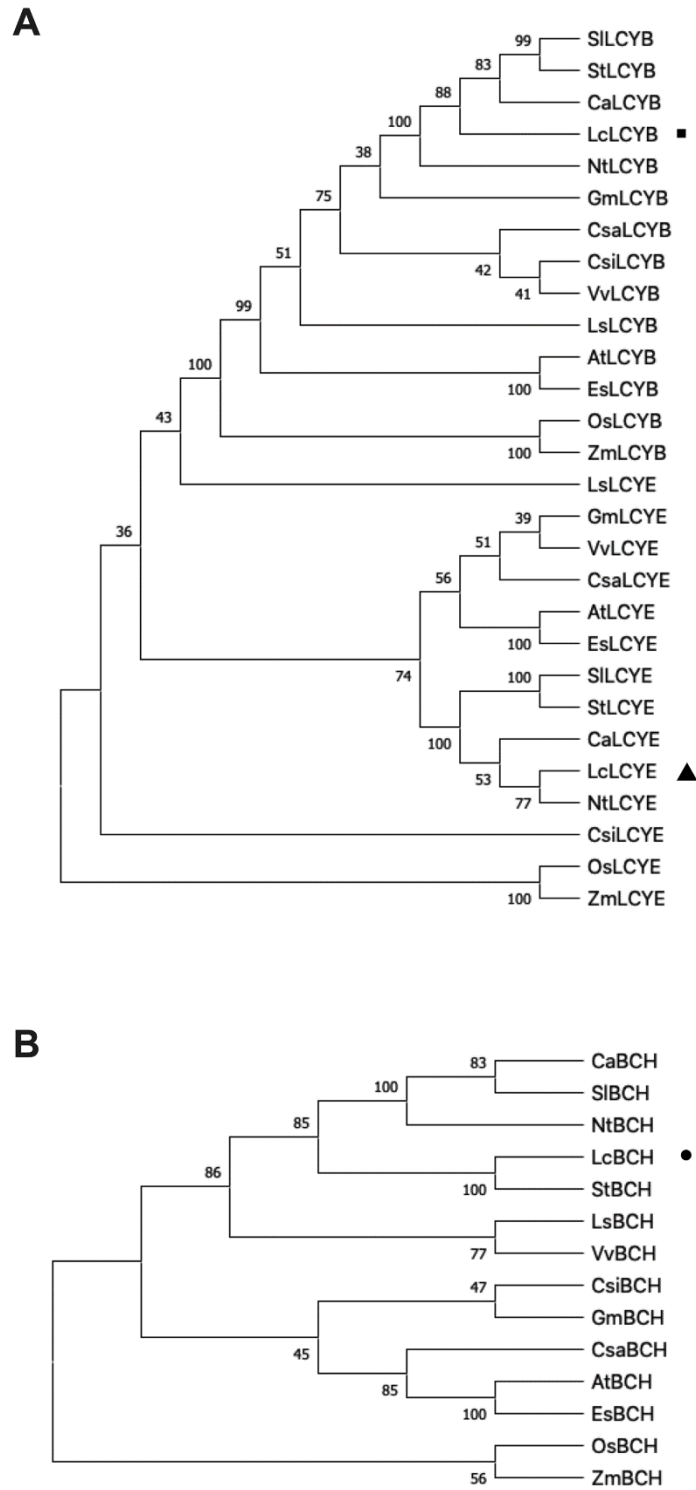


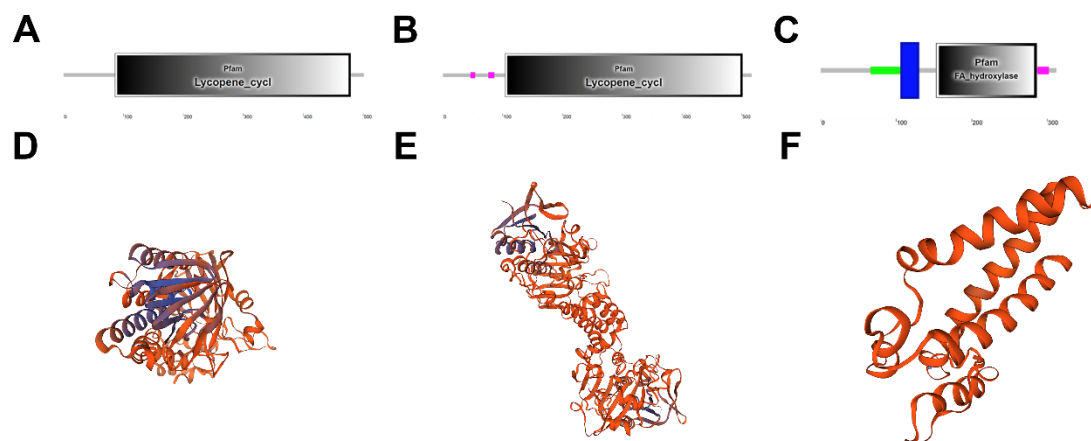
Supplementary Figure 1. Different ripening stages of wolfberry fruits. The genes were isolated from the stage (D), the red ripened fruits.

LcLCYB	... MDTLLKTPNKLKLEFLPQHGFVSVKSNFTSVKPK ...	KFGSR KSCENMGRK VCVARNSSSTLLEVPETKRELDPEFLMVDPTKGLAVDIAVGGGPAGLAVACQVSAGLSVCSIDFS	116
AtLCYB	... MDTLLKTPNKLKLEFLPQHGFVSVKSNFTSVKPK ...	VRIQVKKRAIKIVSSV ... VSGSAALDVPETKRELDPEFLMVDPTKGLAVDIAVGGGPAGLAVACQVSAGLSVCSIDFS	114
CaLCYB	... MDIWPRTNKLKLEFLPQHGFVSVKSNFTSVKPK ...	KFGFRNFRSGMGRG VCVKAS SSTLLEVPETKRELDPEFLMVDPTKGLAVDIAVGGGPAGLAVACQVSAGLSVCSIDFS	116
CaLCYB	... MDTLLRINIKYQFLPQHGFVSVKSNFTSVKPK ...	KSRILKIKKQ QGVGVK SSALDVPETKRELDPEFLMVDPTKGLAVDIAVGGGPAGLAVACQVSAGLSVCSIDFS	119
CaLCYB	... MDTLLKTPNKLKLEFLPQHGFVSVKSNFTSVKPK ...	PTRALVCR4AAAG ... EALRSALPPTRPETLSLDLIRVDPAPARVDIAVGGGPAGLAVACQVSAGLSVCSIDFS	99
EsLCYB	... MDTLLKTPNKLKLEFLPQHGFVSVKSNFTSVKPK ...	VKLGVKRAIKI OGS ... SSSALDVPETKRELDPEFLMVDPTKGLAVDIAVGGGPAGLAVACQVSAGLSVCSIDFS	112
GmLCYB	MI P MDTLLKTPNKLKLEFLPQHGFVSVKSNFTSVKPK ...	KPI VYWGIC ONLIRAS SSALDVPETKRELDPEFLMVDPTKGLAVDIAVGGGPAGLAVACQVSAGLSVCSIDFS	122
LsLCYB	... MDSLRLTHSSPEFLHAI NRFAGNATLSSSKSQI HETRFPPK ...	KPHLKWGHGCOVKAS SSALDVPETKRELDPEFLMVDPTKGLAVDIAVGGGPAGLAVACQVSAGLSVCSIDFS	120
NtLCYB	... MDTLLKTPNKLKLEFLPQHGFVSVKSNFTSVKPK ...	KFGSR KICENMGRG VCVKAK SSALDVPETKRELDPEFLMVDPTKGLAVDIAVGGGPAGLAVACQVSAGLSVCSIDFS	115
OsLCYB	... MDTLLKTPNKLKLEFLPQHGFVSVKSNFTSVKPK ...	PTRALVCR4AAAG ... EALRSALPPTRPETLSLDLIRVDPAPARVDIAVGGGPAGLAVACQVSAGLSVCSIDFS	99
SILCYB	... MDTLLKTPNKLKLEFLPQHGFVSVKSNFTSVKPK ...	KFCENMGRG VCVKAK SSTLLEVPETKRELDPEFLMVDPTKGLAVDIAVGGGPAGLAVACQVSAGLSVCSIDFS	115
SILCYB	... MDI LKTPNKLKLEFLPQHGFVSVKSNFTSVKPK ...	KFCENMGRG VCVKAK SSTLLEVPETKRELDPEFLMVDPTKGLAVDIAVGGGPAGLAVACQVSAGLSVCSIDFS	115
VvLCYB	... MDTLLKTPNKLKLEFLPQHGFVSVKSNFTSVKPK ...	KFCENMGRG VCVKAK SSTLLEVPETKRELDPEFLMVDPTKGLAVDIAVGGGPAGLAVACQVSAGLSVCSIDFS	119
ZmLCYB	... MDTLLKTPNKLKLEFLPQHGFVSVKSNFTSVKPK ...	KFCENMGRG VCVKAK SSTLLEVPETKRELDPEFLMVDPTKGLAVDIAVGGGPAGLAVACQVSAGLSVCSIDFS	99
Consensus MATTALLLRTHHPCPKPAPRASVLCR ATAGMAGPASA	
		l p e l p d v d l v g g g p g l a v a q v a g l v i d p	
LcLCYB	PKLIWPNNYGVWDFEAMLDLCLATWSGAVYVDDDRMRLDRPYGRVNRGLKLSAMQKQLLNGVGFHARVVKVIFEEASMLICSDGVITICAVVLDTATGFSRGLVGYDRIPNYQV	240	
AtLCYB	PKLIWPNNYGVWDFEAMLDLCLATWSGAVYVDEGVRRDRPYGRVNRGLKLSAMQKQLLNGVGFHARVVKVIFEEASMLICSDGVITICAVVLDTATGFSRGLVGYDRIPNYQV	238	
CaLCYB	PKLIWPNNYGVWDFEAMLDLCLATWSGAVYVDDDRMRLDRPYGRVNRGLKLSAMQKQLLNGVGFHARVVKVIFEEASMLICSDGVITICAVVLDTATGFSRGLVGYDRIPNYQV	240	
CaLCYB	PKLIWPNNYGVWDFEAMLDLCLATWSGAVYV TNEQSTRDARPYGRVNRGLKLSAMQKQLLNGVGFHARVVKVIFEEASMLICSDGVITICAVVLDTATGFSRGLVGYDRIPNYQV	243	
CaLCYB	PKLIWPNNYGVWDFEAMLDLCLATWSGAVYV I DDTNTTRDARPYGRVNRGLKLSAMQKQLLNGVGFHARVVKVIFEEASMLICSDGVITICAVVLDTATGFSRGLVGYDRIPNYQV	243	
EsLCYB	PKLIWPNNYGVWDFEAMLDLCLATWSGAVYV I DDOYTRDARPYGRVNRGLKLSAMQKQLLNGVGFHARVVKVIFEEASMLICSDGVITICAVVLDTATGFSRGLVGYDRIPNYQV	236	
GmLCYB	PKLIWPNNYGVWDFEAMLDLCLATWSGAVYV I DDKTRDARPYGRVNRGLKLSAMQKQLLNGVGFHARVVKVIFEEASMLICSDGVITICAVVLDTATGFSRGLVGYDRIPNYQV	246	
LsLCYB	PKLIWPNNYGVWDFEAMLDLCLATWSGAVYV I NENSIPNDRPYGRVNRGLKLSAMQKQLLNGVGFHARVVKVIFEEASMLICSDGVITICAVVLDTATGFSRGLVGYDRIPNYQV	244	
NtLCYB	PKLIWPNNYGVWDFEAMLDLCLATWSGAVYV I DDTNTTRDARPYGRVNRGLKLSAMQKQLLNGVGFHARVVKVIFEEASMLICSDGVITICAVVLDTATGFSRGLVGYDRIPNYQV	239	
OsLCYB	PKLIWPNNYGVWDFEAMLDLCLATWSGAVYV I DDTNTTRDARPYGRVNRGLKLSAMQKQLLNGVGFHARVVKVIFEEASMLICSDGVITICAVVLDTATGFSRGLVGYDRIPNYQV	224	
SILCYB	PKLIWPNNYGVWDFEAMLDLCLATWSGAVYV VDDDRMRLDRPYGRVNRGLKLSAMQKQLLNGVGFHARVVKVIFEEASMLICSDGVITICAVVLDTATGFSRGLVGYDRIPNYQV	239	
SILCYB	PKLIWPNNYGVWDFEAMLDLCLATWSGAVYV VDDDRMRLDRPYGRVNRGLKLSAMQKQLLNGVGFHARVVKVIFEEASMLICSDGVITICAVVLDTATGFSRGLVGYDRIPNYQV	239	
VvLCYB	PKLIWPNNYGVWDFEAMLDLCLATWSGAVYV I DDOYTRDARPYGRVNRGLKLSAMQKQLLNGVGFHARVVKVIFEEASMLICSDGVITICAVVLDTATGFSRGLVGYDRIPNYQV	243	
ZmLCYB	PAVVWPNNYGVWDFEAMLDLCLATWSGAVYV I DDOYTRDARPYGRVNRGLKLSAMQKQLLNGVGFHARVVKVIFEEASMLICSDGVITICAVVLDTATGFSRGLVGYDRIPNYQV	223	
Consensus	p wpnnnygvwdf eam l d cl d w s g a v y v d d d r m r l d r p y g r v n r g l k l s a m q k q l l n g v g f h a r v v k v i f e e a s m l i c s d g v i t i c a v v l d t a t g f s r g l v g y d r i p n y q v		
LcLCYB	AYCI LADVEHPFDITKLVMDWRDHI NNDELKER SRVPTLYAAPPSSNRI FLEETSIVARPGAMDQI QERMAARLRHLQI NKRRI EEDERCIPMAGGLPVPVQRVVI GGTIAGVHFS	365	
AtLCYB	AYCI LADVEHPFDITKLVMDWRDHI NNDELKER SRVPTLYAAPPSSNRI FLEETSIVARPGAMDQI QERMAARLRHLQI NKRRI EEDERCIPMAGGLPVPVQRVVI GGTIAGVHFS	363	
CaLCYB	AYCI LADVEHPFDITKLVMDWRDHI NNDELKER SRVPTLYAAPPSSNRI FLEETSIVARPGAMDQI QERMAARLRHLQI NKRRI EEDERCIPMAGGLPVPVQRVVI GGTIAGVHFS	365	
CaLCYB	AYCI LADVEHPFDITKLVMDWRDHI NNDELKER SRVPTLYAAPPSSNRI FLEETSIVARPGAMDQI QERMAARLRHLQI NKRRI EEDERCIPMAGGLPVPVQRVVI GGTIAGVHFS	368	
CaLCYB	AYCI LADVEHPFDITKLVMDWRDHI NNDELKER SRVPTLYAAPPSSNRI FLEETSIVARPGAMDQI QERMAARLRHLQI NKRRI EEDERCIPMAGGLPVPVQRVVI GGTIAGVHFS	368	
EsLCYB	AYCI LADVEHPFDITKLVMDWRDHI NNDELKER SRVPTLYAAPPSSNRI FLEETSIVARPGAMDQI QERMAARLRHLQI NKRRI EEDERCIPMAGGLPVPVQRVVI GGTIAGVHFS	361	
GmLCYB	AYCI LADVEHPFDITKLVMDWRDHI NNDELKER SRVPTLYAAPPSSNRI FLEETSIVARPGAMDQI QERMAARLRHLQI NKRRI EEDERCIPMAGGLPVPVQRVVI GGTIAGVHFS	371	
LsLCYB	AYCI LADVEHPFDITKLVMDWRDHI NNDELKER SRVPTLYAAPPSSNRI FLEETSIVARPGAMDQI QERMAARLRHLQI NKRRI EEDERCIPMAGGLPVPVQRVVI GGTIAGVHFS	369	
NtLCYB	AYCI LADVEHPFDITKLVMDWRDHI NNDELKER SRVPTLYAAPPSSNRI FLEETSIVARPGAMDQI QERMAARLRHLQI NKRRI EEDERCIPMAGGLPVPVQRVVI GGTIAGVHFS	364	
OsLCYB	AYCI LADVEHPFDITKLVMDWRDHI NNDELKER SRVPTLYAAPPSSNRI FLEETSIVARPGAMDQI QERMAARLRHLQI NKRRI EEDERCIPMAGGLPVPVQRVVI GGTIAGVHFS	349	
SILCYB	AYCI LADVEHPFDITKLVMDWRDHI NNDELKER SRVPTLYAAPPSSNRI FLEETSIVARPGAMDQI QERMAARLRHLQI NKRRI EEDERCIPMAGGLPVPVQRVVI GGTIAGVHFS	364	
SILCYB	AYCI LADVEHPFDITKLVMDWRDHI NNDELKER SRVPTLYAAPPSSNRI FLEETSIVARPGAMDQI QERMAARLRHLQI NKRRI EEDERCIPMAGGLPVPVQRVVI GGTIAGVHFS	364	
VvLCYB	AYCI LADVEHPFDITKLVMDWRDHI NNDELKER SRVPTLYAAPPSSNRI FLEETSIVARPGAMDQI QERMAARLRHLQI NKRRI EEDERCIPMAGGLPVPVQRVVI GGTIAGVHFS	368	
ZmLCYB	AYCI LADVEHPFDITKLVMDWRDHI NNDELKER SRVPTLYAAPPSSNRI FLEETSIVARPGAMDQI QERMAARLRHLQI NKRRI EEDERCIPMAGGLPVPVQRVVI GGTIAGVHFS	348	
Consensus	aygi a v h p f d i t k l v m d w r d h i n n d e l k e r s r v p t l y a a p p s s n r i f l e e t s i v a r p g a m d q i q e r m a a r l r h l q i n k r r i e e d e r c i p m a g g l p v p q r v v i g g t i a g v h f s		
LcLCYB	TOYVARTLAAAPVADAVI VQVGS EKN ... HL NDL ASVWR LWP	RRRRQREFFCFGMD LLKLDL PATRRFFDAFFDI ERYWHGLSSRL LPLEIFGLSIFSLASNSRDI I MFG	485
AtLCYB	TOYVARTLAAAPVADAVI VQVGS EKN ... NSLR DQL AEVWR LWP	RRRRQREFFCFGMD LLKLDL PATRRFFDAFFDI ERYWHGLSSRL LPLEIFGLSIFSLASNSRDI I MFG	485
CaLCYB	TOYVARTLAAAPVADAVI VQVGS EKN ... HL NDL ASVWR LWP	RRRRQREFFCFGMD LLKLDL PATRRFFDAFFDI ERYWHGLSSRL LPLEIFGLSIFSLASNSRDI I MFG	485
CaLCYB	TOYVARTLAAAPVADAVI VQVGS DGR ... FGDAL SEVWR LWP	RRRRQREFFCFGMD LLKLDL PATRRFFDAFFDI ERYWHGLSSRL LPLEIFGLSIFSLASNSRDI I MFG	488
CaLCYB	TOYVARTLAAAPVADAVI VQVGS DRS ... I S EHL AEVWR LWP	RRRRQREFFCFGMD LLKLDL PATRRFFDAFFDI ERYWHGLSSRL LPLEIFGLSIFSLASNSRDI I MFG	488
EsLCYB	TOYVARTLAAAPVADAVI VQVGS SSK ... NSLR DQL AEVWR LWP	RRRRQREFFCFGMD LLKLDL PATRRFFDAFFDI ERYWHGLSSRL LPLEIFGLSIFSLASNSRDI I MFG	484
GmLCYB	TOYVARTLAAAPVADAVI VQVGS DRC ... FS QETS AEVWR LWP	RRRRQREFFCFGMD LLKLDL PATRRFFDAFFDI ERYWHGLSSRL LPLEIFGLSIFSLASNSRDI I MFG	491
LsLCYB	TOYVARTLAAAPVADAVI VQVGS EKT ... VS TDL AGI WR LWP	RRRRQREFFCFGMD LLKLDL PATRRFFDAFFDI ERYWHGLSSRL LPLEIFGLSIFSLASNSRDI I MFG	489
NtLCYB	TOYVARTLAAAPVADAVI VQVGS EKD ... LL NDL AEVWR LWP	RRRRQREFFCFGMD LLKLDL PATRRFFDAFFDI ERYWHGLSSRL LPLEIFGLSIFSLASNSRDI I MFG	484
OsLCYB	TOYVARTLAAAPVADAVI VQVGS DGD ... SAFA DAL AEVWR LWP	RRRRQREFFCFGMD LLKLDL PATRRFFDAFFDI ERYWHGLSSRL LPLEIFGLSIFSLASNSRDI I MFG	472
SILCYB	TOYVARTLAAAPVADAVI VQVGS DKD ... HL NDL ASVWR LWP	RRRRQREFFCFGMD LLKLDL PATRRFFDAFFDI ERYWHGLSSRL LPLEIFGLSIFSLASNSRDI I MFG	484
SILCYB	TOYVARTLAAAPVADAVI VQVGS DKD ... HL NDL ASVWR LWP	RRRRQREFFCFGMD LLKLDL PATRRFFDAFFDI ERYWHGLSSRL LPLEIFGLSIFSLASNSRDI I MFG	484
VvLCYB	TOYVARTLAAAPVADAVI VQVGS DRC ... FS QETS AEVWR LWP	RRRRQREFFCFGMD LLKLDL PATRRFFDAFFDI ERYWHGLSSRL LPLEIFGLSIFSLASNSRDI I MFG	483
ZmLCYB	TOYVARTLAAAPVADAVI VQVGS DRC ... FS QETS AEVWR LWP	RRRRQREFFCFGMD LLKLDL PATRRFFDAFFDI ERYWHGLSSRL LPLEIFGLSIFSLASNSRDI I MFG	488
Consensus	t g y v a r t l a a a p v a d a v i v q v g s e k n g l n d l a s v w r l w p r r r r q r e f f c f g m d l l k l d l p a t r r f f d a f f d i e r y w h g l s s r l l p l e i f g l s i f s l a s n s r d i i m f g		
LcLCYB	TLFVVMNINLQDRE	501	
AtLCYB	TLFVVMNINLQDRD	501	
CaLCYB	TLFVVMNINLQDRD	499	
CaLCYB	TLFVVMNINLQDRD	504	
CaLCYB	TLFVVMNINLQDRD	504	
EsLCYB	TLFVVMNINLQDRD	500	
GmLCYB	TLFVVMNINLQDRE	507	
LsLCYB	TLFVVMNINLQDRE	505	
NtLCYB	TLFVVMNINLQDRE	500	
OsLCYB	TLFVVMNINLQDRD	489	
SILCYB	TLFVVMNINLQDRE	500	
SILCYB	TLFVVMNINLQDRE	500	
VvLCYB	TLFVVMNINLQDRE	504	
ZmLCYB	TLFVVMNINLQDRG	490	
Consensus	t l f v v m n i n l q d r e		

Supplementary Figure 2. Multiple sequence alignments of LcLCYB with the selected corresponding proteins. AtLCYB (*Arabidopsis thaliana*, NP_187634), CaLCYB (*Capsicum annuum*, PHT71462), CsaLCYB (*Cucumis sativus*, XP_004150761), CsiLCYB (*Citrus sinensis*, AAM21152), EsLCYB (*Eutrema salsugineum*, XP_006407592), GmLCYB (*Glycine max*, XP_003554132), LsLCYB (*Lactuca sativa*, XP_023755637), NtLCYB (*Nicotiana tabacum*, NP_001311716), OsLCYB (*Oryza sativa*, XP_015627234), SILCYB (*Solanum lycopersicum*, XP_010312096), SlLCYB (*Solanum tuberosum*, XP_006351264), VvLCYB (*Vitis vinifera*, XP_002275769) and ZmLCYB (*Zea mays*, NP_001169155).



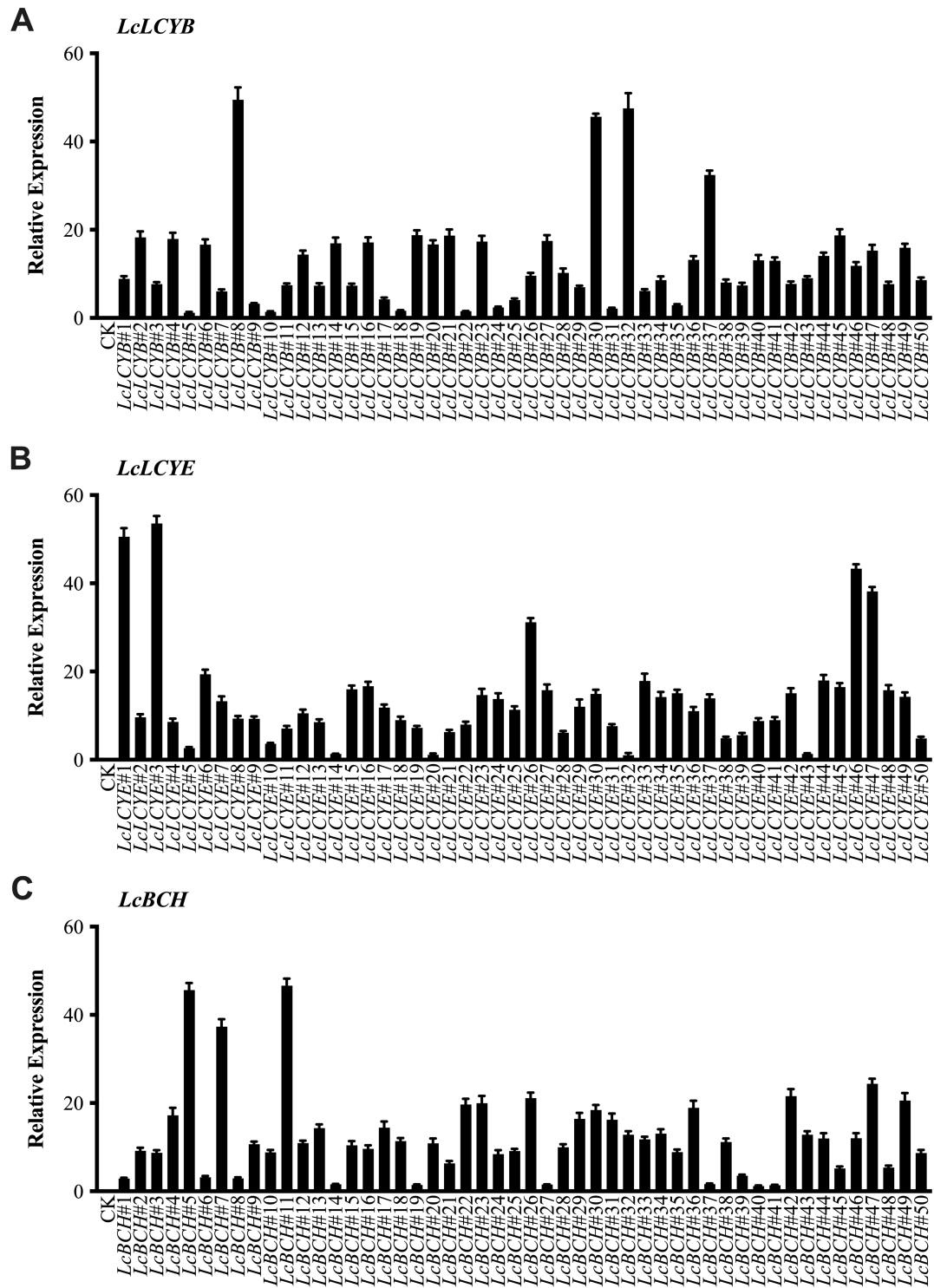
Supplementary Figure 5. Phylogenetic analysis of (A) LCYB and LCYE and (B) BCH were constructed using the Neighbor-Joining method with MEGA X software. The LcLCYB, LcLCYE, and LcBCH were indicated with ■, ▲ and ●, respectively.



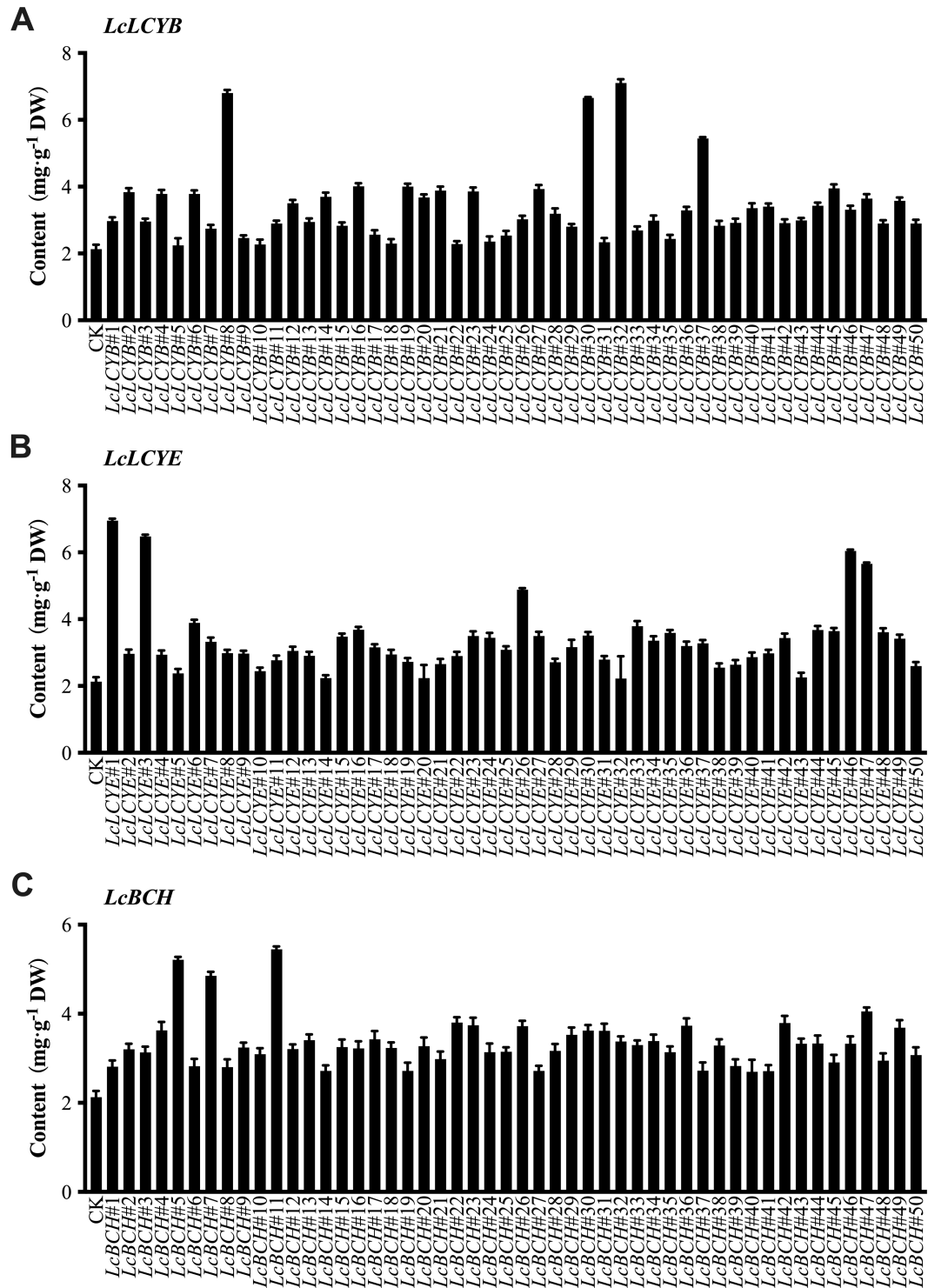
Supplementary Figure 6. Conserved domain analysis of (A) LcLCYB, (B) LcLCYE, and (C) LcBCH were accomplished with PFAM online tools (<http://pfam.xfam.org/>), and 3D structure prediction of (D) LcLCYB, (E) LcLCYE, and (F) LcBCH were applied with SWISS-MODEL Workspace (<https://swissmodel.expasy.org/>).



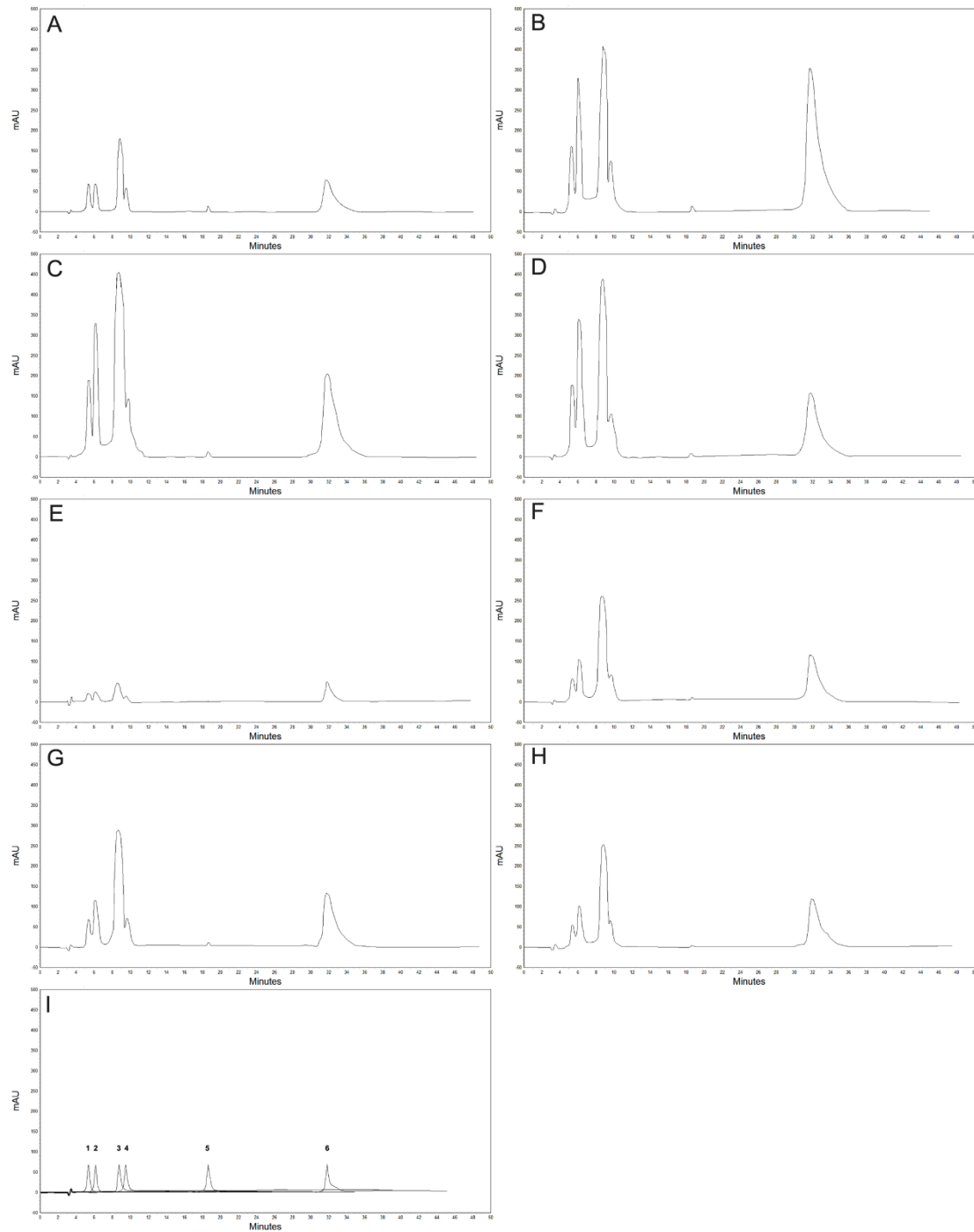
Supplementary Figure 7. The color complementation of *LcLCYB*, *LcLCYE*, and *LcBCH* in engineered *E.coli*. Recombined *E.coli* strains containing plasmid (A) pACCRT-*EBI* (carring genes coding geranylgeranyl diphosphate synthase, 15-cis-phytoene synthase, and phytoene desaturase), (B) pACCRT-*EBI* and pET-28a-*LcLCYB*, (C) pACCRT-*EBI* and pET-28a-*LcLCYE*, and (D) pACCRT-*EBI*, pET-28a-*LcLCYB* and pET-28a-*LcBCH* were displayed.



Supplementary Figure 8. Expression levels of (A) *LcLCYB*, (B) *LcLCYE*, and (C) *LcBCH* in transgenic tobaccos were measured by Real-time PCR, and results were normalized to reference gene *NtActin*. Tobacco overexpression lines were named as *Gene#Number*. Data were obtained from three independent experiments and performed as means \pm standard deviation.



Supplementary Figure 9. Total carotenoid contents in (A) *LcLCYB*, (B) *LcLCYE*, and (C) *LcBCH* in transgenic tobacco leaves. Tobacco overexpression lines were named as *Gene#Number*. Data were obtained from three independent experiments and performed as means \pm standard deviation.



Supplementary Figure 10. The chromatogram figures of HPLC analysis. The chromatogram figures of (A) control plants and tobacco over-expressing (B) *LcLCYB*, (C) *LcLCYE*, and (D) *LcBCH* growing under normal condition; (E) control plants and tobacco over-expressing (F) *LcLCYB*, (G) *LcLCYE*, and (H) *LcBCH* growing under salt stress. The chromatogram figures of standard samples were shown in (I), and peaks labeled with numbers were standard samples of (1) neoxanthin, (2) violaxanthin, (3) lutein, (4) zeaxanthin, (5) lycopene, and (6) β -carotene.

Supplementary Table 1. Physicochemical properties and predicted subcellular localizations

Gene	Accession No.	Length of ORF (bp)	Number of amino acids (aa)	Molecular weight (Da)	pI of protein	Predicted Subcellular location
<i>LcLCYB</i>	KJ624406	1272	423	47807.6	8.06	chloroplast
<i>LcLCYE</i>	KJ143993	1749	582	64949.0	6.50	chloroplast
<i>LcBCH</i>	KF430643	939	312	34850.3	8.47	chloroplast

Supplementary Table 2. Information of the protein for the sequence analysis

Protein	Species	Accession number
AtBCH	<i>Arabidopsis thaliana</i>	NP_200070
CaBCH	<i>Capsicum annuum</i>	KAF3668875
CsaBCH	<i>Cucumis sativus</i>	XP_004140758
CsiBCH	<i>Citrus sinensis</i>	NP_001275830
EsBCH	<i>Eutrema salsugineum</i>	XP_006413280
GmBCH	<i>Glycine max</i>	NP_001242409
LsBCH	<i>Lactuca sativa</i>	XP_023769464
NtBCH	<i>Nicotiana tabacum</i>	NP_001313021
OsBCH	<i>Oryza sativa</i>	XP_015628773
SIBCH	<i>Solanum lycopersicum</i>	NP_001234348
StBCH	<i>Solanum tuberosum</i>	ADF28628
VvBCH	<i>Vitis vinifera</i>	RVW41947
ZmBCH	<i>Zea mays</i>	NP_001105865
AtLCYB	<i>Arabidopsis thaliana</i>	NP_187634
CaLCYB	<i>Capsicum annuum</i>	PHT71462
CsaLCYB	<i>Cucumis sativus</i>	XP_004150761
CsiLCYB	<i>Citrus sinensis</i>	AAM21152
EsLCYB	<i>Eutrema salsugineum</i>	XP_006407592
GmLCYB	<i>Glycine max</i>	XP_003554132
LsLCYB	<i>Lactuca sativa</i>	XP_023755637
NtLCYB	<i>Nicotiana tabacum</i>	NP_001311716
OsLCYB	<i>Oryza sativa</i>	XP_015627234
SILCYB	<i>Solanum lycopersicum</i>	XP_010312096
StLCYB	<i>Solanum tuberosum</i>	XP_006351264
VvLCYB	<i>Vitis vinifera</i>	XP_002275769
ZmLCYB	<i>Zea mays</i>	NP_001169155
AtLCYE	<i>Arabidopsis thaliana</i>	NP_200513
CaLCYE	<i>Capsicum annuum</i>	PHT73568
CsaLCYE	<i>Cucumis sativus</i>	XP_004141172
CsiLCYE	<i>Citrus sinensis</i>	AAS48096
EsLCYE	<i>Eutrema salsugineum</i>	XP_006401252
GmLCYE	<i>Glycine max</i>	XP_003533775
LsLCYE	<i>Lactuca sativa</i>	XP_023756930
NtLCYE	<i>Nicotiana tabacum</i>	XP_016467034
OsLCYE	<i>Oryza sativa</i>	XP_015622198
SILCYE	<i>Solanum lycopersicum</i>	NP_001234337
StLCYE	<i>Solanum tuberosum</i>	XP_006353544
VvLCYE	<i>Vitis vinifera</i>	RVW43956
ZmLCYE	<i>Zea mays</i>	AQK96213

Supplementary Table 3. Primers used for vector construction in this study

Gene	Primer sequences for vector construction (5'-3')
<i>LcLCYB</i>	F: ATCGGGATCCATGGATACTTTGTTGAAAACCCCAAATA R: ATCGGTCGACTTATTCTGAATCCTGTAACAAATTG
<i>LcLCYE</i>	F: ATCGGGATCCATGGAATGTGTTGGAGTTCAAATTTTG R: ATCGGTCGACTTAAAATGTAAGATAAGTTCTTATC
<i>LcBCH</i>	F: ATCGGGATCCATGGCTGCCGGAATTCAGGCATTG R: ATCGGTCGACTCATAATCCCTTAGAAATTTAACT

Supplementary Table 4. Information of carotenoids analyzed with HPLC

Peak Number	Chemical Name	CAS Number	Retention Time (second)
1	neoxanthin	14660-91-4	322.37
2	violaxanthin	126-29-4	369.71
3	lutein	127-40-2	525.26
4	zeaxanthin	144-68-3	570.35
5	lycopene	502-65-8	1118.2
6	β -carotene	7235-40-7	1909.4

Supplementary Table 5. Primers used for Real-time PCR in this study

Gene	Primer Sequence (5'-3')	Accession number
<i>NtActin</i>	F: CCTGAGGTCCTTTTCCAACCA R: GGATTCCGGCAGCTTCCATT	XM_016658252.1
<i>NtIPI</i>	F: AAGAGCATTGAAGAGGACGAG R: AACAATGACCAATAACTCCAGGC	NM_001326211.1
<i>NtGGPS</i>	F: CTGTCAATCGAGCCTTAGATGC R: AAACCCGCTTGCCTTCG	NM_001325671.1
<i>NtPSY</i>	F: TGTTGCTTTGTTGTGGGTTG R: TTTGTCTCCCGCCTTTCA	NM_001325140.1
<i>NtPDS</i>	F: AGTCAGACTAAACTCACGAATAAA R: CTCCCCTAGCTTCTCCAA	XM_016642616.1
<i>NtZDS</i>	F: GGGAGCTTGATTTCCGATT R: CCCGCACCACTGGACTAA	XM_016658599.1
<i>NtCRTISO</i>	F: GCAGGACCAGATTCAGCG R: GATGGATAAAGGAGGTAGAGCC	NM_001325775.1
<i>NtLCYB</i>	F: AAGAGCATTGAAGAGGACGAG R: TGAGGGATGAACCAGACCAG	NM_001324787.1
<i>NtLCYE</i>	F: GCTCTTGCTGCGGAGTC R: GAATTGGATCGGCATCGT	NM_001325477.1
<i>NtBCH</i>	F: CTTGGCAAATGGAGGGTG R: AAGAAGAGCAATGGCTGGAA	NM_001326092.1
<i>NtVDE</i>	F: CTGAAAGAGTGCAGGTTAGAGC R: TGGAGACAGGCAACATTAGC	NM_001324805.1
<i>NtZEP</i>	F: CAACAGCAGAACTGAGCCAT R: AACAATGACCAATAACTCCAGGC	XM_016582459.1
<i>NtNSY</i>	F: AAGCCAAAGTAGGTGCCCAA R: AACGGTAAGATGGAGAATGGCT	XM_016625496.1
<i>NtAPX</i>	F: GGAAGAGTTGGGAGTGGTGG R: ACAGCTGCCAAATTCAAATCCT	NM_001324874.1
<i>NtCAT</i>	F: GTCTTGACAGGAAGGCGTGA R: AACGGAAGACAGAGTAGCAGC	NM_001325412
<i>NtP5CR</i>	F: AAGAGCGTGGCACAATCACT R: AGCTTTTCTCGAGTTTCTTCTGC	XM_016610055.1
<i>NtPOD</i>	F: GGACAAATGGAGAGATTCGTTTCAG R: TGCTGACTTGGCCTACCAAC	XM_016632447.1
<i>NtSOD</i>	F: TCCTCCCCAGGTTTCGGAATA R: TGCGCTACATTTGGCAAGAG	XM_016631233.1
<i>LcLCYB</i>	F: ACATCCCTTG TAGCTCGTCCTGG R: ACCATGCCAGCAGTACCACCA	KP262047.1
<i>LcLCYE</i>	F: AACGTTGGGCTCGTTGGGCCT R: CTCCTCGTGCAGTAAATGGCGACT	KF768738.2

LcBCH

F: AGGCTGGCGGAAAAATTGGCGA

R: GCAGCGCCAAACGAGAGAGCGA

KF430643.1