Comparative performance under experimental feeding conditions for 38 days ending October 11, 2009, using concentrated forage and Sel-Plex^{TM} as additive.

Based on the growth dynamics under the experimental conditions, *Cornu aspersum* snails were justified to be chemically tested for their meat quality proving to have the best crude protein content of 9.8650% from CF-2(E) batch followed by CF-3(E) with 9.0165% as shown in *Table 3*.

Tab. 3

Meat's chemical composition of the 1-year-old *Cornu aspersum* fed with concentrated forage and Sel-Plex^{TM} as additive during the 2009 experiments, Crăieşti farm

Specification	CF-1 (C) Control batch	CF-2 (E) Sel-Plex 0.02%	CF-3 (E) Sel-Plex 0.04%	CF-4 (E) Sel-Plex 0.10%
(n)	5	5	5	5
Dry substance (%)	11.8120 ±0.3519	15.9676 ±0.2180	14.2113 ±0.1945	13.2404 ±0.1574
Crude protein (%)	8.7376 ±0.1089	9.8650 ±0.1468	9.0165 ±0.1881	8.2114 ±0.2226
Crude lipids (%)	1.0219 ±0.0365	1.4002 ±0.1290	1.1652 ±0.0476	0.8614 ±0.0620
Selenium (Se) (ppb)	4.37 ±0.13	13.01 ±0.12	15.08 ±0.31	23.83 ±0.40

The survival rate, or since were counted the snails found can rather be referred to as "the active snail rate", (some of them could simply be hiding in hibernation in the cracks in the ground), the data appears interesting.

Cornu aspersum presented as being almost equally active 71.25%-77.50% in all batches while *Helix pomatia* from CF-4(E) batch containing concentrated forage with Sel-Plex^{TM} 0.10% additive were found 100% as opposed to 46.88% -10.63% in rest of batches as seen in *Table 4*.

Tab. 4

The survival rate of the 1-year-old *Helix pomati*a and the 1-year-old *Cornu aspersum (Helix aspersa* Muller*)* snails under experimental feeding conditions at the end of the 38 days experiment, October 11, 2009 (%)

Specification	CF-1 (C) Control batch	CF-2 (E) Sel-Plex^{TM} 0.02%	CF-3 (E) Sel-Plex^{TM} 0.04%	CF-4 (E) Sel-Plex^{TM} 0.10%
Helix pomatia	31.88 ±4.27	10.63 ±3.15	46.88 ±2.39	100.00 ±0.00
Cornu aspersum	77.50 ±4.56	74.38 ±2.39	76.25 ±3.23	71.25 ±4.33

The overall performance of Cornu *aspersum* proved to be superior to *Helix pomatia* snails during the 2009 studies, so the experiments conducted during 2010 summer season became of interest. The best indices were obtained under Sel-Plex^{TM} 0.04% in BF-2(E) as expressed in *Table 5* and *6*.

Tab. 5

The production indices obtained in the 0-91 days interval from the 1-year-old *Cornu aspersum* under experimental feeding conditions with concentrated forage and Sel-Plex^{TM} as additive in Băişoara, 2010 (g)

Specification	BF-1(C) Control batch	BF-2(E) Sel-Plex^{TM} 0.04%	BF-3(E) Sel-Plex^{TM} 0.10%
(n)	4	4	4
∑x	6.1408	7.7644	6.0228
Mean	1.5352 ±0.1374	1.9411 ±0.1198	1.5057 ±0.1011
V%	8.95	6.17	6.72

Tab. 6

The individual daily average weight gain evolution for the 1-year-old *Cornu aspersum* under experimental feeding conditions with concentrated forage and Sel-Plex^{TM} as additive in Băişoara, 2010

Specification		BF-1(C) Control batch	BF-2(E) Sel-Plex^{TM} 0.04%	BF-3(E) Sel-Plex^{TM} 0.10%
Daily average gain (0-40 days)	(g)	0.0081	0.0159	0.0183
Daily average gain (41-91 days)	(g)	0.0237	0.0256	0.0152
Daily average gain (0-91 days)	(g)	0.0169	0.0213	0.0165
Daily average gain (91 days)	(%)	0.2454	0.3190	0.2438

The chemical analysis reflects in *Table 7* the increase in lipids content as well selenium (Se) content with the increase in Sel-Plex^{TM} concentration administered while the protein is around 13% in all tree batches.

The difference significations are depicted in *Table 8*.

Tab. 7

Meat's chemical composition of the 1-year-old *Cornu aspersum* fed with concentrated forage and Sel-Plex™ as additive during the May 29 – August 29, 2010 experiments.

Specification	BF-1(C) Control batch	BF-2(E) Sel-Plex™ 0.04%	BF-3(E) Sel-Plex™ 0.10%
(n)	5	5	5
Dry substance (%)	18.3911 ±0.1446	18.3249 ±0.0998	19.1032 ±0.1819
Crude protein (%)	13.8655 ±0.1020	13.6775 ±0.1294	13.5468 ±0.0741
Crude lipids (%)	1.5980 ±0.0605	1.7984 ±0.0508	2.3593 ±0.0448
Selenium (Se) (ppb)	21.01 ±0.11	33.57 ±0.16	49.28 ±0.50

Tab. 8

The signification of meat quality differences obtained under experimental feeding conditions with concentrated forage and Sel-Plex™ as additive from the 1-year-old *Cornu aspersum*. Băişoara, 2010 ANOVA Test–Tukey Test Multiple Comparison Test.

Experimental batches	Median difference	q	P < 0.05?	Signification	95% CI of diff
Dry substance					
BF-1(C) vs. BF-2(E)	0.06626	1.112	No	ns	-0.1745 to 0.3070
BF-1(C) vs. BF-3(E)	-0.7121	11.95	Yes	***	-0.9528 to -0.4714
BF-2(E) vs. BF-3(E)	-0.7784	13.06	Yes	***	-1.019 to -0.5376
Crude protein					
BF-1(C) vs. BF-2(E)	0.188	3.34295	No	ns	-0.0392569 to 0.415256
BF-1(C) vs. BF-3(E)	0.3187	5.66701	Yes	**	0.0914432 to 0.545956
BF-2(E) vs. BF-3(E)	0.1307	2.32407	No	ns	-0.0965565 to 0.357957
Crude lipids					
BF-1(C) vs. BF-2(E)	-0.2004	8.67253	Yes	***	-0.293777 to -0.107023
BF-1(C) vs. BF-3(E)	-0.7613	32.9461	Yes	***	-0.854677 to -0.667923
BF-2(E) vs. BF-3(E)	-0.5609	24.2736	Yes	***	-0.654277 to -0.467523
Selenium (Se)					
BF-1(C) vs. BF-2(E)	-12.56	104.286	Yes	***	-13.0467 to -12.0733
BF-1(C) vs. BF-3(E)	-28.27	234.727	Yes	***	-28.7567 to -27.7833
BF-2(E) vs. BF-3(E)	-15.71	130.441	Yes	***	-16.1967 to -15.2233

*** Very significant positive differences; ** Distinctive significant positive differences; ns – not significant differences

Under the extreme weather conditions such as prolonged heat waves, the survival rate as seen in *Table 9*, is the highest, namely 52.50% in BF-2(E) under Sel-Plex™ 0.04% additive.

Tab. 9

The survival rate of the 1-year-old *Cornu aspersum* snails under experimental feeding conditions with concentrated forage and Sel-Plex™ as additive, Băişoara farm, 2010.

Specification	BF-1(C)	BF-2(E)	BF-3(E)
Survival rate (%) after 91 days	38.13 ±3.75	52.50 ±5.40	38.13 ±1.25

Prolificacy (Tab. 10) of 330% followed by 300% is also the highest in BF-2(E) and BF-3(E) respectively, under Sel-Plex™ 0.04% and Sel-Plex™ 0.10% additive respectively.

The extreme weather conditions have a powerful negative impact on the vitality and resistance of the young snails, therefore, a fitness test, namely crawling speed was applied as to evaluate the influence of Sel-Plex™ as additive upon the 4-7 days old *Cornu aspersum* snails.

Tab. 10

Prolificacy of the 1-year-old *Cornu aspersum* snails under experimental feeding conditions with concentrated forage and Sel-Plex™ as additive, Băişoara farm, 2010.

Specification	BF-1(C)	BF-2(E)	BF-3(E)
Prolificacy (%) after 91 days	90.00 ±8.90	330.00 ±9.13	300.00 ±6.12

The best results, 1.5694±0.0504 mm/s, were found in the case of the snails fed with Sel-Plex™ 0.10% followed by 1.4403±0.0323 in the case of the snails fed with Sel-Plex™ 0.04%, *Table 11*.

Tab. 11

The speed as fitness component indices of the 4-7 days old *Cornu aspersum* snails at the end of the experiments on concentrated forage and Sel-Plex™ as additive.

Specification	BF-1(M) Control batch	BF-2(E) Sel-Plex™ 0.04%	BF-3(E) Sel-Plex™ 0.10%
Snail's individual average moving speed (mm/s)			
(n)	20	20	20
Minim	1.1343	1.3901	1.4627
Maxim	1.3306	1.5104	1.6344
∑x	24.4140	28.8060	31.3880
Mean	1.2207 ±0.0393	1.4403 ±0.0323	1.5694 ±0.0504
V%	3.22	2.24	3.21
The heartbeat rate (HBR) during snail's moving (bpm)			
(n)	13	12	10
Minim	97	98	98
Maxim	102	102	102
∑x	1303	1208	1008
Mean	100.23 ±1.48	100.67 ±1.23	100.80 ±1.23
V%	1.48	1.22	1.22

The heartbeat rate (HBR) means are situated in the area of 100.23-100.80 bpm. The measurements took place under an ambient temperature of 31 -32 °C on August 27-28, 2010.

The difference significations as shown in *Table 12*, indicate the influence of Sel-Plex™ additive upon the strength of the offspring provided by *Cornu aspersum* parent snails fed with concentrated forage and Sel-Plex™.

The Gain to the Proposed Norm (GPN) indicated 83.89 % realization of the proposed 9 grams norm within the 91 days experiment (Tab. 13). Here is to mention that in normal farming conditions, the fields are populated in April early May, depending upon the status of vegetation, as opposed to May 29th as it's the case in this experiment. In addition, the snails are left in the field up to September 15-25, enough time to reach a GPN of 100% to 120%.

Tab. 12

The signification of the Energetic metabolism indices differences registered on the 4-7 days old *Cornu aspersum* snails at the end of the experiments on concentrated forage and Sel-Plex™ as additive, August , 2010, Băişoara farm, ANOVA Test–Tukey Test Multiple Comparison Test.

Experimental batches	Median difference	q	P < 0.05?	Signification	95% CI of diff
Snail's individual average moving speed (mm/s)					
BF-1(C) vs. BF-2(E)	-0.2196	25.995	Yes	***	-0.248752 to -0.190448
BF-1(C) vs. BF-3(E)	-0.3487	41.2771	Yes	***	-0.377852 to -0.319548
BF-2(E) vs. BF-3(E)	-0.1291	15.2821	Yes	***	-0.158252 to -0.0999483
Cardiac rhythm during snail's moving (bpm)					
BF-1(C) vs. BF-2(E)	-0.4359	1.158	No	ns	-1.745 to 0.8729
BF-1(C) vs. BF-3(E)	-0.5692	1.439	No	ns	-1.944 to 0.8059
BF-2(E) vs. BF-3(E)	-0.1333	0.3312	No	ns	-1.533 to 1.266

*** Very significant positive differences; ns – not significant differences

Tab. 13

The average individual weight evolution the 1-year-old *Cornu aspersum* under experimental feeding conditions with concentrated forage and Sel-Plex™ as additive.

Specification	BF-1(C) Control batch	BF-2(E) Sel-Plex™ 0.04%	BF-3(E) Sel-Plex™ 0.10%
Mean average initial weight (g)	6.8750 ±0.0689	6.6860 ±0.0267	6.7860 ±0.0680
Mean average weight (g) after 40 days	7.2005 ±0.0238	7.3202 ±0.0687	7.5188 ±0.0887
Mean average weight (g) after 91 days	8.4102 ±0.0802	8.6271 ±0.1040	8.2917 ±0.0783
Gain to the Proposed Norm (GPN)			
GPN after 40 days (%)	15.32	27.41	33.10
GPN after 91 days (%)	72.24	83.89	68.01
Remaining Difference to Proposed Norm (RDPN)			
RPN after 40 days (%)	84.68	72.59	66.90
RPN after 91 days (%)	27.76	16.11	31.99

Slaughter yield it is a very important factor in the determination of economic efficiency of different snail species. As it can be observed in Tab.14, the slaughter yield of the adult (at consumable age) 1-year-old *Cornu aspersum* registered Y_{sCa}(%)=75.21±2.61 as opposed to the adult (at consumable age) 2-year-old *Helix pomatia* Y_{sHp} (%)=21.36±1.73, at least three times lower than the case of *Cornu aspersum* snails.

Tab. 14

Slaughter yield of the adult edible terrestrial snails

	2-years-old *Helix pomatia*			1-year-old *Cornu aspersum*		
	Total Weight Life snails (WT) (g)	Leg's Weight (WL) (g)	Slaughter yield Y_{sHp} (%)	Total Weight Life snails (WT) (g)	Meat's Weight (Wm) (g)	Slaughter yield Y_{sCa} (%)
(n)	3	3	3	3	3	3
∑x	736.30	157.70	-	220.80	166.10	-
Mean	245.40 ± 20.18	52.57 ± 7.88	21.36 ± 1.73	73.60 ± 11.45	55.37 ± 9.13	75.21 ± 2.61

CONCLUSIONS

Edible snails are an excellent vehicle for Se in human nutrition. The selenium content in snail's meat can be raised by proper snail's diet using Sel-Plex™. Selenium contributes to resistance to extreme weather conditions, promotes growth, surviving rate and prolificacy. *Helix pomatia* responds positive to Sel-Plex™ as additive in concentrations of 0.10%. *Cornu aspersum* snails respond more dynamically towards the end of snail farming season then *Helix pomatia*. From the economical aspect, *Cornu aspersum* snails have a higher slaughter yield then *Helix pomatia*. The protein content of *Cornu aspersum* snails' meat is not being influenced by the concentration of Sel-Plex™ in the forage used. The speed as a fitness component of the very young offspring *Cornu aspersum* snails proved to be superior as the parents were fed to higher concentrations of Sel-Plex™. The Gain to the Proposed Norm (GPN) is a more relevant production and development indicator then a growth indicator expressed by weight units such as grams. It indicates the realization of the proposed norm as opposed to the simple weight gain without an included target to reach, target based on market demand, quality of final product and realization efficiency as time, land as capital investment and resource consumption.

Acknowledgments. This study has been financed in part by Vitagrom and Pacific Services Network, Inc., Glendale, California, USA. Special thanks are directed to Ana Buicu of Baisoara; Mr. Adam Szocs of PSN, Inc, California, USA; Mihai Radu Pop, PhD of "Lucian Blaga" University of Sibiu and Stefan Vanju from Alltech USA, Romania.

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